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OPTIMIZING COMPETENCY-BASED LEARNING IN ENGINEERING: A STUDY ON THE BEST-FIT METHODOLOGIES FOR TRANSVERSAL SKILLS

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Abstract

In modern education, addressing students' lack of motivation, attention deficits, and difficulties in connecting theoretical content with real-world applications is a growing challenge. Traditional lecture-based methodologies often result in passive learning, limiting opportunities for interaction and practical application. At the same time, the continuous exposure to digital technologies has affected students' ability to maintain focus in educational settings. This study proposes an integrated methodological approach combining active learning strategies, teamwork methodologies, and Information and Communication Technologies (ICTs) to develop both specific and transversal competencies in Engineering courses. The methodologies implemented include Problem-Based Learning (PBL), cooperative learning, flipped classroom, gamification, and escape rooms, among others, while the ICT tools used encompass clickers, augmented and virtual reality, digital portfolios, and webquests. Additionally, Artificial Intelligence (AI) has been incorporated to personalize learning experiences and optimize assessment processes. A structured implementation plan was designed across multiple undergraduate and master's degree courses, targeting competencies such as critical thinking, problem-solving, teamwork, autonomous learning, adaptability, sustainability, and digital skills. The evaluation combined quantitative (SEEQ) and qualitative methods (focus groups, student reflections) to assess students' perceptions, learning outcomes, and competency development. The results indicate that integrating active learning methodologies with ICT and AI significantly enhances student engagement and long-term knowledge retention. Based on the findings, the most suitable methodologies and ICT tools are proposed to effectively implement a broad range of transversal skills in the classroom, providing a holistic educational experience aligned with current academic and professional demands.

Keywords: *Active learning, artificial intelligence, engineering education, competency-based learning.*

1. Introduction

Competency-based learning in engineering education requires students to develop transversal skills such as collaboration, critical thinking, communication, and digital skills. In modern education, growing concern about low student motivation, limited attention, and difficulty connecting theory to practice has highlighted the limitations of traditional lecture-based approaches (Freeman et al., 2014). To address these challenges, active learning methodologies, competency-based teaching, and alternative assessment strategies are being adopted to promote student engagement and the development of transversal skills through meaningful learning experiences. This study explores how active methodologies combined with digital tools and generative artificial intelligence can support the acquisition of these competences providing a more meaningful and lasting learning experience.

2. Design and methods

The general objective is to integrate various active methodologies and digital tools in a way that enables students to learn by doing, while developing essential competencies for both their personal and professional lives. To achieve this, it is crucial to engage students in their own learning process and to foster active and attentive participation in the classroom. The specific objectives include implementing these methodologies and assessing their impact on the development of subject-specific competencies, as well as transversal competencies promoted by the university. The aim is to analyze the effectiveness of these methodologies from a holistic perspective, recognizing their complementarity and their contribution to enhancing motivation, attention, and collaborative learning.

The methodology followed to carry out this study is outlined below: (1) Identify the specific and transversal competencies to be developed in each course. (2) Select the active learning methodologies and digital tools that best align with the identified competencies. (3) Design and implement learning activities based on the selected methodologies, objectives, and competencies of each course. (4) Assess student progress and collect feedback from instructors.

3. Discussion and results

This study was carried out by monitoring three undergraduate and master's degree courses in Agricultural Engineering, Industrial Engineering, and Computer Engineering at the University of Almería. Each course selected several transversal competencies from the general framework defined by the university for its academic programs, in addition to the specific competencies relevant to each course. The selected transversal competencies included teamwork, critical thinking, problem-solving, autonomous learning and time management, effective communication, adaptability, digital skills, and sustainability.

Given the engineering context, it is important to highlight that teamwork is a critical competency in most professional environments. Active learning methodologies, such as cooperative learning and problem- or project-based learning, have proven particularly effective in fostering key interpersonal skills, including collaboration, communication, leadership, and conflict resolution. Consequently, teamwork and digital competence—integrated through the use of a group digital portfolio—were established as core transversal competencies across all three courses analyzed.

In the master's degree course in Computer Engineering, the implemented methodologies included both formal and informal cooperative learning, service-learning, flipped classroom, and gamification (Gil et al., 2011). These approaches aimed to develop transversal competencies such as teamwork, critical thinking, and sustainability, particularly through the service-learning component. The methodologies were integrated with various digital tools, including audience response systems (clickers) using Wooclap (Gil et al., 2018), WebQuests created with Google Sites (Shaukenova, 2015), a collaborative digital group portfolio (also hosted on Google Sites), and generative artificial intelligence. Table 1 presents an activity entitled "Green ICT Challenge: Reducing Our Digital Footprint," proposed in the Computer Engineering course, designed to foster transversal competencies through the selected active methodologies and digital tools.

Table 1. Summary of the "Green ICT challenge: reducing our digital footprint" activity.

Objectives	To develop transversal competencies such as teamwork, critical thinking, digital competence, and sustainability by analyzing the energy impact of ICT use in the university environment and proposing innovative solutions.			
Methodologies	**Cooperative learning**	**Flipped Classroom**	**Service-Learning**	**Gamification**
	Teams of 3–4 students with defined roles (research, data analysis, communication, and source verification)	Students watch videos and complete readings before class on topics related to the energy impact of device usage, cloud storage, generative AI, etc.	The final proposal must be applicable within their faculty or to students' daily digital habits, ensuring real-world impact.	Weekly missions and challenges are introduced, such as conducting an energy audit of students' digital habits.
Digital tools	**Wooclap (Clickers)**	**WebQuest**	**Digital Group Portfolio**	**Generative AI tools**
	Initial survey on digital habits ("How many hours of streaming do you do per week?") Quick quizzes following flipped-classroom videos	Guides the research and reflection process. Example tasks include: Investigating how much CO_2 a one-hour video call generates.	Each group documents their proposals for reducing energy consumption, critical reflections, and evidence of the use of reliable sources.	Use counterfactual scenarios with prompt such as: *"What would happen if all students reduced their screen time by one hour per day?"*
Assessment	Rubric-based evaluation of transversal competencies	Participation in Wooclap activities and reflections in the digital portfolio.	Submission of a viable, data-driven intervention	Group self-and peer- assessment using rubrics

In the Industrial Engineering course, the methodologies applied included cooperative learning, problem-based learning, and flipped classroom strategies, all aimed at fostering teamwork, problem-solving, autonomous learning, and time management. These were supported by digital tools such as clickers, digital group portfolios, and subject-specific simulators. In the Agricultural Engineering course, project-based learning (PBL), gamification, and flipped classroom approaches were employed to strengthen teamwork, effective communication, and adaptability. These were likewise supported by clickers, digital group portfolios, and generative artificial intelligence tools.

Student progress was evaluated using the Student Evaluation of Educational Quality (SEEQ) questionnaire (Marsh, 1982), an instrument designed to assess teaching effectiveness across ten dimensions. Each dimension consists of several items rated on a five-point Likert scale. A total of ninety students across the three courses completed the questionnaires. Figure 1 displays the average scores for each dimension in the SEEQ questionnaire. All categories achieved scores above 4—except for workload and difficulty—which, given the scale midpoint of 3, indicates a highly satisfactory evaluation of the learning experience.

Figure 1. Average score for each dimension of the SEEQ questionnaire.

In addition to the quantitative evaluation, students were asked to reflect on how they had improved in each competency throughout the course, supporting their reflections with examples of work included in their digital portfolios. Participating faculty members were also invited to share the most positive aspects of the experience, as well as the main challenges encountered during the implementation of the methodologies. All participating faculty members rated the experience very positively in all aspects, although one of the main difficulties they highlighted was the increased workload required to assess the wide range of proposed activities. Their insights will be valuable for refining and improving future implementations.

4. Conclusions

The integration of active learning methodologies, digital tools, and artificial intelligence in engineering education has proven effective in fostering transversal competencies and enhancing student engagement. The results underscore the value of combining cooperative strategies with emerging technologies to improve learning outcomes. This approach supports meaningful, competency-based learning that is closely aligned with real-world professional demands. Student feedback, gathered through the SEEQ questionnaire, indicated high levels of satisfaction across all evaluated dimensions—particularly in learning, enthusiasm, and organization—reinforcing the positive impact of the implemented strategies.

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