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Section I
Special Issue
Innovation in Applied Bioscience and Bioengineering Education

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Amid clarion calls for universities to forge stronger links between research and teaching, this paper offers practical guidance for teachers wishing to involve their students in authentic research in a course setting. The pedagogical and practical pointers offered here are grounded in a longitudinal study of student learning experiences in a tissue engineering course. This course allows students to carry out a research project by participating in faculty members' ongoing research. Data was gathered using both quantitative and qualitative methods. We draw on a framework for inquiry-based learning, consisting of five phases, in order to structure the analysis of the data as well as the pedagogical and practical pointers. Overall, the students strongly valued learning about and through research, which they mainly attributed to (1) being involved in all phases of the inquiry cycle, (2) being immersed in a real research environment, and (3) at the same time being offered scaffolding through various course activities. From a practical and organizational stand-point, it is important to consider access to laboratories, equipment and consumables, as well as the running costs for projects, which can be greater than a typical laboratory course exercise.

Keywords: tissue engineering; undergraduate research; inquiry-based learning; learning experiences

In this work we present the implementation of a course titled Computational Modeling in Biological Systems that integrates three broad topics of programming, numerical methods, and their application to biological systems. The course was offered in a lab setting with significant components of active learning focused on integrating the key principles of behaviorism, cognitive and constructivist theories of learning. The course was offered to two sections, one of which had a mandatory attendance policy. Student learning was measured using weekly lab assignments, a midterm exam and a comprehensive final exam. It was found that the section with mandatory attendance policy fared much better in the exams, meeting majority of the learning outcomes. This is attributed to the fact that there was more participation from this cohort in the classroom session where: (1) the instructor routinely set the context and defined the targeted learning outcomes, (2) conducted the active learning sessions to enhance the students' cognitive learning and (3) focused on defining meaningful contexts for applying the concepts to real-world biotechnology problems, encouraging collaboration and thoughtful reflection, thereby imbibing the constructivist principles of learning.

Keywords: biotechnology; computational modeling; numerical methods

In 2016, our biomedical engineering (BME) department created a new model of instructional change in which undergraduate BME curriculum is closely tied to the evolution of the field of BME, and in which faculty, staff, and students work together to define and implement current content and best practices in teaching. Through an Iterative Instructional Design Sequence, the department has implemented seven BME-in-Practice modules over two years. A total of 36 faculty, post docs, doctoral candidates, master's students, and fourth year students participated in creating one-credit BME-in-Practice Modules exploring Tissue Engineering, Medical Device Development, Drug Development, Regulations, and Neural Engineering. A subset of these post docs, graduate students and undergraduates (23) also participated in teaching teams of two-three per Module and were responsible for teaching one of the BME-in-Practice Modules. Modules were designed to be highly experiential where the majority of work could be completed in the classroom. A total of 50 unique undergraduates elected to enroll in the seven Modules, 73.33% of which were women. Data collected over the first two years indicate that Module students perceived significant learning outcomes and the Module teaching teams were successful in creating student centered environments. Results suggest that this mechanism enables effective, rapid adaptation of BME curriculum to meet the changing needs of BME students, while increasing student-centered engagement in the engineering classroom. Findings also suggest that this approach is an example of an intentional curricular change that is particularly impactful for women engineering students.

Keywords: biomedical engineering, instructional change, instructional design

This paper explores the implementation of process engineering design software, specifically UniSim®, as a vehicle to investigate student interest, engagement, and confidence in learning engineering design and their experiences of group work. This research gathered information about student's perception and experience about (1) the role of engineering design software as a motivator for learning engineering design calculation and (2) the importance of group work in engineering education. This paper outlines the results of a pilot project concerning second- and third-year biotechnology students' experiences in learning engineering design concepts using simulation software. The process design software was found to be an excellent complement to traditional classroom teaching as it facilitated learning via repeated practice allowing students to perform engineering design calculation of problems with

various levels of difficulty while the complete solutions of the problems were generated by the software. Problem solving using the software not only helped students to confirm their hand calculations but also allowed them to better focus on comprehending and analyzing the results of complex problems. According to survey results, over 70% of students commented that the simulation-based learning modules increased their interest in learning math-based concepts in the process engineering design and therefore facilitated their understanding of the course materials. Students also commented higher performance working in groups due to idea sharing and troubleshooting together. This survey could serve as a basis for instructors intending to further implement software-based learning at their respective institutions.

Keywords: biotechnology; level of interest; engineering design; UniSim®; group work

Unique and innovative curriculum in engineering biotechnology has been created at School of Engineering Practice and Technology, Faculty of Engineering, McMaster University. The curriculum was created to address industry requirements for Bachelor of Technology (B.Tech.) with outcomes dealing with experiential learning and hands-on new technologies in Applied Bioscience, Engineering and Management. The curriculum is formed with 48% Applied Biosciences, 26% Engineering and 26% Management courses, in addition to one-year mandatory co-op on two terms of four and eight months. The curriculum is supported by state-of-the-art labs and two research centers of excellence at McMaster University. The curriculum aims to prepare students for a career in specific biotechnology industries such as: Agriculture, Food, Pharmaceutical, Forensics, Medical, Biofuel, and Regulatory Biotechnology. The curriculum reflects the unique model of Bachelor of Technology/ Biotechnology stream with Engineering, Management, and Technical (Biotechnology) components. Through this interdisciplinary curriculum, hands-on learning and innovative teaching practice, B.Tech. students are inspired to be the best in their field – both in school and at work.

Keywords: curriculum; engineering biotechnology; Bachelor of Technology

Case-based learning (CBL) is an active learning technique that has traditionally been underutilized in engineering technology education research. Real-life case studies were developed and used in teaching and learning two biotechnology courses in winter 2019. The overall student evaluation of CBL was positive: 71% of students agreed that CBL enhanced their learning, while 13% disagreed and 16% of students were neutral. 74% of students found that CBL helped them in team working skill and 24% were neutral. Detailed evaluation and discussion of CBL enhancement on problem solving, critical thinking, learning experience and technical skills are carried out in this study.

Keywords: active learning, experiential learning, engineering technology, education, biotechnology

Online education has the potential to revolutionize the way engineering educators teach fundamental engineering principles and deliver content to engineering students, while increasing access, flexibility, and affordability for both students and academic units. While numerous approaches have been implemented and studied, hybrid teaching approaches, where some portion of the class is online and some is face-to-face, remain a popular approach. Over the past decade, numerous studies have examined hybrid education, but rarely have these studies told us whether students learn equally well in both the online and face-to-face modalities of such courses, nor have they explained how students perceive the online portion of a hybrid course in comparison to the face-to-face portion. Furthermore, studies in engineering education are rare. To address this, we studied a 16-week, hybrid modality, bioengineering course, where we assigned students to one of two groups, with one group beginning the term with the online modality and the other group beginning the term with the face-to-face modality. Mid-term, we then switched the online and face-to-face learning modalities for both groups to inspect how the switch may affect the two groups' learning outcomes and their perceptions of the online portion of the course. The results indicate that (1) overall, both groups had no significant differences in learning outcomes; (2) the group that started from face-to-face learning and ended up with online learning had higher learning satisfaction and course ratings than the group that reversed the order of learning modality; and (3) deliberately switching online/face-to-face modality in the middle of the course may not advisable. Implications are discussed.

Keywords: Engineering education; hybrid learning; switch online/face-to-face; learning outcomes; learners' perceptions; learners' satisfaction

Section II
Contributions in: Capstone Courses, Industry 4.0, PBL, STEM, Socialization Process, TRIZ Learning, Diversity, Inclusivity, Assessment, Accreditation, Reflective Thinking, Social Capital, Motivation, Identity, Active Learning, Attrition Rates, Knowledge Transfer, Grassroot Teams, Gamification, Microprocessors, Aerospace Engineering, Biologically Inspired Design, Mechanical Engineering, Product Development

This paper presents an interdisciplinary capstone course for creative product development with cross-college collaboration in a research-intensive university. The primary focus of this course is to give undergraduate students the experience of owning their problem through finding and defining a novel and useful problem by themselves. Then, they solve the problem by creating a corresponding product as an interdisciplinary team. To accomplish this goal at Seoul National University, a teaching team was formed with cross-college faculty from the electrical, mechanical, information, industrial, and architectural engineering departments. This paper reports how to integrate this course into a research-intensive engineering college, where both students and faculty are possibly unsympathetic to or skeptical of this top-down education approach. Our assessment method is highlighted to evaluate a student's work regarding creative and interdisciplinary learning. The impact of the cultural learning context is also considered in the course. We present our findings, the lessons learned, limitations observed and recommendations with how this course extends to building a new academic makerspace at SNU.

Keywords: Capstone course; creativity education; engineering education; project-based learning; undergraduate research

The Industry 4.0 has become an important concept as well as direction in the industrial and social development. In the core of this new shift is implementation of new technologies that open a number of important issues, starting from managing complexity of the systems, up to new educational and training needs for students and employees. In this paper we will preset usage of microprocessor boards and cloud systems in engineering education. The given example will be presented using NodeMCU card, sensors and ThingSpeak cloud system, as well as, Virtuino for communication and data presentation. In addition, application in undergraduate courses, educational tasks, and student's satisfaction will be presented.

Keywords: education for industry 4.0; prototyping microprocessor boards; cloud systems; NodeMCU; Virtuino; ThingSpeak

This study investigated 35 Chinese university teachers' development of learner-centered beliefs and practices through a six-month problem and project-based (PBL) professional learning program in Denmark using a mixed-methods research. Both qualitative and quantitative analyses of the participants' teaching and learning portfolios, which each included six entries, identified a significant change in their beliefs, from teacher-centered domination at the program's start to more learner-centered beliefs by the end (Nine teachers held learner-centered beliefs, seventeen teachers held dual beliefs and nine teachers still held teacher-centered beliefs.). Survey analysis identified a significant change in participants' intended practices at the end of the program. Participants reported a significant increase in using classroom interactions and formative assessment and a significant decrease in using summative assessment, yet content delivery remained the focus of their practices. A significant correlation was identified between participants' beliefs and practices at the program's end, which was not found at the program's start. The results indicate a noteworthy impact of the PBL-based professional learning program on the participants' changes in beliefs and practices, and an association between beliefs and practices was found. However, systemic, individual and cultural factors may constrain changes in teaching practices.

Keywords: China; Denmark; PBL; professional learning program; STEM instructors; teaching practices; university teachers' beliefs

Research suggests that engineers generally undergo socialization through two sets of socialization processes when they are newly hired to an organization: (1) initiating proactive behaviors and (2) participating in company-initiated actions, called organizational tactics. This study provides a first-look at socialization in the U.S. aerospace and defense (A&D) industry by examining how newly-hired engineers at A&D organizations initiate proactive behaviors and participate in organizational tactics to adjust to their new jobs and organizations. First, the relationships between two sets of socialization processes and socialization outcomes of new engineers were examined. Second, holistic profiles that best characterize newly hired engineers' socialization processes, and whether engineers with different types of profiles present varying socialization outcomes were identified. A total of 86 new engineers who had less than two years of working experience in their A&D organizations were included in this study. Multiple regression and Latent Profile Analyses (LPA) were employed. Study findings show that newly-hired engineers in the A&D industry frequently rely on social interactions to adjust to their job position and organization, and they often participate in organizational tactics more than proactive socialization behaviors. Implications of these findings in the context of A&D workplaces and aerospace engineering education settings are discussed.

Keywords: socialization processes; socialization outcomes; aerospace and defense organizations; aerospace engineering education

Biologically inspired design (BID) is a complicated cognitive process that largely depends on designers' capability to transfer biological inspirations into design solutions. It usually requires special training for engineering designers to gain this capacity. As a systematic invention approach, TRIZ, the abbreviation of Russian Theory of Inventive Problem Solving, is suggested to help improve designers' innovative capabilities. An experimental research is conducted by this paper to investigate the impact of TRIZ learning on performances of 20 engineering postgraduates in BID. The outcomes show that participants with TRIZ learning experience generated more novel design solutions. In addition, the relation between experience of TRIZ learning and students' BID performance is also analyzed. The result suggests the positive influence of TRIZ learning on BID and reveals several insights for upgrading education approaches of BID.

Keywords: TRIZ learning; BID; Knowledge representing; Design experiment

Efforts to increase diversity and inclusivity in engineering have had limited success in the United States where the percentage of women enrolling in engineering remains around 20%. One theory as to why women and minorities enroll in engineering at lower rates is stereotype threat which is the fear of fulfilling a negative stereotype about a group to which one belongs. In our study, we utilized Picho and Brown's Social Identities and Attitudes Scale (SIAS), which we adapted for engineering students, to measure stereotype threat vulnerability in engineering undergraduates in the southern United States. With 179 survey responses, we answered the following research questions: (1) Is the Social Attitudes and Identities Scale psychometrically sound when modified for engineering students? (2) What populations are most vulnerable to stereotype threat? (3) How does stereotype threat impact students in terms of the six constructs laid out within the Social Identities and Attitudes Scale? Our results show that the SIAS scale can be effective in measuring stereotype threat vulnerability in engineering students and that women are significantly more impacted by stereotype threat than any other group.

Keywords: diversity; inclusivity; stereotype threat; undergraduates

This paper focused on how a competent faculty member could improve the learning experience and reduce the anxiety of the students of the capstone design projects in the mechanical engineering program. The faculty advisor provides the students with the guidelines of the best engineering practices and frequent feedback throughout the project. Two main changes have been implemented and tested in managing the capstone design project course in the mechanical engineering program. First, the course requirements have been divided into multiple deliverables that were distributed throughout the semesters instead of having all the requirements delivered at the end of the semester. The overall grade was distributed among these deliverables instead of having only a final report and a presentation. Second, for each deliverable, a customized rubric which detailed the expectations of the project sponsor and the faculty advisor, was provided to the students. Such rubrics act as a roadmap for the students so that they can accomplish the project goals with minimum day-to-day help from the faculty advisor. Additionally, rubrics for the soft skills, such as teamwork effectiveness and time and communication skills were provided as well, so that students were aware of what were expected from them. Mixed qualitative and quantitative approaches have been used in this study including, questionnaires, surveys,

course evaluations, and observations. The new changes proved to be effective in improving students' learning experience, reducing the students' anxiety, and improving the assessment objectivity and transparency as well. However, the effect of using rubrics to assess the soft skills was not measured separately.

Keywords: mechanical engineering capstone design projects; self–learning assessment rubrics; assessment of students' soft skills; students' anxiety

The Electrical Engineering program at Texas A&M University-Texarkana is accredited by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET). This paper explains how Texas A&M University-Texarkana (TAMUT) Electrical Engineering faculty implemented the newly approved ABET-EAC Criterion 3 – Student Outcomes (SOs). As the new criterion has been voted to be effective, beginning of the 2019–2020 assessment cycle with no transition period for implementation, many programs question the utility of the new SOs as compared with the ubiquitous a–k outcomes. Moreover, programs actively started to abide by the new criteria in the midst of uncertainties and confusion about the new language used in Criterion 3. This paper not only discusses the new changes to the ABET-EAC criteria but also presents a practical assessment plan that can serve as a reference for other programs that are in the process of implementing the new changes. Moreover, different methods of presenting and documenting the assessment process are explained.

Keywords: accreditation; ABET assessment; TAMUT

Prior literature in engineering education has focused on student-centered learning by utilizing active, constructive, and interactive instructional strategies. However, most research focused on evaluating the effectiveness of these instructional strategies by comparing them with traditional approaches, which typically placed students in passive roles. The goal of this paper is to investigate the relative effectiveness of constructive and interactive strategies and understand the unique contribution of each once introduced simultaneously in a large engineering class. Specifically, we used team-based learning and prompting students to reflect on their learning experiences. We hypothesized that these instructional strategies enhance students' academic performance and achievement goals. In this semester-long study, we collected data from 120 engineering students. The dataset included a total of 3430 student reflections in 26 lectures, teamwork behaviors, collected four times during the semester, pre and post-survey of students' achievement goals, students' prior academic success, and students' three exam scores as academic performance measures. To effectively collect the data, we used educational technology tools designed specifically for these instructional strategies. We used CourseMIRROR to collect students' reflections data, and CATME Smarter Teamwork to collect students' peer evaluation of teamwork behaviors. The results indicated that students' reflection specificity and teamwork behaviors improved over time in a semester. Further, teamwork behaviors were strong predictors of students' academic performance in the exams after controlling for prior success. We also found that while teamwork behavior had a better contribution predicting students' mastery and performance goals, the reflection specificity was a better predictor of students' avoidance goals. Lastly, while there was no significant difference from pre to post in performance-approach and performance-avoidance, there was a significant decline in students' mastery approach after being engaged in both instructional strategies.

Keywords: reflective thinking; teamwork behaviors; achievement goals; students' motivation; students' learning; students' performance

This paper presents results from a qualitative analysis that examined the role of pedagogical approaches, support resources, and classroom policies in developing social capital among students in a sophomore-level STEM course at a large Midwestern university. The course was pedagogically transformed by faculty into an Active, Blended, and Collaborative (ABC) learning environment with multiple avenues for students to create and develop social ties. The ABC learning environment encourages students to use their peers as a resource and work collaboratively, supported by digital resources, to enhance their learning experience in the course. Results from a thematic analysis show that the ABC learning environment mediated the development of cognitive, relational, and structural social capital. Students in the course built weak social ties by working with their peers on the online course blog, and they constructed strong ties through in-person collaboration, both inside and outside of the classroom. The collaboration outside of the classroom was also fostered by the departmental culture, demonstrating the complexity of students' network-building and the importance of the broader context beyond a single class intervention. The results illustrate how a learning environment can shape the social capital shared among students, with potential implications for how large, core STEM courses can be organized to support student peer networks.

Keywords: active learning; blended learning; collaborative learning; social capital

Despite widespread reliance on Graduate Teaching Assistants (GTAs) in higher education, little is known about their identity as teachers and motivation toward teaching. To begin closing this gap, we conducted a sequential mixed methods study focused on GTAs in large first-year engineering programs. Our goal was to establish profiles of current GTAs based on key features of identity and motivation. Our analysis yielded three teaching identity profiles: strong, transitional, and weak. The data reveal that motivation constructs matter to GTAs individually but perhaps do not contribute to profiles. A key finding was that identity is the strongest driver of clustering and grouping across the quantitative and qualitative data. We describe potential implications of current teaching development practices for GTAs in each profile.

Keywords: graduate teaching assistants; motivation; identity

Project-based learning (PjBL) activities let students deal with authentic engineering problems where other abilities are trained instead of rote memorization or simple algorithmic substitution. In this paper, we propose a PjBL approach in a master degree of design and manufacturing where the students have to develop a lighting product from the conceptual design to the manufacturing and promotion of the product, finishing with a physical prototype made by 3D printing. The goal of the paper is to analyze the benefits of conducting a PjBL approach within a group of subjects that can be coordinated under the same project and where the students can put into practice the fundamentals of each subject for the physical realization of a real product. The paper describes the evolution of the PjBL experience throughout four years, the improvements and changes made according to students' and instructors' perceptions. As a result of the improvement of the project along the 4 year experience, the student's performance and the student's satisfaction related to the project increased from 7.2 to 8.9 out of 10 and from 3.7 to 4.8 out of 5, respectively. The motivation and engagement of the students were also improved according to the quality and dedication of the resulting products manufactured by the students.

Keywords: active learning; project-based; engineering education; product development; 3d printing; design

US degree completion data show that historically underrepresented students and women are less likely to complete doctorate degrees, particularly in engineering. While there are many studies on persistence, few compare student and faculty perspectives especially in engineering. The purpose of this case study is to compare what experiences motivate doctoral students and what experiences faculty aim to provide based on what faculty believe motivates students, particularly for women and historically underrepresented students in the United States. Drawing on Eccles' Expectancy Value Theory, we answer the questions: What relationships exist between ability beliefs and subjective task values for underrepresented students persisting in earning a doctorate in engineering? How do student and faculty beliefs compare? Our findings show that while both students and faculty agree on ability beliefs to remain motivated, they showed differences in the value they assigned to doctoral experiences; students focus on attainment value and faculty on utility value. Our findings suggest that both advisors and students should prioritize clear communication in their needs and intentions to better support student motivation in the doctoral degree process. While the context of this study is in the US, practitioners can find parallels in our findings to other contexts and their respective underrepresented populations. Our findings have the indirect impact that supporting the motivation of underrepresented students in particular can contribute to increasing diversity in doctorate degree completion rates.

Keywords: motivation; graduate students; doctoral education; minorities

In previous research on fluid mechanics courses, students expressed engagement by relating moments of noticing fluid phenomena in everyday life. This implies learning transfer and cognitive flexibility about fluids. This study lays the foundation for connecting perceptual experiences with conceptual understanding, with implications for sensory-rich learning experiences. Emulating cognitive psychology experiments in visual expertise, we tested two groups of participants: "novices" (no formal fluids education, n = 56), and "experts" (passed at least one fluid mechanics course, n = 36). Without being told the categories, participants were trained to sort static images of fluid flows as laminar or turbulent. Half the participants in each group trained on flow images with a specific format (Von Kármán vortex streets), half on a more varied group of flow images. Participants were then tested on the same type of images as their training (post-test) and tested again on images from the other training group (alt-test). Training resulted in statistically significant gains for all four participant groups, comparing post-test to pre-test. An ANOVA of between-group differences revealed that experts did significantly better than novices ($p = 0.0266$), whereas a comparison by training-type was not significant ($p = 0.2758$). A comparison of alt-test to pre-test data revealed that learning generalized for Novices trained on General Images ($p = 0.0266$) but not for Novices trained on Vortex Streets ($p = 1.0$). Expert results non-significantly trended toward learning generalization. Despite inconclusive results on expert learning, this study provides a new direction to explore the learning of fluids and other constraint-based interactions.

Keywords: Knowledge transfer; experimental research; mechanical engineering; expert-novice; conceptual learning

Efforts to introduce and evaluate change in engineering education have focused primarily on pedagogical change. Our article examines organizational-culture change within a U.S. Engineering School of a large R1 university in the U.S. Midwest. It integrates elements of organizational change (primarily from psychology) and cultural transformation (from anthropology) to demonstrate their combined usefulness for engineering educators. The broad change effort, structured as 12 grassroots problem-solving teams, was organized to solve specific issues that were expected to have a positive influence on student outcomes, as well as on the Engineering School culture; the teams chose projects whose outcomes did not rely on approvals from department, school, or university leadership. Through interviews, observation, survey data, and participant observation, we document team formation, implementation of their initiatives, and their outcomes. Individual agency and leadership play a critical role in launching initiatives. Initiatives grow and develop with alignment between team goals and day-to-day work roles on campus. Institutionalization of change into programs, practices, and policies occurs when individuals are responsible and accountable for them. Our findings reflect a raw, realistic form of organizational change where change and continuity are intertwined with cultural alignment, clashes, and individual agency and where no single trajectory of change dominates.

Keywords: organizational culture; change; psychology; anthropology, grassroots teams, institutionalization

Over the last few years, the concept of gamification has received increasing attention from a number of researchers, especially in education fields, as a tool to improve student performance by increasing motivation and engagement. However, previous research has not attempted to empirically investigate the effects of game elements on the quality of motivation (i.e., intrinsic and extrinsic motivation). Thus, this study investigates in detail the relationship between gamification and motivation through the lens of self-determination theory and seeks to determine whether gamification can maintain student motivation for the duration of an entire semester. The experiment was conducted in the fall semesters of 2016 and 2017 with 122 students (63 in 2016, 59 in 2017). Overall, the results showed that (1) gamification can maintain student motivation over the course of the semester and (2) gamification positively affects intrinsic and extrinsic motivation, negatively affects amotivation, and may, therefore, positively affect academic performance.

Keywords: engineering education; gamification; motivation; self-determination theory