

IMPROVING THE METHODOLOGY FOR PREPARING FUTURE ENGINEERS FOR PROFESSIONAL ACTIVITY IN THE CONTEXT OF DIGITAL TECHNOLOGICAL AND PEDAGOGICAL KNOWLEDGE

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Abstract

This study investigates how integrating digital technologies and pedagogical strategies improves the preparation of future engineers. A quasi-experimental design was implemented to compare students exposed to digital tools and active learning with those taught traditionally. The experimental group demonstrated superior improvements in theoretical knowledge and practical skills. Because digital simulations, CAD tools, and collaborative methods promote deeper understanding and engagement, they outperformed traditional approaches. Results suggest that incorporating modern instructional technologies enhances student outcomes by fostering critical thinking and real-world problem-solving. This research highlights the need for curriculum innovation to meet the demands of the digital era and the engineering profession.

Keywords: Active learning, Digital technologies, Engineering education, Pedagogical strategies, Professional preparation.

1. Introduction

The educational landscape for engineering students is undergoing a significant transformation, driven by the growing demands of the digital age. As modern engineering practice becomes increasingly reliant on automation, artificial intelligence, and complex problem-solving, traditional educational approaches must adapt [1]. Curricula that focus solely on theoretical foundations and isolated assignments no longer suffice to prepare students for dynamic real-world environments [2-8]. In this context, the integration of digital technologies and modern pedagogical strategies into teaching becomes essential.

Recent developments in science and technology have introduced powerful digital tools (such as computer-aided design (CAD) software, simulations, modelling platforms, and online collaborative environments) that can enhance the teaching and learning process [9]. These technologies support visualization, experimentation, and problem-based exploration, offering learners the ability to interact with content in ways that were previously impossible.

Concurrently, pedagogical strategies like active learning, cooperative problem-solving, and project-based instruction have emerged as effective methods for engaging students and fostering deeper cognitive processing. These approaches are rooted in constructivist and socio-cultural learning theories, which emphasize the active construction of knowledge through interaction with tools and peers. The teaching of engineering must therefore evolve to include these modern approaches, particularly in developing countries where educational systems are striving to meet global standards.

Integrating digital technologies with pedagogy can enhance students' theoretical understanding while also equipping them with practical skills, creativity, and teamwork abilities essential for 21st-century professional life. Moreover, science and technology-based learning environments support individualized instruction and real-time feedback, contributing to higher student motivation and learning outcomes. Digital platforms also allow for remote access, flexibility, and resource-rich environments that accommodate diverse learner needs.

The purpose of this study is to evaluate the effectiveness of integrating digital technologies and pedagogical strategies in preparing future engineers for professional activity. The novelty lies in assessing a blended instructional model that combines simulations, CAD applications, and collaborative projects within a quasi-experimental design. The impact of this research is significant, as it provides empirical evidence supporting a shift toward digitally enhanced, student-centred learning environments to foster better academic and professional outcomes for engineering students.

2. Method

This study adopted a quasi-experimental design to assess the impact of integrating digital technologies and active pedagogical strategies on the professional preparation of engineering students. Detailed information regarding this method is explained elsewhere [9]. The research was conducted over a 15-week academic semester involving two groups: an experimental group that received instruction through digital simulations, CAD software, and collaborative learning strategies, and a control group that followed a traditional, lecture-based curriculum.

Participants were 200 undergraduate students from three departments (i.e., Mechanical Engineering, Electrical Engineering, and Computer Science) randomly assigned to either group. Before and after the intervention, students completed theoretical and practical assessments. Additional data were gathered through student surveys, instructor feedback, and semi-structured interviews to evaluate engagement, satisfaction, and perceived effectiveness of the instructional methods. Quantitative data were analysed using descriptive statistics and paired t-tests, while qualitative responses were thematically coded to extract meaningful insights. We analysed statistics to get a better understanding of the results. Detailed information on how to analyse using statistical analysis is reported elsewhere [10].

3. Result and Discussion

Table 1 presents the comparison between pre-test and post-test scores of students from both groups. Before the intervention, students from the experimental and control groups had similar baseline knowledge levels. However, after 15 weeks of instruction, the experimental group, which was taught using digital tools and active pedagogical strategies, showed a marked improvement of 26%, while the control group showed only a 10% increase. This substantial difference indicates that the integration of simulation platforms, CAD software, and collaborative tasks significantly enhanced students' theoretical understanding of engineering concepts. The data confirms previous findings that digitally supported instruction promotes deeper engagement with content and facilitates better retention and conceptual mastery.

Table 1. Pre and post-test scores of experimental and control groups.

Group	Pre-Test Score (%)	Post-Test Score (%)	Knowledge Improvement (%)
Experimental Group	58%	84%	26%
Control Group	60%	70%	10%

The integration of science and technology in practical applications was equally impactful. Table 2 summarizes the development of students' practical skills based on performance tasks requiring real-world problem-solving using digital engineering tools. Students in the experimental group improved their practical performance by 20%, indicating that hands-on use of simulations and CAD tools fostered greater technical competence and creativity.

In contrast, the control group, which relied on textbook-based assignments, showed only a 6% improvement. These results suggest that authentic, technology-driven learning experiences are more effective in developing the applied skills necessary for professional engineering tasks. This finding aligns with constructivist learning theories emphasizing experiential learning through modern tools.

Further supporting the effectiveness of the integrated methodology, Table 3 shows that students in the experimental group reported significantly higher levels of engagement and satisfaction. Their average engagement score was 8.7 out of 10, and their satisfaction score was 9.2. These students perceived the learning process as more meaningful and stimulating, likely due to the use of interactive digital content and collaborative activities. The control group, on the other hand, reported only moderate engagement and satisfaction, reflecting the passivity of lecture-

based methods. The high engagement scores among students exposed to technology-enhanced teaching demonstrate how digital pedagogical environments contribute to increased motivation and sustained interest in learning, which are essential for knowledge transfer and retention.

Table 2. Practical skills assessment results.

Group	Pre-Assessment Score (%)	Post-Assessment Score (%)	Practical Skills Improvement (%)
Experimental Group	65%	85%	20%
Control Group	68%	74%	6%

Table 3. Student engagement and satisfaction scores.

Group	Engagement Score (1–10)	Satisfaction Score (1–10)
Experimental Group	8.7	9.2
Control Group	6.2	7.4

Instructors' perspectives also provide valuable insight into the implementation of the integrated teaching approach. As seen in Table 4, instructors assigned the highest ratings to the usefulness of digital tools (4.8 out of 5), reflecting their perceived effectiveness in supporting learning and instruction. The development of students' practical skills was also rated very positively (4.7), while engagement (4.5) and ease of curriculum integration (4.3) were slightly lower but still favourable. These evaluations confirm the practicality of implementing science and technology-driven instruction, although they also highlight the need for teacher training and institutional support to ensure seamless integration into existing curricula.

Table 4. Instructor survey results.

Criteria	Mean Score (1–5)
Student Engagement	4.5
Improvement in Practical Skills	4.7
Ease of Integration	4.3
Usefulness of Digital Tools	4.8

Taken together, the results demonstrate that modernizing engineering education through digital technologies and pedagogical innovation yields significant improvements across cognitive, affective, and psychomotor domains. Students learned more deeply, applied skills more effectively, and felt more engaged (all outcomes supported by both quantitative metrics and qualitative feedback). These findings are consistent with global trends toward smart education and are backed by scholarship on instructional design and technology-enhanced learning environments. In line with the Sustainable Development Goals (SDG 4: Quality Education and SDG 9: Industry, Innovation and Infrastructure), this study illustrates how science and technology can transform professional education to meet the challenges of the digital future. This study adds new information regarding SDGs, as reported elsewhere (Table 5).

Table 5. Previous studies on SDGs.

No.	Title	Ref.
1	Sustainable development goals (SDGs) in engineering education: Definitions, research trends, bibliometric insights, and strategic approaches.	[11]
2	Sustainable packaging: Bioplastics as a low-carbon future step for the SDGs.	[12]
3	Production of wet organic waste ecoenzymes as an alternative solution for environmental conservation supporting SDGs.	[13]
4	HIRADC for workplace safety in manufacturing: A risk-control framework and bibliometric review to support SDGs.	[14]
5	Techno-economic analysis of production ecobrick from plastic waste to support SDGs.	[15]
6	Techno-economic analysis of sawdust-based trash cans and their contribution to Indonesia's green tourism policy and the SDGs.	[16]
7	Definition and role of sustainable materials in reaching global SDGs completed with bibliometric analysis.	[17]
8	Bibliometric insight into materials research trends and innovation to support SDGs.	[18]
9	Analysis of student's awareness of sustainable diet in reducing carbon footprint to support sustainable development goals (SDGs) 2030.	[19]
10	Enhancing job satisfaction through HRIS and communication: A commitment-based approach to SDGs.	[20]
11	Enhancing innovative thinking through theory-based instructional model to support SDGs.	[21]
12	Influence of self-efficacy on affective learning outcomes in social studies education toward achieving SDGs.	[22]
13	Enhancing occupational identity and self-efficacy through self-education in art/design aligned with SDGs.	[23]
14	Integrating generative AI-based multimodal learning in education to enhance literacy aligned with SDGs.	[24]
15	Dataset on Sulawesi schools and cultural implications to support SDGs.	[25]
16	Enhancing professional readiness in vocational education aligned with SDGs.	[26]
17	School feeding program and SDGs in education: Linking food security to learning outcomes.	[27]
18	Influence of eco-friendly packaging on consumer interest to meet SDGs.	[28]
19	SDG 12 implementation through lemon commodities and waste reduction.	[29]

4. Conclusion

This study confirms that integrating digital technologies with active pedagogical strategies significantly enhances engineering students' theoretical knowledge, practical skills, and engagement. Students exposed to simulations, CAD tools, and collaborative learning outperformed peers in traditional classrooms. Because digital environments foster interactive, problem-based experiences, they lead to

deeper understanding and stronger professional preparation. Instructor feedback also supports the feasibility and effectiveness of this approach. These findings highlight the urgent need to modernize engineering curricula with science and technology-based instruction to meet the demands of the digital era and align with sustainable educational development goals.

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