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Guest Editorial

Current Developments in Interactive Pedagogies in Teaching and Learning of Energy-related Engineering Subjects

Interactive pedagogies play an important role in explaining abstract and complex science and engineering concepts, fostering deeper understanding and engagement among learners. In teaching such subjects, educators employ various interactive methods tailored to cater to diverse learning techniques and enhance comprehension. One effective approach involves employing hands-on experiments or demonstrations to illustrate abstract theories. For instance, in physics, using simple household items to simulate complex principles like wave interference or electromagnetism can make these concepts tangible. Research by Hestenes [1] and others has shown that such active learning methods, like hands-on experiments or interactive simulations, significantly improve students' understanding and retention of scientific concepts. Collaborative learning through group activities or projects has also proven beneficial in enabling students to engage in discussions, share perspectives, and collectively tackle challenging problems. This approach, supported by research from Prince [2] and Vygotsky's [3] sociocultural theory, emphasizes the significance of social interaction in learning complex concepts. By working collaboratively, students can leverage each other's strengths, troubleshoot difficulties, and construct a deeper understanding of intricate scientific theories. With the boom of immersive technologies, integrating technology-based tools, such as virtual laboratories, simulations, or augmented reality, provides immersive experiences that bridge the gap between abstract theories and real-world applications. Studies highlight the effectiveness of utilizing technology-enhanced learning environments to reveal complex scientific concepts, fostering active engagement and conceptual understanding among students [4–6].

Understanding energy-related subjects can be challenging due to their abstract nature and multifaceted principles spanning across various disciplines like physics, engineering, and environmental science. One significant challenge is that energy itself is not a tangible entity, but rather a concept that manifests in various forms, making it difficult for learners to visualize. Employing interactive simulations or virtual labs, as advocated by research [7, 8], can provide students with visual representations and hands-on experiences, enabling them to explore energy transformations and interactions in a more concrete manner. Active learning strategies that encourage collaboration among students from diverse backgrounds facilitate a holistic understanding by promoting discussions, sharing perspectives, and relating concepts across disciplines [9, 10]. Interactive pedagogies incorporating case studies, field trips, or guest lectures, enable students to connect theoretical knowledge to practical scenarios, fostering a deeper appreciation and comprehension of energy-related topics [11, 12].

In the realm of energy-related engineering education, the dynamics of teaching and learning are continuously evolving. This issue presents a comprehensive exploration of innovative pedagogical approaches aimed at enhancing the understanding and application of critical subjects within this domain. Eight papers within this issue delve into diverse methodologies, each contributing unique perspectives to innovate the learning environment. The papers included in this issue encompass diverse methodologies and insights, offering a compelling story of the commitment of educators and researchers in fostering a more immersive and effective learning environment.

The special issue starts with a paper presenting *a hands-on workshop approach in heat transfer classes* where each student had their own measurement kit for exploratory investigation. This type of pedagogy emerges as fundamental in bridging theoretical knowledge with practical application. As mentioned above, literature suggests that by providing students with tangible experiences, these workshops foster a deeper comprehension of complex concepts and facilitate a more seamless transition from theory to real-world scenarios. Participants in this study were undergraduate engineering students enrolled in a heat transfer course divided into two sections: the first underwent twelve hands-on workshops, while the second group of equal size, was assigned corresponding homework problems. Despite maintaining other aspects identical between the groups, findings show that the workshop section outperformed the non-workshop class significantly. This superiority extended to both understanding concept-based questions and solving quantitative problems. The specific workshops that proved beneficial focused on transient conduction, energy balance involving multiple conduction pathways and relative resistances, external convection, and gray body radiation. Student feedback regarding the workshops was used to identify effective elements and areas for improvement, particularly for workshops related to fins and lumped capacitance. Additionally, an established criteria for evaluating the efficacy of this teaching method is offered.

The issue continues with a contribution from our colleagues from the School of Engineering and Materials Science at Queen Mary University of London. Their paper introduces an integration of *game-based learning in a flipped classroom.* A game-based learning approach offers an engaging avenue for students to immerse themselves in interactive experiences. Through game-based learning, educators tap into the intrinsic motivation of learners, enabling them to grasp intricate engineering concepts while enjoying the learning process. In their study Jivani et al. seek to explore gaming's potential in promoting active learning and deepening understanding of course material. The study results underscore the positive impact of game-based learning on student engagement and academic performance in an undergraduate engineering module. By incorporating game elements like Kahoot and a leader board system, students demonstrated increased motivation and active participation throughout the course. This research study emphasizes the potential of integrating flipped learning and game-based strategies as a comprehensive educational framework that caters to diverse student needs and maximizes learning outcomes.

The development and evaluation of *teaching tools* are pivotal in modern education. These tools serve as catalysts for effective comprehension, aiding both educators and students in navigating intricate subject matter with clarity and efficiency. Researchers from the Faculty of Technical Sciences at University of Kragujevac in Serbia enrich the special issue with showcasing newly created applications focused on Electrical Machines and Drives (EMD) intended for university courses. The applications are tailored to facilitate the understanding of complex physical phenomena in the field of EMD, specifically aiming to support remote and online learning. The authors present their work in two parts – paper 3 in the special issue describes the development of the applications and paper 4 evaluates the usefulness and quality of the described set of applications. Students studying electrical power engineering were involved in assessing the EMD applications, recognizing them as highly significant and valuable aids for learning and mastering relevant courses. The focus in both papers lies on highlighting the benefits of these applications and outlining how they can enhance the learning process through their software capabilities. These EMD applications, customized for different electronic devices, are available for public access.

Electrical instrumentation labs play a crucial role in elevating student engagement and performance. By offering a hands-on environment coupled with modern instrumentation, students are empowered to explore and comprehend electrical engineering principles firsthand, fostering a deeper understanding of the subject. Colleagues from the Department of Electrical and Electronic Engineering at University of Navarra, Spain, introduce an innovative laboratory setup and approach aimed at enriching basic electrical energy and instrumentation laboratory sessions in paper 5. This method employs a more visual and interactive platform, facilitating students in associating electrical concepts with real-life applications. Students were asked to engage with instructional videos before class that demonstrated the required practical procedures. This aligns with the flipped classroom learning strategy, the pedagogical technique that Jivani et al. utilized in their game-based learning in paper 2, mentioned earlier. The study's findings highlight that students exhibited increased confidence during the lab sessions, actively participating by asking questions and defending their perspectives. Instructors noted more efficient use of time, enabling a better grasp of topics and clarification of complex content. Overall, these innovative lab sessions significantly enhance the learning experience of first-year physics students, promoting their independence in learning.

The sixth paper of the special issue demonstrates that the impact of *virtual office hours* on engineering students' learning experiences cannot be overstated. In later years, this innovative pedagogical approach breaks geographical barriers, providing students with personalized interactions and support, thereby enhancing their overall learning journey. Bakic et al. study the student experience of virtual office hours in comparison to conventional face-to-face sessions across three engineering courses – two in mechanical engineering and one in electrical engineering. Their paper discusses the logistical setup of virtual office hours, details the interactions during these sessions, and describes the content delivery. The study evaluates the impact of virtual office hours on engineering students' learning, assesses the efficiency of these sessions for both students and instructors, and elucidates the differences between virtual and traditional face-to-face office hours. The perspectives of students enrolled in these courses were collected through end-of-semester surveys specifically addressing their experiences with virtual office hours. Analysis of survey responses indicate that the integration of virtual office hours was advantageous for both students and instructors within these engineering courses.

Another contribution in the special issue introduces *pendulum projects in controls education* to offer a practical application of theoretical knowledge, enabling students to explore and analyze dynamic systems. Through these projects, students develop critical thinking skills and a comprehensive understanding of control systems. In his article, Kraus showcases the step-by-step development of an innovative cart/pendulum system intended for educating on feedback control. The system's affordability enables students to take it home, granting them the flexibility to engage with it whenever they choose. To ensure the system improves student learning, various challenges relating to hardware, software, and modeling had to be addressed. The completed project appears to boost student learning and foster a better understanding of control theory among students.

The author of the last paper in the special issue explores *pedagogical approaches applicable to engineering thermodynamics*. By adopting diverse teaching methodologies tailored to this subject, educators can effectively convey complex thermodynamic principles, ensuring students grasp these fundamental concepts thoroughly. The study completed by Subbarao examines a course that comprises five modules covering fundamental thermodynamics: thermodynamic laws, entropy, power cycles, fuels, and combustion aspects. It also explores various teaching methods tailored to each module and the overall syllabus. For instance, teaching temperature and pressure measurement concepts can involve bringing measurement tools into the classroom. The study also examines student grades and the attainment of course outcomes longitudinally. Analysis reveals the use of innovative teaching approaches alongside conventional methods, ensuring students acquire the necessary skills. This research identifies appropriate teaching approaches applicable to foundational engineering courses, providing valuable insights for instructors in energy engineering and related programs.

In closing, the tapestry of pedagogical approaches showcased in the special issue highlights the diverse avenues fostering enhanced learning experiences. Beyond techniques and methods, the scholarly contributions from three distinct continents underscore the global alignment in current and innovative pedagogies, encouraging exchange of knowledge to enrich educational practices. As we navigate the ever-evolving landscape of engineering education, it is imperative to embrace these innovative pedagogical strategies. They not only enhance understanding but also cultivate a passion for learning, paving the way for a new generation of adept, informed, and innovative engineers poised to tackle the challenges of the energy sector.

We extend our gratitude to the contributors for their insights and dedication to advancing educational methodologies within the domain of energy-related engineering. It is our hope that this issue serves as a catalyst for further exploration and implementation of interactive pedagogies, fostering universality of the pursuit for innovative and impactful education, promoting a global community dedicated to advancing learning paradigms.

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