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Editorial

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*Ahmad Ibrahim***Harnessing Generative AI to Enhance Feedback Quality in Peer Evaluations within Project-Based Learning Contexts** 998–1012*Susan Sajadi, Mark Huerta, Olivia Ryan and Katie Drinkwater*

This paper explores using generative artificial intelligence (AI) large language models (LLMs) to augment traditional peer feedback processes within project-based learning (PBL) environments where students work in teams. Our study contributes to the expanding digital educational frontier by harnessing the power of LLMs for summarizing and enhancing self and peer feedback. We present a novel educational innovation that utilizes GPT-4 to effectively summarize self and peer comments for student teams in PBL courses. Our research involved the development of a specific prompt grounded in relevant educational theories and the analysis of 118 AI-summarized Performance Feedback Reports that were generated for students. The findings reveal that the LLM significantly improves the quality of peer feedback by making it more constructive and actionable, addresses off-topic or inappropriate comments, and provides a meaningful comparison between a student's self-evaluation and peer comments. Our paper underscores the importance of peer feedback systems as valuable pedagogical tools in PBL classes and demonstrates how AI tools can enhance these systems. The outcomes of this research serve as a foundational guide for faculty, especially those teaching in PBL environments with student teams, who are considering using AI to enhance teaching and learning. We demonstrate the potential of integrating these innovative practices in PBL classrooms to support students' development of teamwork skills, marking a significant step towards a new digital frontier in engineering education.

Keywords: generative AI; LLMs; feedback; teamwork; problem or project-based learning (PBL)

Effect of ChatGPT on Undergraduates' Cognitive and Performance Skills of Database Management Learning 1013–1023*Ali Suwayid Alqarni*

Artificial intelligence (AI) has gradually and rapidly redefined engineering education. With this in mind, this study set out to explore the effects of AI's applications (ChatGPT a case in focus) as educational scaffolding in developing database management skills at the undergraduate level in Saudi Arabia. A quantitative approach with a quasi-experimental design was used for two equal groups to determine the effects, and a survey was used to collect the experimental group's opinions about the pros and cons of ChatGPT in learning database management. The sample consisted of 98 students from the College of Computer Science at a Saudi University, randomly distributed into experimental and control groups, each of 49 students. The experimental results showed a medium-sized effect of ChatGPT on the cognitive aspect. Results also show that ChatGPT affects, to a large extent, students' performance in database management. In the study, both positive and negative aspects of ChatGPT are evident. The most notable positives include enabling learners to solve content problems, saving time and effort, and enhancing self-learning opportunities. The negative aspects include plagiarism, lack of Arabic language support, and weakening of students' research skills. In closing, the study recommended using ChatGPT in database management learning and solving relevant problems. It also recommends directing learners on how to avoid the negative aspects that result from overreliance on ChatGPT without effort from learners.

Keywords: artificial intelligence; ChatGPT; generative AI; SQL language

Students as Partners to Enhance an Introductory Course on the Engineering Profession: A Case Study 1024–1035*Lawrence R. Chen, Mahmoud Amin, Celina Belleville, Mia Bruno, Maria Gostraya, Toufic Jrab, Mathias Pacheco Lemina, Diana Rekkas and Arin Yaffe*

We describe a teaching and learning partnership – a students as partners (SaPs) project – to gather information about first-year students' perceptions of engineering and their learning experiences in an introductory course on the engineering profession. We explain the process to setup the SaPs project, including how to select the number of SaPs involved, when and how to engage them, and the need to create an environment that ensures important values such as trust (and respect), reciprocity, and responsibility. The information gathered from the SaPs is then used to revise the course instructional and assessment strategies so that students have opportunities to develop skills and competencies associated with graduating engineering student attributes. These include professionalism, especially in terms of understanding the roles and responsibilities of an engineer to the public and in society; analyzing the impact of engineering on society and the environment; resolving dilemmas and issues related to ethics, equity, diversity, and inclusivity; communications; and teamwork.

Keywords: teaching and learning partnerships; student-faculty partnerships; students as partners; student perceptions; engineering professional values

Zhenhua Yao, Qing Hu, Ruiquan Zhang and Maocong Hu

External accrediting bodies demonstrate the rigour of higher education courses internationally, offering security that educational levels are comparable between countries. Here we briefly reviewed the history of chemical engineering (ChE) education and its accreditation system in China while the overview of the typical pyramidal structure of the China Engineering Education Accreditation Association (CEEAA) accreditation system was offered. The Graduate Attributes (GAs)-Course Outcomes (COs) matrix was further identified as the critical raw data underpinning our goal of helping ChE educators design curricula satisfying the accreditation criteria of CEEAA by addressing the following two questions “Which courses should be chosen to support a specific GA?” and “Which GAs can be supported by a specific course?”. This manuscript conducts a statistical analysis of the current GAs-COs matrices from 61 ChE programs across China. The typical curriculum of an accredited ChE undergraduate program was then sketched out, which included 61 courses based on the total COs number ranking. The courses with COs supporting every GA were further identified while those aiming to support GA11 (Project management) are still far from a requirement. The process of determining the outcomes of a specific course is quite complex and many factors have to be considered. The observations and insights may be employed by educators interested in improving their curricula for accreditation purposes in the future.

Keywords: accreditation; curriculum; statistical analysis; chemical engineering; China

Factors Precluding the Adoption of a Pedagogical Innovation: An Engineering Case Study Showcasing the Implementation of *Freeform* 1045–1061

Fredy R. Rodríguez-Mejía, Aldo A. Ferri, Edward J. Berger and Jeffrey F. Rhoads

Pedagogical innovation efforts in engineering education and other STEM fields highlight some of the inherent challenges and opportunities in the process of strengthening undergraduate education. While interactive pedagogical approaches involving peer teamwork and a mix of in-person and online resources have strengthened the quality of teaching/learning, few studies provide a close-up examination of how faculty members navigate the implementation of new learning systems developed in other institutional settings. In this paper we examine factors contributing to the lack of sustained adoption of an engineering learning system called *Freeform* in a new academic context. We found that while students lauded the learning system’s potential for deep learning practices, the lead instructor encountered several challenges in its implementation which precluded him from adopting the system in the long term. While the lead instructor recognized the pedagogical value of *Freeform* in helping students engage deeply with engineering concepts, he found its implementation to differ too greatly from his traditional teaching trajectory in addition to increasing his preparation workload and having other logistical barriers. Ultimately, *Freeform* was not compatible with the specific institutional culture of the engineering department where the study took place. We offer some potential solutions to ameliorate issues of compatibility when attempting to diffuse and implement pedagogical systems in different institutional contexts.

Keywords: pedagogical innovations; diffusion; case study; blended learning; active learning

Enhancing Skills Transfer for First-year Engineering Students in Higher Education 1062–1075

Titlollo Sidwell Hlalele

Engineering students in their first years attending universities in South Africa are faced with different challenges one of which is understanding the topic that will equip them with appropriate skills. These students transition from being high school students to university students and as a result experience behavioral changes, performances, and learning rates. One of the important components of the process is the transfer of skills, and this should be done both theoretically and practically to train an engineer. Fresh students usually struggle to apply what they learn in classrooms to real-life situations when joining the college as engineers. This paper seeks to discuss skills transfer and how skills transfer can be improved for first-year Students in engineering as the methodology adopted for this research work shall be qualitative research whereby an extensive review of the literature and secondary sources relating to skills transfer in engineering education shall be conducted. There is a critical review of more than 30 journal articles and industry research papers, academic newsletters, and studies to assess the current state and efficiency of transfer of skills approaches. The main idea is that by using active learning approaches, problem-based scenarios, mentorship activities, and external corporate partnerships universities can provide students with the skills necessary for the modern engineering profession. Faculty is also under consideration in the paper, followed by a consideration of curriculum design and an examination of the application of technology in bridging the gap between skills gained in class and skills as applied in practice. With these approaches, first-year engineering students can effectively learn and enhance their motor and cognitive skills, thus empowering them academically and professionally.

Keywords: skill transfer; engineering education; curriculum design; practical skills; team-based learning

The Effects of Professional Identity, Empathy with Nature, and Consideration of Future Consequences on Sustainability Consciousness among Chinese Undergraduate Engineering Students 1076–1089

Lingling Lu, Hidayah Mohd Fadzil, Peng Yen Liew, An Jie Lye, Quanwang Wang and Chan Choong Foong

Sustainability consciousness is important for engineers’ effective execution of sustainable development goals. Today’s students are tomorrow’s engineers. Hence, exploring factors that influence undergraduate engineering students’ sustainability consciousness is essential. This study explored the effects of professional identity, empathy with nature, and consideration of future consequences on three dimensions of sustainability consciousness, namely knowingness, attitudes and behaviors. A survey was conducted among 263 first-year undergraduate mechanical engineering students in Shanxi, China. Using SPSS AMOS, the measurement model verified that the questionnaires were valid and reliable. Subsequently, the structural model analysis reported that (1) professional identity positively influenced three dimensions of sustainability consciousness; (2) empathy with nature was a positive predictor of three dimensions of sustainability consciousness; (3) consideration of future consequences significantly predicted sustainability behaviors but did not predict sustainability knowingness and attitudes. The present study provides justifications for integrating professional identity and empathy with nature in the engineering curriculum.

Keywords: Sustainability consciousness; professional identity; empathy with nature; consideration of future consequences; undergraduate engineering students; structural equation modeling; confirmatory factor analysis

Tea Borozan, Milica Maričić and Dragan Bjelica

Educational institutions are exploring innovative teaching methods due to evolving technology and market demands. Among these methods, simulation games are becoming popular for their potential to enhance learning. However, their effectiveness in developing students' business skills remains underexplored. This study analyses the relationship between simulation game mechanisms, motivation, understanding of theoretical concepts, and their impact on students' business skills development. Empirical research was conducted on engineering students enrolled in the Strategic Management course at the University of Belgrade – Faculty of Organizational Sciences, which included a simulation game component. Out of the 127 engineering students enrolled in the simulation game, 113 participated in the research (88.97%). Structural equation modelling (SEM) was used to assess hypotheses. Results show that while the game mechanism has limited direct impact on business skills development, it significantly enhances student motivation and comprehension of theoretical concepts. Furthermore, motivation and understanding of theoretical concepts are found to be critical for developing business skills. These findings provide valuable insights for educators and higher education institutions aiming to integrate modern and effective teaching methods to develop skills that meet labour market demands.

Keywords: simulation games; engineering students; contemporary teaching methods; skills development

Precollege Mathematics and Engineering Learning Outcomes: Implications for Equitable Preparation, Recruitment, and Retention

1101–1113

Robert M. Capraro, Niyazi Erdogan, Luciana R. Barroso, Jamaal Young and Mary Margaret Capraro

The importance of precollege mathematics achievement is well documented, but the complex relationships between different measures of precollege mathematics achievement and engineering outcomes has not been fully explored. The purpose for this study was to better understand the interrelationship between common measures of precollege mathematics achievement and success in post-secondary engineering. The principal research question was “How are precollege mathematics achievement measures associated with intercorrelated engineering course success for those who graduated with an engineering degree?” We used extant enrollment and transcript data in our canonical correlation analysis to assess the relationship between two variant sets: measures of precollege mathematics achievement and engineering course success. The precollege mathematics variant set was statistically significantly related to the engineering learning outcomes. Two canonical functions were retained and examined: (1) Mathematics Placement Exam performance was the most influential factor in the precollege mathematics variant, and (2) Advanced Placement Calculus BC scores and time to graduation were the most influential factors. The results contribute a parsimonious model of mathematics achievement variables useful in capturing prerequisites for successful completion of an engineering degree. We provide evidence that there is no meaningful relationship between taking and passing the Calculus AB or BC exams and time to graduation and credit earned. These results can be useful to school counselors and science, technology, engineering, and mathematics teachers for advising high school students.

Keywords: canonical correlation; mathematics achievement; engineering education preparation; retention; calculus; ACT; SAT

Cultural (In)Congruence: How Black Women Navigate Individual, Academic, and Societal Dimensions of Engineering

1114–1128

Brooke Coley, Meseret F. Hailu, Prince K. Kwarase and Ketu Tsofniasvili

Despite efforts to diversify engineering, limited attention has been paid to the trajectories of Black women in STEM education scholarship. To address this gap, we asked two research questions about a STEM-subdisciplinary field in this empirical study. The first question focuses on cultural (in)congruence as it exists across the individual, academic, and societal domains for a group of Black women engineering students; while the second focuses on what higher education institutions can learn from the experiences of cultural (in)congruence to establish thriving academic environments for Black women engineering students. We define cultural congruence as the process of finding an individual's identities, values, beliefs, and practices to be mirrored and/or reflected in their environment. This is a critical concept because of the cognitive and emotional labor that is exerted when minoritized individuals code-switch. Drawing from the ecological framework of Bronfenbrenner, we explored cultural (in)congruence across the micro-(individual), meso-(academic), and macro-system (societal) realms. We used a qualitative, case study approach, involving 45 one-time interviews with Black women undergraduate students from a single university. After conducting a qualitative analysis, we arrived at four major findings: (1) for Black women, cultural congruence is often a self-initiated pursuit found in non-engineering spaces; (2) while students were able to find congruence across individual, academic, and societal domains, this was often forged at a personal cost to themselves; (3) students anchored in strong individual culture were better suited to endure the incongruence across academic and societal realms; and (4) there is much room for higher education institutions to make engineering environments less culturally taxing for minoritized Black students.

Keywords: Black women; cultural congruence; ecological systems; engineering; undergraduate students

Undergraduate Engineering Students' Understanding of Engineering Disciplines: An Empirical Study

1129–1149

Sinan Onal and Ezra Temko

This study investigates the perceived familiarity with different engineering disciplines among engineering students at Southern Illinois University, Edwardsville (SIUE), with a focus on disparities across gender, race, and academic majors. Data were collected via an online Qualtrics survey from undergraduate engineering students at SIUE during the Fall 2022 and Spring 2023 semesters. The survey, which achieved a 25% response rate with 275 completed surveys, assessed students' ability to identify six key engineering disciplines. Quantitative analysis methods, including linear regression and multivariate analysis, were applied to examine how demographic factors influence students' familiarity and identification skills. Weighted data were used in the analysis to correct for non-response bias related to gender, race, and major selection. Findings indicate notable disparities: male and White students exhibited higher familiarity compared to Female and Gender Queer (FGQ) students and students of color, especially Asian American and Pacific Islander (AAPI) students. Students enrolled in broad-based and interdisciplinary engineering programs demonstrated better overall understanding than their peers in more specialized programs. The study confirms that perceived familiarity significantly predicts correct identification, suggesting that increased educational exposure to various engineering fields can enhance accuracy. These results underscore the importance of revising educational curricula to include more inclusive and comprehensive exposure to all engineering disciplines. Interventions such as redesigned coursework, expanded mentorship programs, and increased support for underrepresented groups are recommended to address the observed disparities. Future research should aim to validate these interventions and explore longitudinal trends in engineering education familiarity.

Keywords: engineering education; perceived familiarity; gender disparities; racial disparities; interdisciplinary programs

Breanna Graven, Patricia Ralston and Thomas Tretter

First-year engineering students have an academic mindset that can consist of many latent factors such as self-efficacy, test anxiety, sense of belonging in college, sense of belonging in engineering, perceived cost, and interest. The literature reports that such non-cognitive factors separately impact student performance and persistence, but that they should be studied in an integrated fashion rather than one at a time. Before exploring how these factors impact performance, we must have a measurement model of the factors. We present a structural equation measurement model (SEM) of these six factors and demonstrate that we have good measures of these factors for our population of engineering students. The strength of an SEM analytic approach is the avoidance of modeling relationships in a stepwise fashion, but instead allowing for simultaneous analysis of all interrelationships with each other in a comprehensive model. We confirmed the model fit through calibration testing on one randomized half of our population of 2253 students from five cohorts 2018–2022, and then verified the model on the other randomized half of the population. We further analyzed that the model is an equally good fit for underrepresented racial groups and represented racial groups, as well as for men and women.

Keywords: first-year engineering; sense of belonging; interest; self-efficacy; perceived cost

An International Overview of Teaching Control Systems During COVID-19 Pandemic

1162–1180

José Luis Guzmán, Katarina Zakova, Ian Craig, Tore Hägglund, Daniel E. Rivera, Julio Normey-Rico, Paulo Moura-Oliveira, Liuping Wang, Atanas Serbezov, Takao Sato, and Antonio Visioli

This paper aims to provide an overview of the impact of the COVID-19 pandemic on control engineering education worldwide. The authors, who are educators in the control education field from various countries across all continents, first summarize their experiences to present a global perspective on the different solutions adopted in control education during the pandemic. Afterwards, collected information from the international community through a questionnaire enabled insightful comparisons between pre-pandemic and during-pandemic educational resources and methods, which are shared in this paper. The feedback from the authors' experiences, along with the questionnaire responses, serves as a valuable resource for learning and improving teaching activities. The questionnaire was distributed among the international control engineering community in collaboration with the International Federation of Automatic Control (IFAC) to explore the diverse alternatives employed globally for conducting online educational activities during the pandemic. These activities include methodologies, tools, theoretical exercises, laboratory experiments, exam types, simulators, and software for online lecturing.

Keywords: control system education; online teaching; COVID-19 pandemic; learning

Causes for the Asymmetric Adoption of Active Learning Methodologies in Engineering Education: A Rogers' Theory Perspective

1181–1192

Borja Bordel, Ramón Alcarria and Calimanut-Ionut Cira

Active learning methodologies are educational strategies where students take a proactive role, and where they must meaningfully work and reflect on the competencies of the academic units. More than twelve different active methodologies have been developed in recent years. Selecting one or another usually depends on the available time and physical space, the nature of the academic unit to be learned, or the number of students. But many authors also highlight the comfort level of professors as a key factor to understand the adoption of some active strategies over others. This article aims to study how this “comfort level” affects the adoption of the different active learning methodologies, in engineering education centers, and using the Rogers Diffusion of Innovation theory. A collection of survey questions was conducted among engineering professors at Universidad Politécnica de Madrid and Universidad Alfonso X el Sabio. Responses were based on the Likert scale and statistical methods were used to analyze the collected data. Results confirmed that the relative advantage has the highest positive impact on the adoption rate and observability. However, complexity, the nature of the social system and the type of innovation-decision have a negative impact on the adoption rate. Engineering education centers are suggested to increase the social recognition of active learning adoption to improve the adoption rate.

Keywords: engineering education; Rogers theory; active learning; adoption of innovations; education research; statistical analysis

Organizational Learning in Adoption and Adaptation of Reformed Instructional Practices of Engineering Instructors: A Case Study

1193–1208

Hong H. Tran, Edward J. Berger, Fredy Rodriguez-Mejia and Anyerson Cuervo-Basurto

Despite a large body of work devoted to understanding why instructors struggle to implement reformed instructional practices, researchers only understand part of the variation in instructor learning and implementation of the practices. This narrative inquiry case study explored how a mechanical engineering department adopted and adapted Freeform (Ff), which is a pedagogical system, that includes instructional resources and instructional ethos. Findings show that the department adopted Ff with a vision to standardize its dynamics course. The three instructors of four sections of the course had some shared and unshared mental models of engineering teaching and learning that somewhat aligned with the vision. While one instructor adopted all five critical components of Ff in her teaching, the other two instructors did not leverage all the components. The instructors shared some resources for the course and discussed their teaching with others but not sufficient to come to a consensus on the final exam. Consequently, the department could standardize the course materials, homework, quizzes, and schedule, but not the final exam. Via eliciting different dimensions of organizational learning that occurred at the mechanical engineering department, the research suggests ways to improve adopting reformed instructional practices. Moreover, our study contributes to the body of literature by revealing the complexity of instructors' decision-making to adopt and adapt Ff and the relationship and interaction among disciplines of organizational learning in the context of teaching the dynamics course.

Keywords: instructional practices; engineering instructors; adoption; organizational learning; mechanical engineering

Factors Influencing Career Decisions of High School Students in Japan: A Gender Perspective

1209–1218

Yutaro Ohashi, May Kristine Jonson Carlon and Jeffrey Scott Cross

A nationwide questionnaire survey was administered to 215 high school students to examine their career decision-making process. The results showed that female students were more likely to choose vocational schools and medical-allied fields (e.g., nursing, health, and hygiene fields), whereas male students were more likely to choose science, engineering, and agriculture fields. Regarding people and things that influence career decisions, males were more influenced by their fathers and newspapers, whereas females were more influenced by their mothers and friends, TV programs, social networking sites, and family financial situation. For some females, adults in family leadership positions were a disincentive to make career decisions.

Keywords: career decision; high school students; questionnaire survey; gender gap; Japan

Lluc Canals Casals and Beatriz Amante García

This study presents a grade individualization method tested in a class of Project Management where the value of teamwork deliverables weighs half of the total grade. This is done by applying and analyzing the results of five different evaluation techniques along the course, with their corresponding individual effect on the overall grade. Results show that, in most cases, the modification of the teamwork grade does not follow any pattern, meaning that the positive or negative effect on the students' grade changes between deliverables ending up in an almost invariable grade at the end of the course. Moreover, by the end of the course, most students considered that it was neither necessary nor fair to individualize a teamwork grading.

Keywords: teamwork; individual testing; individualized education; work satisfaction

Innovative Approach to Teaching Distributed Systems in Education 4.0

1229–1244

Safet Purkovic, Irfan Fetahovic, Edis Mekic, Gokmen Katipoglu and Semih Utku

This paper presents an innovative pedagogical approach for teaching university-level computer science courses, specifically distributed systems. Integrating concepts from computer science and educational sciences, the approach combines large language models (LLMs), tools integrating and automating software development (Dev) and IT operations (Ops), i.e. DevOps tools, and the educational framework based on agile approach in which students take responsibility for organizing their own learning process (eduScrum) within the vision of aligning education with the demands of the 21st century (Education 4.0). Over four academic years, the new approach was compared to traditional teaching methods. The course was structured into three sprints, each encompassing theoretical and practical tasks. ChatGPT was utilized in example solutions for code generation and debugging, while Git repositories supported practical programming exercises. Efficiency was measured through qualitative and quantitative analysis, indicating a marked improvement with the new methodology. The study demonstrates the potential of modern technologies to create dynamic, effective learning environments and suggests a pathway for updating computer science and software engineering education to keep pace with technological advancements.

Keywords: eduScrum; distributed systems; large learning models; Education 4.0; DevOps

Trends Affecting Curriculum Reform in Engineering Education: A Scoping Review

1245–1261

Isabel Hilliger, Julian "Iñaki" Goñi and Catalina Cortázar

Different influences have shaped curriculum elements in engineering education over the last decade. Prior work has referred to faculty background, accreditation criteria, and industry demands. A recent influence has been the digitalization of the curriculum during the COVID-19 pandemic, forcing many engineering schools to incorporate curriculum changes. In this context, we addressed the following research question in this study: What factors have influenced curriculum reforms in engineering education in the last decade? Thus, the main research objective is to illustrate the main influences over curriculum elements from an academic perspective, aiming to inform future research and innovations in curriculum development. We used a scoping review to synthesize evidence and assess the literature's scope concerning engineering education curriculum reforms. We collected the papers from the Scopus database to point out key factors and knowledge gaps in the research on curriculum education reforms. According to a two-stage screening process, we selected 73 studies from 80 papers published between 2011 and 2021. Out of these 73 publications, 11 correspond to scientific articles, two to book chapters, and 60 to proceedings of different conferences. To identify emerging themes, all three authors analyzed the abstracts of the remaining 73 papers. This scoping review highlights the significant impact of economic and technological changes on engineering reform, particularly post-COVID-19. It aggregates studies to provide a global perspective, contrasting with prior research on individual institutions. These aggregated approaches reveal broader trends and emerging challenges that support a shared vision in engineering curriculum development and improvement.

Keywords: scoping review; engineering education; curriculum reform

Assessing Industry-Critical Skill Development in Engineering Technology Capstone Courses

1262–1272

Rustin Webster and Matthew Turner

To meet industrial expectations, engineering and engineering technology (ET) graduates are expected to possess the critical competencies of design, problem-solving, communication, and teamwork. However, industry stakeholders and academic studies routinely identify these as skills gaps: areas graduates need to develop to a higher standard or are currently lacking when entering the work force. To address this issue, many undergraduate programs in the United States have implemented a comprehensive and integrative experience at the end of an academic program, often called a capstone course(s). The rate of adoption has grown such that approximately three-quarters of all undergraduate and graduate institutions include capstones. This case study describes how an engineering design focused capstone impacted ET students' competencies (i.e., related knowledge, skills, and abilities). Central to the two-course sequence was an authentic learning experience that required students to follow the engineering design process to solve an internally or externally sourced open-ended problem. Forty-four students from two cohorts over two consecutive years strongly indicated that they had made progress in improving their design, problem-solving, communication, and group/teamwork competencies as a result of taking capstone.

Keywords: engineering technology; capstone; competency; skill gap; design