Enhancing Comprehension of Electromagnetic Field and Its Application Challenges through Open and Collaborative Active Learning

Dominique PERSANO ADORNO (1), Nicola PIZZOLATO (2)

(1) Dipartimento di Fisica e Chimica "E.Segré", Viale delle Scienze Ed.18, Università di Palermo, 90128 Palermo (Italy)
(2) ICS "Maredolce", Via Fichidindia 6, 90100 Palermo (Italy)

Abstract. Active learning methods foster curiosity, enjoyment, and engagement by creating an immersive learning environment. Offering a tangible application of physics concepts could enhance both student interest and academic performance, especially in today's fast-paced and evolving landscape. Here, we discuss a workshop tailored for second-year Cybernetics Engineering undergraduates, aimed at cultivating design ability, enhancing problem-solving skills, and providing a meaningful comprehension of the electromagnetic field and its potential applications. Beginning with fundamental principles of electromagnetism, learners were empowered to devise and execute collaborative research endeavors, thereby deepening their grasp of key disciplinary concepts while honing interpersonal and teamwork proficiencies.

Introduction and context

The cultivation of soft and transversal skills should be emphasized in every academic program to empower learners in acquiring and sustaining abilities that enhance active participation in social life, foster active citizenship, encourage social inclusion, and improve employment or entrepreneurial prospects. In alignment with these goals, a voluntary supplementary activity has been introduced at the conclusion of the Physics 2 (Electromagnetism) course for second-year Cybernetics Engineering undergraduates at the University of Palermo (Italy). Through collaborative group work, students had the opportunity to independently design and execute in-depth projects, deepening their understanding of fundamental disciplinary concepts and reinforcing soft skills and teamwork abilities. To offer students a tangible opportunity to bridge theoretical principles with real-life applications and simultaneously foster the development of transversal skills, it is imperative to integrate research-like experiences alongside traditional lecture-based instruction in university settings. One of the most crucial skills for aspiring scientists, physicists, and engineers is the ability to reason effectively, and this ability is best cultivated through engaging in research, discussing findings, and sharing ideas with peers, all driven by curiosity and thoughtful questioning. Research in science and engineering education consistently promotes the involvement of undergraduate students in student-centered active learning strategies as discovery-based or problem-based learning activities [1-4].

The workshop presented herein immersed students in an in-depth exploration of electromagnetic fields' presence in our daily lives. Topics ranged from the Northern Lights phenomenon to plasma confinement in a Tokamak, the utilization of e.m. radiation in forensic medicine, or the application of particle accelerators in Medical Physics. This approach not only could bolster motivation, transversal skills, and learning outcomes but also present challenges and opportunities for self-directed thinking and learning activities, a topic that will be further explored in our presentation.

Methods, findings and conclusion

42 students, representing approximately 60% of the second-year cohort in Cybernetics Engineering at the University of Palermo, voluntarily participated in the described supplementary activity. Acting autonomously, they organized themselves into 13 groups, each comprised of 2 to 5 members. Following their interests, students chose specific areas/aspects for in-depth exploration and were assigned to create a multimedia presentation showcasing their research. They could opt for various formats such as video, PowerPoint, PDF, podcast, or webinar, depending on their preferences. This presentation has then been shared with the entire second-year undergraduate cohort. Notably, only one group opted to deeply explore the physical principles, design, practical realization (using a 3D printer and an Arduino board) and testing of a prototype of an electromagnetic gun. The diverse range of topics chosen by the teams is detailed in Table I.

Table I

List of the topics discussed in the multimedia final presentation
Combined use of electric and magnetic fields in Engineering
Mass spectrometers: simulations and operation (Dempster spectrometer, Velocity selector, Bainbridge spectrometer)
Applications of mass spectrometers in proteomics, Stardust Project
Mass spectrometers and forensic sciences (Toxicology, Fight against Covid-19)
The physics of the magnetic bottle, Tokamak and plasma confinement, Magnetohydrodynamic generators, Sherwood Project, Biconical Cusp, BASE Project (measurement of the magnetic moment of antimatter)
The Physics of the Van Allen Belts (Project Pamela, Atlantic Anomaly, Choir of the Magnetosphere)
The Physics of the Northern Lights
Particle accelerators (LINAC, Cyclotron, Synchrotron, Betatron, Electrosynchrotron) and their applications (Radiopharmaceutical production, Scintigraphy, PET, SPECT, Electra, Hadrontherapy, CERN)
Physical principles, design, realization (utilizing a 3D printer and an Arduino board), and testing of a prototype of an electromagnetic gun

The final activity significantly enhanced student comprehension and retention of theoretical concepts, fostering communication, collaboration, and discussion among peers. The spectrum of chosen subjects was broad, facilitating a comprehensive discussion on diverse real-world applications, resulting in an enhanced understanding and revitalized enthusiasm for learning among the students actively participating in the workshop. Moreover, by offering tangible contextualization of theoretical concepts, learning outcomes were positively impacted, as evidenced by exam grades. To justify our conclusion, we will compare the performance of students who undertook this workshop with that of students who did not and with the performance in other exams of the same semester. Although our findings are derived from a single case study, they align with the educational framework promoting effective instruction in Physics characterized by concrete contextualization and student-centered research-oriented tasks.

References

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