Volume 40 Number 1 2024 ISSN 0949-149X

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Evaluation of the Effectiveness of Individual Hands-on Workshops in Heat Transfer Classes to Specific Student Learning Outcomes 5–15
Thomas Diller and Diana Bairaktarova

Twelve hands-on workshops were assigned to one fifty-person lecture class of heat transfer, while a second class of the same size was given corresponding homework problems. Although everything else between the classes was maintained the same, the overall performance of the workshop class was previously shown to be significantly better than the non-workshop class. This was true including both concept questions and quantitative problem solutions. The current paper looks in detail at specific workshops that were helpful on the topics of transient conduction, energy balance with multiple conduction pathways and relative resistances, external convection, and gray body radiation. Student feedback on the workshops is used to help elucidate what worked for each workshop and what needs improvement. This includes suggestions for better workshops on fins and lumped capacitance based on what concept is most difficult for the students to grasp. Finally, a basis for evaluating this teaching method is established.

Keywords: thermal measurements; heat transfer concepts; hands-on workshops; heat flux

Effects of Game-Based Learning on Engagement and Academic Performance for Undergraduate Science and Engineering Students 16–22
Saqib R. Jivani, Mouna Chetehouna, Sanaa Hafeez and Mohamed H. Adjali

In recent years, the adoption of flipped learning as an educational approach has gained significant momentum. This pedagogical method involves the delivery of direct instruction outside of the classroom, utilising videos, quizzes and lecture slides to facilitate active learning during class time. To address the challenge of student motivation and enhance overall engagement, the incorporation of game-based learning within the flipped learning approach has emerged as a promising solution. This research aims to explore the potential of gaming in promoting active learning and fostering a deeper understanding of course material. The findings highlight the positive impact of gamification on student engagement and academic performance within an undergraduate Engineering module. Through the integration of game elements, such as Kahoot and a leader board system, students exhibited increased motivation and active participation throughout the course. The implementation of game-based strategies effectively captured students' attention and facilitated a dynamic learning environment. The results demonstrated a positive correlation between engagement levels and academic performance, affirming the efficacy of gamification in promoting enhanced learning outcomes. Furthermore, this study highlighted the importance of recognising and celebrating student achievements through public displays of accomplishment. The public acknowledgement of high achievers not only instilled a sense of pride and motivation in these students but also inspired their peers to strive for excellence. The collective applause and recognition from the entire class served as a powerful reinforcement of the value and significance of active engagement in the module. These findings emphasise the potential of integrating flipped learning and game-based strategies as a comprehensive educational framework that caters to diverse student needs and maximises learning outcomes. Future research will focus on scaling up the study to encompass a wider range of undergraduate Engineering modules, involving a larger cohort of students from various disciplines. By expanding the investigation, a more comprehensive understanding of the effects of gamification on different student populations can be attained. Overall, this study contributes to the growing body of literature on gamification in education, underscores its potential to transform traditional instructional practices and promotes effective teaching and learning experiences.

Keywords: student engagement; student experience; gamification; Kahoot; flipped learning; active learning

GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support 23–37
Miroslav Bjekić, Marko Rosić and Marko Šućurović

The paper reviews a set of developed GeoGebra applications designed to be used in several university courses related to Electrical Machines and Drives (EMD). The applications are developed to support students' learning of relatively complex physical phenomena in the field through remote and online learning. A detailed review of the possibilities of newly developed applications in the field of electrical engineering and various types of electrical machines is presented in the Part I of the research. The emphasis is placed on the advantages of the applications and procedures for making conclusions based on the software possibilities in terms of learning process improvement. The presented developed EMD GeoGebra applications, adapted for different e-equipment, are publicly available. The Part II of this research presents the evaluative research on the applicability and quality of the described set of applications. The students of electrical power engineering assessed the quality of the EMD GeoGebra applications as very important and useful tools for learning and mastering related courses. Finally, the usefulness and effectiveness of these applications are summarised in the conclusion of the paper.

Keywords: electrical machines; electrical drives; characteristics; GeoGebra; distance learning; educational software evaluation

The Efficacy of GeoGebra Tool in Enhancing Electrical Machines and Drives Instruction 38–42
Marko Rosić, Miroslav Bjekić and Dragana Bjekić

The two related articles (GeoGebra Tool: Development of Applications for Electrical Machines and Drives Teaching Support and The Efficacy of GeoGebra Tool in Enhancing Electrical Machines and Drives Instruction) are parts of the unique and comprehensive research approach to improving university instruction of electrical machines and drives. The second part of this educational investigation presents the evaluative research on the applicability and quality of the described set of applications. The students of electrical power engineering assessed the quality of the developed EMD GeoGebra applications as very important and useful tools for learning and mastering related courses. Finally, the usefulness and effectiveness of these applications are summarised in the conclusion of the paper.

Keywords: electrical machines, electrical drives; GeoGebra; distance learning; educational software evaluation

A New Practical Approach for a Basic Electrical Instrumentation Lab to Enhance Student Engagement and Performance 43–53
Ainhoa Rezola, Andoni Beriain, Héctor Solar and Noemí Pérez

Basic energy and electricity concepts are often misunderstood by first-year engineering students. One of the main reasons for this is that these concepts are perceived as abstract, making it challenging for students to relate them to real-life situations. Experimental laboratories are designed to help students delve deeper into these concepts. However, the demand for more visual aids by students, coupled with their limited ability to grasp complex ideas, often leads to the perception that some labs are outdated and reinforces misconceptions. To address this issue, this article introduces a novel laboratory workbench and methodology aimed at enhancing basic electrical energy and instrumentation laboratory sessions. The approach utilizes a more visual and interactive platform that enables students to connect electrical concepts with real-life elements. Prior to attending the class, students watch instructional videos that demonstrate the practical procedures, following the Flipped Learning strategy. The results of this study reveal that students felt more confident during the laboratory sessions and exhibited a more active attitude, actively asking questions and defending their viewpoints. Professors also observed that time was utilized more effectively, allowing for a better understanding of topics and clarification of confusing content. Overall, the proposed lab sessions significantly improve the learning experience of first-year Physics students and foster their autonomy in learning.

Keywords: electrical engineering; laboratory; undergraduate; flipped classroom

Exploring the Impact of Virtual Office Hours on Engineering Students' Learning: A Case Study in Higher Education 54–68
Maeve Bakic, Krishna Pakala and Devshikha Bose

Student-teacher interaction is a vital part of course design, for this reason many instructors in higher education have established office hours to further ensure this interconnection. However, office hours are often limited by time and physical space, creating a less than optimal learning environment for students who already have many other time commitments. For this reason, attendance rates are often low. A solution to these constraints was posed with the concept of virtual office hours. This low-stakes environment addresses the attendance issue and allows students the flexibility of experiencing meaningful learning from anywhere they choose. This study reports on the student experience of virtual office hours, as compared to the traditional face-to-face office hours, offered in three engineering courses. Students varying from sophomore to junior levels were enrolled in one of three semester-long courses, two mechanical engineering and one electrical engineering. 154 students between the two disciplines were enrolled in a course offering virtual office hours. The implementation logistics of these virtual office hours, key details on interactions during the sessions, and content presentation are discussed in this paper. Goals of this study were: to identify how virtual office hours impact engineering students' learning, ascertain whether the sessions were an efficient use of time for both students and instructors, and to determine the differences between virtual office hours and traditional face-to-face office hours. The students' perspectives were acquired through surveys administered at the end of the semester-long implementation of virtual office hours. Data analysis of the survey responses revealed that the implementation of virtual office hours within these courses was beneficial for both the students and instructors.

Keywords: office hours; virtual office hours; online learning; STEM learning; student perspective

Inverted Pendulum Projects in Controls Education: A Five-Year Journey 69–74
Ryan W. Krauss

This paper presents the iterative design of a novel cart/pendulum system for feedback control education. Because the system is inexpensive, students can be allowed to take it home, allowing them to interact with it at any time. In order for the system to enhance student learning, multiple hardware, software, and modeling issues had to be overcome. The final version of the project seems to enhance student learning and help students appreciate control theory.

Keywords: feedback control; inverted pendulum; pedagogy; project-based learning

Analysis on the appropriate Pedagogy approaches applicable for 'Engineering Thermodynamics' Course 75–82
Rayapati Subbarao

Teaching – Learning processes are vital in making the students understand better in diverse classroom environments. Few innovative approaches used may ensure that the class work is more interesting and make the students deliver better in order to gain the desired output, at the end of the course. Different aspects of T-L processes are possible to implement in all the courses, leading to any engineering program. With the invention of new technologies, these have got a new dimension, which are not so conventional as earlier. In this work, 'Engineering Thermodynamics' course, which is taught in an undergraduate energy engineering program is considered. Course contains five modules, covering fundamentals of thermodynamics, laws of thermodynamics, entropy, power cycles, fuels and combustion aspects. Different pedagogy approaches suitable according to the modules and the entire syllabus are exemplified and elaborated. Temperature and pressure measurement concepts can be taught effectively by the teacher by bringing the gauging equipment to the class. Laws can be taught with the help of a software, showing the uniformity of temperature or work done as per the heat input. Entropy can be taught with the practical examples shown in presentation/videos or through demonstration. Teacher can demonstrate an experiment in the lab to identify the performance of the engine, in order to make the students understand the concepts of power cycles. With the help of group tasks (or) case studies on live problems, the environmental aspects can be clearly understood by the students. In the end, grades obtained by the students and course-wise outcome attainment are also plotted for the last four years. Analysis finds the use of innovative pedagogy approaches, while sticking to the conventional teaching methodology, in order to ensure that students achieve the required abilities. Thus the present work uses appropriate pedagogy approaches applicable for a basic engineering course and is very much useful for implementation by the teachers of energy engineering and allied programs.

Keywords: Teaching – Learning process; Pedagogy approaches; Innovative teaching methods; Experiential learning; Collaborative learning

Section II

Contributions in: K-12 Engineering, Learning Outcomes, Student Engagement, Gamification, Distance Learning, Flipped Classroom, STEM, Virtual Office Hours, PBL, Pedagogy Approaches, Motivation, Technical Reports, Interpersonal Skills, Creativity, Attendance and Performance, Curriculum Demands, Retention, Teamwork, Simulations, Thermodynamics, Power Engineering, Instrumentations, Chemical Engineering, Civil Engineering, Industrial Engineering

Effects of High School Engineering Course Participation on Persistence Attitudes and Engineering Self-Efficacy 83–96

Kristin Sandberg, Jean Mohammadi-Aragh, Jenna Johnson, Shane Brauer and Deborah Eakin

The demand for engineers continues to grow. Retaining engineering students through to degree completion is a key step in filling more engineering jobs. Retaining engineering students is easier said than done. An area that has grown in popularity in the fight to close the STEM gap is K-12 engineering programs. This research studied high school engineering courses and their effects on undergraduate engineering student persistence attitudes and engineering self-efficacy. A large-scale, national sample was sought by surveying undergraduate engineering students from across the United States. Responses from 1612 undergraduate engineering students provided the sample for this study. The percentage of the survey sample that participated in high school engineering classes was 40.3% which accounted for 649 participants. Overall, no significant relationship was found between high school engineering class participation and students' persistence attitudes or engineering self-efficacy. The only area of self-efficacy showing significance with high school engineering was Engineering Career Success Expectations. High school engineering courses present engineering as a career worth working toward. However, once students are in engineering school, collegiate factors such as GPA and engineering work experience show more clear relationships with persistence and self-efficacy.

Keywords: engineering retention; K-12 engineering; pre-engineering; high school engineering; engineering persistence; engineering self-efficacy

Engineering Students' Varying Motivation and Self-concept in Mathematics 97–107

Evgeniya Burtseva, Marcus Sundhäll, Timo Tossavainen and Peter Wall

This study investigates engineering students' views about the factors which have influenced their motivation, mathematical self-concept, and their performance in mathematics. Eleven students from three engineering programmes at one Swedish university were interviewed about their experience from studying mathematics in university. All students were motivated to study mathematics in the beginning of the first year at university but some of them lost motivation after the first year, mostly because of private reasons. However, independent of their study performance, students reported that they had become more self-confident in studying mathematics after the first year which in turn enhanced their mathematical self-concept. Furthermore, a majority of students indicated that transition to online education, prompted by the COVID-19 pandemic, had a negative impact on their motivation and performance. Specifically, they highlighted the absence of in-person communication as a significant challenge. Additionally, students conveyed that receiving continuous feedback and engaging in practice-oriented lectures would greatly benefit their mathematics studies.

Keywords: engineering student; motivation; self-concept; online education

Validation of a Senior-Level Chemical Engineering Laboratory Course Technical Report Rubric that Aligns with Industry Expectations 108–115

Stephanie G. Wettstein, Douglas J. Hacker, Jennifer R. Brown

A challenge instructors face is developing and accurately assessing technical communication skills to ensure students can apply and transfer the skills from the academic context into the context of engineering practice. By intentionally balancing teaching transferrable communication skills relevant to engineering practice and evaluating student understanding, engineering educators can foster competence and prepare students for the expectations of their professional careers. This study addresses two questions: (1) how can chemical engineering instructors reliably and consistently assess student communication skills, and (2) are instructor expectations aligned with those of practicing engineers? The use of well-designed rubrics is important for setting clear expectations for students, providing constructive feedback, and in team taught courses, grading consistently. This study discusses how a rubric for assessing technical communication skills in senior-level chemical engineering laboratory reports was validated and demonstrated reliability across five chemical engineering instructors. Additionally, five industry partners evaluated student reports for comparison to instructor rubric scores. Expectations and perceptions of the quality of student work align between instructors and practicing engineers, but practicing engineers prioritized safety and abstract clarity, while instructors prioritized the students' abilities to interpret results and draw conclusions.

Keywords: lab reports; industry; rubrics; chemical engineering; multi-instructor

Perceptions of the Importance of Interpersonal Skills by Engineers, Students, and Faculty 116–125

Morgan Green, Alta Knizley and Lesley Strawderman

Engineering undergraduates are expected have a base level of technical skills upon graduation. Teaching technical skills comes naturally to engineering programs as the conceptual understanding of the material forms the foundation of engineering ability. However, engineering graduates also are expected to have a base level of professional, or interpersonal, skills, which are more subjective in nature and do not have a standardized approach for teaching or assessing them at the undergraduate level. This work explored the perceptions held by engineering students, engineering faculty, and practicing engineers toward the importance of specific interpersonal skills. Eight interpersonal skills were investigated: collaboration, communication, ethical considerations, inclusivity, leadership, professional judgment, task management, and teamwork. Statistical analysis of survey data indicated that students, faculty, and practicing engineers have similar views of the importance of each of the eight professional skills. Results showed that student ratings of their peers' abilities align with the perceptions that practicing engineers have of student abilities. Peer and practicing engineer ratings were statistically significantly lower than student ratings of their own abilities. The discrepancies in perceptions of student ability show the subjective nature of interpersonal skills. Work to align these perceptions is needed to provide a more consistent assessment of interpersonal skills.

Keywords: interpersonal skills; communication; leadership; efficacy

Teaching Creativity in Engineering Schools: A review of the Literature 126–143
Yasemin Tekmen-Araci

Creativity is an imperative catalyst for innovation within engineering education. This research undertakes a semi-systematic integrative literature review to examine various creativity teaching approaches within engineering schools across diverse universities. By analyzing 60 papers published or presented between 1995 and 2019, this study identifies distinct strategies employed in fostering creativity. One pivotal approach revolves around the decision to introduce creativity as a standalone subject or integrate it into the existing curriculum. Furthermore, the discussion extends to the timing of creativity instruction, whether it is incorporated at the outset or towards the conclusion of the four-year program. The results indicate a progressive increase in endeavors to cultivate creativity in engineering education over time, with a shift towards its integration within the core curriculum. This materializes through the introduction of creativity-enhancing tools, the adoption of Problem-Based Learning (PBL) methods, and the establishment of interdisciplinary environments in education. This study serves to enrich the landscape of creativity in engineering education by presenting a spectrum of teaching approaches from engineering schools globally, offering valuable insights to educators and researchers in the field.

Keywords: creativity; teaching philosophies; higher education

Group Quizzing to Improve Attendance and Performance in a Civil Engineering Classroom – A Case Study 144–153
Congrui Jin and Tareq Daher

During the post-COVID years, higher education sectors across the globe are having difficulties keeping students motivated, engaged, and regularly attending classes. Poor attendance is one of the key reasons for inferior course performance, and thus many concerns are raised about the social and economic impacts of this level of disengagement. In this case study, the effectiveness of using in-class group quizzes to improve students' attendance and performance was assessed for a civil engineering course entitled CIVE 378 Materials of Construction, which is a required three-credit course for senior and junior students at the Department of Civil and Environmental Engineering at the University of Nebraska-Lincoln. In the semesters of Spring 2021 and Spring 2023, when the case study was conducted, 54 and 47 students were enrolled in the course, respectively. The classes are taught early in the mornings on Mondays and typically have very poor attendance. A series of in-class group quizzes were purposefully designed and implemented in the classes. Students' attendance rates, course performance data, and anonymous survey results were analyzed to evaluate the effectiveness. The results suggested that several design principles should be applied when using this method, which could lead to significantly improved attendance, engagement, and teamwork.

Keywords: attendance; group quizzing; collaborative testing; post-COVID education; engineering education

Learning to Cope in Undergraduate Chemical Engineering: A Comparative Study of Second Year Students Across Three Countries 154–165
Nicole P. Pitterson, Jan McArthur, Ashish Agrawal, Alaa Abdalla and Jennifer M. Case

The impact of the time-pressured and demanding engineering curriculum has been shown in many studies to impact negatively on student success in engineering. To understand this phenomenon more closely, as well as to explore how different institutional and curricular contexts might offer different possibilities for students, this study draws on semi-structured interviews with 51 second year chemical engineering students at five institutions across three national contexts. The article reports findings on the interplay between the structures that both constrain and enable learning (especially via curriculum and assessment). We show that an important personal transformation for students across all contexts involves learning how to "cope" with the stringent structural requirements of their curricula. Additionally, we highlight how students across three national contexts describe their ability to cope or not with curriculum related demands. Our findings show that these demands vary by context in relation to how much scheduled class times students have, how students structure their weeks around pending deadlines and other assessments and as well as how students transition between coping and not coping based on the prior academic years' experience. Our study allows useful conclusions to be drawn about the influence of different curricular structures, and how best to support student engagement with demanding curricular and assessment structures. We show that learning to cope is not a passive process but involves active engagement of students with the curriculum. Further, we suggest implications for educators who are interested in supporting students successfully progress from one academic level to another.

Keywords: coping; workload; curriculum demands; chemical engineering students

Coming and Going: What Draws Students to Industrial Engineering and What Pushes Them Away 166–178
Sara C. Vick, Brian K. Smith and Lesley Strawderman

Seven undergraduate engineering students were interviewed regarding their experiences transferring into or out of industrial and systems engineering programs. An narrative research approach was used to highlight the individual behind the data and encourage exploration of the decision-making process at a personal level. Although the decision whether to change majors is one faced by many university students, it remains a deeply individualized choice, regardless of similarities in motivation or outcome. Through the medium of semi-structured interviews, these students' stories were told. Emergent themes included concerns about discipline rigor, responses of peers and family, and appreciation of available career opportunities. Although the sample size is small, the results suggest personal interest may play a larger role in student movement between engineering disciplines.

Keywords: industrial engineering; systems engineering; narrative; degree change; ethnography

The Reflective Modeling Practitioner: Promoting Self-regulation and Self-confidence in Computational Modeling and Simulation Practices 179–195
Joreen Arigye, Joseph A. Lyon, Alejandra J. Magana and Elsje Pienaar

This study investigated the effects of a team-based modeling intervention that implemented reflective practices to support students' self-regulated learning in the context of modeling assignments. We used a mixed method design to answer the three research questions: (1) What metacognitive strategies do students, organized in teams, implement when solving computational modeling assignments? (2) What are students' levels of performance in solving computational modeling assignments in teams? (3) What are the relationships between teams' level of confidence and their implemented metacognitive strategies and level of performance in the computational modeling assignment? The learning intervention was guided by a reflective modeling practitioner model, bringing together modeling practices with elements of self-regulated learning. The results illustrate students' levels of self-reported confidence in three levels, showing that from the twelve teams studied, seven reported an increase in confidence as the project progressed, three reported a decrease in their confidence, and two reported an initial struggle, but their confidence increased as they completed the assignment. The implications relate to the learning interventions in the team modeling activity that can influence the teams' reported self-confidence, which can impact the skills students acquire and the strategies they use when faced with challenges.

Keywords: computational modeling and simulation, engineering education, self-regulated learning, teamwork

"Not a Therapist": Why Engineering Faculty and Staff Do/n't Engage in Supporting Student Mental Health and Wellbeing 196–213
Jeanne Sanders, Eileen Johnson, Joseph Mirabelli, Andrea Kunze, Sara Vohra, and Karin Jensen

The engineering culture of stress may negatively impact student mental health and wellbeing (MHW). Engineering faculty and staff are in a key position to support undergraduate students, but there is limited research examining their beliefs about students' MHW. The purpose of this article is to explore engineering faculty and staff's perceptions of their responsibility in supporting their undergraduate engineering students' MHW as well as the impact of engineering culture on this perceived responsibility. In this qualitative study, we interviewed 28 engineering faculty and staff at 18 institutions in the United States about their perceived responsibility in supporting undergraduate students' MHW. Results show that faculty and staff care about their students' MHW and want to support it; however, engineering culture acts as a barrier to this care. Faculty and staff feel underprepared to support student MHW, and their own MHW is often also diminished. Faculty at institutions of smaller sizes were more likely to describe expectations of relationship building as a necessary part of teaching. Our results indicate a need for increased awareness of the impacts engineering culture has on faculty comfort engaging with student MHW. In addition to increasing opportunities for supporting students' MHW, faculty and staff MHW need further support. We recommend specific strategies for dismantling a culture of stress by highlighting and prioritizing movement towards a culture of wellness in engineering.

Keywords: multi-institution; faculty attitudes; institutional culture; qualitative; interviews; mental health and wellbeing

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