

## SUSTAINABILITY IN STEM: TEACHING ENERGY AWARENESS IN ICT THROUGH INTERDISCIPLINARY APPROACHES

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### Abstract

Sustainability and STEM (Science, Technology, Engineering, and Mathematics) education are deeply interconnected, as STEM disciplines play a crucial role in addressing environmental and societal challenges. As sustainability becomes an increasingly relevant global issue, STEM professionals must be equipped with the necessary competencies to actively contribute to sustainable development in their careers. This study explores the integration of sustainability in STEM education, emphasizing the need for interdisciplinary collaboration. It reviews various pedagogical strategies, including problem-based learning (PBL), service-learning, and experiential learning, to foster critical thinking and problem-solving skills. The study examines case studies from higher education institutions that have adopted sustainability-focused STEM programs and evaluates their impact on students' learning experiences. A case study on raising awareness of energy sustainability has been conducted with engineering students. This intervention aims to increase awareness and encourage engineering students to adopt responsible behaviours to reduce energy consumption associated with ICT usage. The findings indicate that by embedding sustainability education in STEM programs, universities can prepare students to become agents of change, equipped to develop innovative solutions for a more sustainable future.

**Keywords:** *STEM education, problem-based learning, interdisciplinary curriculum, energy sustainability in ICT.*

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### 1. Introduction

STEM education, which integrates Science, Technology, Engineering, and Mathematics, promotes interdisciplinary learning aimed at fostering critical thinking and problem-solving skills. This educational approach equips students with essential 21st-century competencies, preparing them for a rapidly evolving global workforce. Additionally, it addresses contemporary societal challenges through active methodologies and the application of computational thinking.

In parallel, embedding sustainability into educational frameworks is vital to raising awareness and promoting responsible decision-making among future generations. Aligning educational practices with the Sustainable Development Goals (SDGs) (United Nations, 2015) empowers students to tackle global environmental and social challenges. This integration enriches STEM learning by connecting it to real-world problem-solving with long-term implications. The relationship between sustainability and STEM education is both significant and multidimensional, as STEM plays a key role in addressing complex global issues (Angelaki et al., 2024). Given the worldwide relevance of sustainability, STEM professionals must be equipped to respond to these challenges throughout their careers.

The aim of this study is to analyze how sustainability has been integrated into STEM curricula through interdisciplinary approaches in higher education. It begins by examining a series of case studies that illustrate the impact of sustainability-oriented programs on students' learning experiences. Particular attention is given to the challenges of designing STEM courses that effectively combine technical content with sustainability principles. Drawing on the insights gained from this analysis, an educational intervention was designed and implemented in several engineering courses at the University of Almería. The intervention comprised a series of activities aimed at increasing students' awareness of energy-saving practices related to the use of ICT (Information and Communication Technologies). These activities were structured using active learning methodologies, especially collaborative work and problem-based learning. Data collection focused on student perceptions and learning outcomes related to sustainability awareness.

## 2. Design and methods

In recent years, educational institutions have increasingly sought to incorporate sustainability into STEM curricula and assess its impact on student learning. However, implementing an interdisciplinary curriculum that integrates STEM and sustainability presents significant challenges. Craig et al. (2022) designed, implemented, and evaluated an interdisciplinary course combining STEM, sustainability, and management using the ADDIE instructional design model (Analyze, Design, Develop, Implement, Evaluate). Qualitative findings from student focus groups revealed that learners perceived the course content as highly relevant, both in terms of employability and its alignment with their academic programs.

Teaching sustainability in STEM subjects can be approached through various creative and integrated strategies. Problem-based learning encourages students to design projects that address real-world sustainability challenges using their STEM skills (Alkair et al., 2023). Service-learning offers opportunities to collaborate with local or community organizations on sustainability initiatives, allowing students to observe the real-world impact of their work. Martín-Sánchez et al. (2022) presented and evaluated a Service Learning (SL) methodology as an Education for Sustainable Development (ESD) strategy. Using a pre- and post-test design, the study revealed significant improvements in students' understanding of innovative teaching strategies and the SDGs. Participation in the SL project also increased awareness of community engagement and environmental responsibility. Similarly, Angelaki et al. (2023) found that a short-term intervention significantly enhanced ICT students' intention to engage in sustainability. Their findings highlight the importance of fostering critical, informed digital consumption and promoting literate citizenship to address collective behavioral challenges.

Our intervention aims to enhance awareness and sensitize prospective engineering students about the importance of adopting responsible behaviors to mitigate the energy consumption associated with ICT usage. Without portraying ICT in a negative light, the intervention also seeks to promote understanding of its potential to reduce environmental resource use and, consequently, global CO<sub>2</sub> emissions. Therefore, the focus is on raising awareness about ICT energy consumption at the user level. First, we analyze the most common habits among students and then develop activities to promote awareness and educate students on the responsible use of ICT and AI to reduce energy consumption. A mixed-methods approach (quantitative and qualitative) is employed to assess students' knowledge and awareness regarding ICT use. Initially, a pre-intervention questionnaire is used to identify students' digital habits (Gil, et al., 2024). Sample questions include: How often do you use electronic devices such as mobile phones, tablets, or computers in your daily life? How much time do you spend on social media each day? How often do you compress or reduce the size of PDF files and photos? How often do you avoid sending large email attachments and instead use web links? Have you ever considered how the intensive use of electronic devices may impact energy consumption and CO<sub>2</sub> emissions?

Subsequently, academic activities were implemented to raise awareness and educate students on the responsible use of ICT and AI. One such activity was titled "Simulation of a Digital Green Start-Up." A project-based learning methodology was employed, where each team was tasked with designing a technology start-up aimed at minimizing energy impact. The activity culminated in a presentation to potential investors, represented by the teaching staff. Finally, qualitative research was conducted through focus groups to evaluate the outcomes of the intervention and examine the importance of integrating sustainable practices in the use of ICT within STEM education.

## 3. Discussion and results

The questionnaires were completed by ninety-three students: fifty-seven women (61.3%), thirty-five men (37.6%), and one respondent identifying as another gender (1.1%). The participants were predominantly young adults aged between 21 and 27. Results from the pre-questionnaire revealed that around 98% of students spend a significant portion of their day using ICT devices and applications. Over 50% reported using social media for more than two hours daily. While approximately 83% were familiar with the concept of a carbon footprint and environmental sustainability, about 60% were unaware of the energy consumption and CO<sub>2</sub> emissions associated with ICT use. Notably, over 60% reported habits such as leaving electronic devices turned on and sending heavy attachments instead of links via email. Conversely, nearly 80% avoid printing on paper. Interestingly, over 90% were surprised to learn that sending stickers or GIFs in messaging apps can significantly contribute to energy consumption, given the scale of global messaging activity.

Post-questionnaire results highlight a strong need for further education on the environmental impact of digital behavior. Encouragingly, more than 89% of students expressed a willingness to reduce time spent on social media and the use of stickers and GIFs in messaging. Additionally, 95% reported an intention to manage their inboxes more responsibly by deleting unnecessary emails. When asked how they

would reduce their digital carbon footprint by half, responses included reducing GIF usage (22%), limiting non-essential video content consumption (33%), spending less time on social media (35%), and uploading fewer posts (8.6%).

Finally, a qualitative analysis was conducted at the end of the course using focus groups, where students addressed the question: *What role does sustainability education play in the context of information technologies and artificial intelligence?* The findings revealed strong student motivation to integrate sustainability and AI into their future professional practices. However, participants also noted a lack of training and critical awareness regarding the environmental impact of these technologies. Students identified several pedagogical opportunities to be explored within innovative teaching initiatives, particularly those involving active methodologies and challenge-based learning. The results highlight the need to design educational experiences that examine the energy consumption associated with ICT and AI, apply counterfactual reasoning to promote critical thinking about alternative scenarios, and foster sustainable digital skills and informed digital citizenship.

#### 4. Conclusions

This study reviews various pedagogical strategies and case studies from higher education institutions that have implemented sustainability-focused STEM programs, evaluating their impact on students' learning experiences. It also presents an educational intervention aimed at raising awareness of energy sustainability, while introducing key concepts and practical digital tools. It is important to highlight that the intervention did not involve any changes to the official curriculum or course syllabi. The research employed a mixed-methods approach: a quantitative phase included a pre-intervention questionnaire to assess ICT usage habits, followed by a post-intervention survey to evaluate the effectiveness of sustainability awareness activities. Additionally, a qualitative analysis was conducted through focus groups to explore participants' perceptions regarding the importance of integrating energy consumption awareness related to ICT and AI into education. The findings indicate that even minimal interventions can significantly and positively influence students' intentions to engage in sustainability practices and incorporate them into their future professional endeavors.

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#### References

- Alkair, S., Ali, R., Abouhashem, A., Aledamat, R., Bhadra, J., Ahmad, Z., & Al-Thani, N. J. (2023). A STEM model for engaging students in environmental sustainability programs through a problem-solving approach. *Applied Environmental Education & Communication*, 22(1), 13-26.
- Angelaki, M. E., Bersimis, F., Karvounidis, T., & Douligeris, C. (2024). Towards more sustainable higher education institutions: Implementing the sustainable development goals and embedding sustainability into the information and computer technology curricula. *Education and Information Technologies*. 29, 5079-5113.
- Craig, C. A., Petrun Sayers, E. L., Gilbertz, S., & Karabas, I. (2022). The development and evaluation of interdisciplinary STEM, sustainability, and management curriculum. *International Journal of Management Education*, 20(2).
- Gil, C., Martínez, F., Ventura, J., Isanbaev, V., Baños, R., & Montoya, M.G. (2024). Promoting energy sustainability in ICT. *Proceedings of the First International Conference on Sustainable Energy Education* (pp. 543-551). SEED. Valencia, Spain.
- Martín-Sánchez, A., González-Gómez, D., & Jeong, J. S. (2022). Service learning as an education for sustainable development (ESD) teaching strategy: Design, implementation, and evaluation in a STEM university course. *Sustainability*, 14(12).
- United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development*. United Nations. <https://sdgs.un.org/2030agenda>