The Impact of Educational Planning on the Integration of Digital Learning and Computer Simulations in Metallurgical Engineering for Sustainable Development

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Abstract: The study examined the role of educational planning in the adoption and integration of digital learning and computer simulations in metallurgical engineering in four selected universities in South-East, Nigeria. The study was guided by four research questions. The population comprised 1,200 undergraduate engineering students from the University of Nigeria, Nsukka (350), Nnamdi Azikiwe University, Awka (300), Enugu State University of Science and Technology (280), and Federal University of Technology, Owerri (270). No sampling technique was used, as the population was considered manageable. A structured questionnaire, titled: Educational Planning, Digital Learning, and Simulation Questionnaire (EPDLSQ), was used for data collection. The instrument was validated by three experts: one from the Faculty of Education and two from the Faculty of Engineering, all at the University of Nigeria, Nsukka. The reliability test, using Cronbach's Alpha method, yielded a coefficient of 0.84, confirming the instrument's consistency. Data were analyzed using mean and standard deviation, with a decision rule of 3.50 and above for agreement. The findings revealed that educational planning plays a crucial role in the adoption of digital learning and computer simulations in metallurgical engineering. It was also found that digital learning enhances sustainability in metallurgical engineering education by improving resource efficiency and reducing environmental impact. The study contributes to knowledge by providing empirical evidence on the integration of digital learning in metallurgical education in South-East Nigeria. Based on the findings, it is recommended that higher institutions should develop comprehensive digital learning policies to enhance the integration of computer simulations in metallurgical engineering programs.

Keywords: Educational planning, digital learning, computer simulations, metallurgical engineering, sustainability.

1. Introduction

The impact of educational planning on the integration of digital learning and computer simulations in metallurgical engineering for sustainable development is a critical area of study. The evolving demands of the metallurgical industry necessitate a curriculum that aligns with technological advancements, promotes sustainability, and enhances skill acquisition among students. Effective educational planning serves as a strategic framework for integrating digital learning tools and computer simulations into metallurgical engineering programs, ensuring that graduates are equipped with the competencies required to meet contemporary industrial and environmental challenges (Kumar & Prasad, 2022). Educational planning plays a crucial role in shaping curricula by ensuring that academic programs align with industry demands, technological advancements, and sustainable development goals. In the field of metallurgical engineering, structured educational planning is essential for equipping students with the necessary knowledge, skills, and competencies to address contemporary challenges in metallurgy, including resource efficiency, environmental sustainability, and technological innovation (Smith & Brown, 2023).

The integration of digital learning and computer simulations in metallurgical engineering education has become increasingly significant. Traditional teaching methods, which rely heavily on theoretical instruction and physical laboratory experiments, are being enhanced by the incorporation of digital tools that facilitate interactive learning, visualization of complex processes, and real-time experimentation in virtual environments (Chen et al., 2021). Digital learning enables students to access a wide range of educational resources, participate in remote laboratories, and engage in self-paced learning, thereby improving knowledge retention and skill development. Computer simulations provide a cost-effective and efficient means of demonstrating metallurgical processes such as smelting, refining, alloy development, and thermomechanical treatment. These simulations allow students to experiment with different process parameters, observe real-time effects, and develop problem-solving skills without the limitations and risks associated with traditional laboratory experiments (Jones & Miller, 2022). Moreover, simulations enhance sustainability in metallurgical education by reducing the need for physical resources, minimizing waste, and promoting environmentally friendly practices (Gonzalez & Rivera, 2023). As global industries shift towards automation, digitalization, and sustainability, it is imperative for metallurgical engineering education to adapt by integrating innovative teaching and learning methods. Educational planning serves as the foundation for this transformation by developing policies, curricula, and strategies that support the incorporation of digital learning and computer simulations. However, challenges such as inadequate infrastructure, resistance to technological change, and limited access to digital resources must be addressed to fully realize the potential of these technologies in metallurgical engineering education (Anderson & Lee, 2023).

The integration of educational planning, digital learning, and computer simulations in metallurgical engineering plays a fundamental role in preparing students for the evolving demands of the industry. A well-structured educational framework ensures that students develop the necessary competencies to address modern challenges in metallurgy while promoting sustainability in resource utilization and process efficiency. Understanding these key concepts provides a foundation for effective curriculum development and the advancement of metallurgical engineering education. Educational planning is the systematic process of designing, implementing, and evaluating academic programs to ensure alignment with technological advancements, industry demands, and societal needs. Bray and Varghese (2022) describe educational planning as a strategic tool that enhances the quality, relevance, and sustainability of curricula by incorporating modern technological developments. Taylor (2023) highlights that structured educational planning foster the continuous improvement of academic programs by integrating industry expectations and emerging trends in education. Supporting these perspectives, this study defines educational planning as a deliberate and structured approach to curriculum design that prioritizes digital learning and practical engagement in metallurgical engineering. Effective educational planning promotes the incorporation of innovative teaching methodologies, collaboration between academia and industry, and the continuous review of curricula to ensure relevance in a rapidly changing technological landscape (Murphy and Scott, 2021).

Digital learning refers to the use of technology-based resources such as virtual laboratories, online learning platforms, and simulation software to enhance the educational experience. Johnson, Roberts, and Stewart (2022) define digital learning as an instructional method that enables flexible, interactive, and self-paced learning through digital platforms. Williams and Zhao (2023) emphasize that digital learning fosters student engagement by providing access to a wide range of multimedia content, virtual experiments, and real-time simulations. Building on these definitions, this study conceptualizes digital learning as the integration of technology-driven educational tools that facilitate experiential learning, allowing students to interact with complex metallurgical processes in a controlled environment. Computer simulations, as a key component of digital learning, enhance the visualization and analysis of metallurgical operations, providing students with hands-on experience without the constraints of physical laboratory setups. Hernandez, Miller, and Cooper (2021) highlight that simulations enable students to manipulate process variables, optimize metallurgical techniques, and develop problem-solving skills essential for industry readiness. By incorporating these technologies, metallurgical engineering education can enhance students' understanding of theoretical concepts while preparing them for real-world applications.

Sustainable development in metallurgy focuses on optimizing resource efficiency, minimizing environmental impact, and promoting eco-friendly technological innovations. Gonzalez and Rivera (2023) define sustainable development as a multidisciplinary approach aimed at balancing economic growth, environmental conservation, and social responsibility. Smith and Brown (2023) emphasize that sustainable metallurgy involves waste reduction, energy conservation, and the adoption of environmentally friendly materials and processes. Aligning with these perspectives, this study defines sustainable development in metallurgy as the integration of strategies that enhance the long-term viability of metallurgical practices while minimizing environmental harm. Educational planning plays a vital role in promoting sustainability by incorporating green technologies into curricula, fostering research on circular economy practices, and encouraging responsible material usage. Chen, Anderson, and Lee (2021) highlighted that the application of digital learning and computer simulations supports sustainable development by reducing material consumption, lowering laboratory waste, and decreasing energy usage. By embedding sustainability principles within metallurgical engineering education, future professionals can be equipped with the skills and knowledge necessary to drive environmentally responsible innovations in the field (Jones and Miller, 2022).

2. Theoretical Framework

The integration of digital learning and computer simulations in metallurgical engineering education is supported by several theoretical perspectives that highlight how technology enhances learning. Constructivist Learning Theory, proposed by Jean Piaget in 1950, emphasizes that learning is an active and constructive process where individuals develop knowledge through experiences and interactions. Piaget argued that learners assimilate new information into existing cognitive structures and accommodate the thinking when faced with new experiences. This theory is particularly relevant to digital learning in metallurgy, as simulations and interactive tools enable students to engage in experiential learning, manipulating virtual models and conducting simulated experiments. Hence, by actively constructing knowledge rather than passively absorbing information, students develop critical thinking and problem-solving skills. The justification for this theory in the study lies in its emphasis on inquiry-based learning, which is essential for understanding complex metallurgical processes through hands-on digital interactions. The Technological Pedagogical Content Knowledge (TPACK) framework, introduced by Mishra and Koehler in 2006, highlights the necessity of integrating technology with pedagogy and content knowledge for effective teaching in the digital era. The framework outlines three core areas: technological knowledge (TK), which involves the ability to use digital tools; pedagogical knowledge (PK), which focuses on effective teaching strategies; and content knowledge (CK), which refers to subject-matter expertise. The TPACK model is relevant to the present study because it underscores the need for educators to possess technological competence in order to effectively incorporate simulation software, virtual laboratories, and digital learning platforms into the teaching. In metallurgical engineering, educators must be able to merge content-specific knowledge with digital tools to enhance instruction, ensuring that students gain hands-on experience with minimal risks. This study justifies the adoption of TPACK by emphasizing the need for faculty training, curriculum development, and resource allocation to support digital learning in engineering education.

Systems Theory, developed by Ludwig von Bertalanffy in 1968, provides another critical perspective by viewing education as an interconnected system where various components such as educational planning, technology integration and faculty development must function cohesively. The theory posits that any change in one part of a system affects the entire structure, highlighting the need for a holistic approach to digital learning implementation. The relevance of Systems Theory in this study lies in its emphasis on interdependence and feedback mechanisms. Effective integration of computer simulations in metallurgical education requires careful planning that aligns curriculum design, infrastructure development, and faculty readiness. This study justifies the application of Systems Theory by demonstrating how structured coordination among these elements ensures a sustainable and efficient digital learning environment. Together, these three theoretical perspectives provide a strong justification for integrating digital learning and computer simulations in metallurgical engineering education. Constructivist Learning Theory supports the need for experiential learning; TPACK highlights the importance of balancing technology with pedagogy and content, while Systems Theory underscores the necessity of a coordinated educational planning approach. These theories collectively reinforce the argument that digital learning is not an isolated tool but a fundamental aspect of modern engineering education, requiring strategic implementation for maximum effectiveness.

3. Literature Review

The impact of educational planning on the adoption of digital learning has been widely explored across different regions, reflecting the evolving nature of education in the digital era. Various studies have investigated the role of structured planning in the integration of digital tools within engineering education, particularly in metallurgical engineering. Examining empirical evidence from Nigeria, Ghana, South Africa, Europe, and the United States provides a comprehensive understanding of how digital learning and computer simulations influence metallurgical education. These studies highlight similarities and differences in implementation strategies, challenges encountered, and the overall effectiveness of digital learning in fostering sustainable development. The adoption of digital learning in higher education is significantly influenced by effective educational planning, which determines the availability, accessibility, and successful implementation of technology-enhanced learning tools. Various studies have examined the role of educational planning in fostering digital learning adoption across different regions, focusing on policy frameworks, institutional strategies, and infrastructural readiness. While some regions have recorded substantial progress in integrating digital learning into the educational systems, others still struggle due to financial constraints, policy inconsistencies, and technological disparities. Examining the impact of educational planning on digital learning adoption in Nigeria, Ghana, South Africa, Europe, and the United States provides critical insights into the successes and challenges associated with technology-driven education. In Nigeria, a study conducted by Adebayo, Okon, and Yusuf (2022) assessed how national educational policies influence digital learning adoption in engineering faculties. The authors research revealed that although government policy frameworks encourage digital integration, weak infrastructural development, lack of funding, and inconsistent implementation have hindered widespread adoption in tertiary institutions. Furthermore, the authors noted that while urban institutions had better access to digital tools, rural universities struggled due to unstable power supply and inadequate internet connectivity. This finding aligns with earlier research by Eze and Chidiebere (2021), which emphasized that digital learning adoption in Nigeria is contingent upon the government's ability to provide sustainable infrastructure and financial support for institutions.

Similarly, in Ghana, Mensah and Boateng (2023) investigated the strategic inclusion of digital learning in higher education planning, particularly focusing on science and engineering faculties. The authors study found that institutions with well-defined digital strategies experienced improved student engagement and better knowledge retention. Unlike Nigeria, where policy implementation gaps were prominent, Ghanaian universities demonstrated a more structured approach by incorporating digital learning tools into curriculum planning and faculty training programs. Supporting this finding, Owusu and Frimpong (2022) highlighted that universities with dedicated digital learning budgets and continuous professional development programs for lecturers witnessed a higher rate of technology adoption in teaching methodologies. However, the study also pointed out that despite institutional readiness, affordability of digital devices and internet connectivity remained a major challenge for students, particularly those from low-income backgrounds. In South Africa, research conducted by Ndlovu and Mkhize (2021) revealed that government-backed initiatives, such as the Digital Learning Support Programme, significantly improved digital resource accessibility in tertiary institutions. The study showed that institutions that received targeted government funding for digital education infrastructure saw a 40% increase in digital tool adoption within three years. However, disparities between urban and rural institutions persisted, with rural universities struggling due to unreliable electricity supply and limited access to high-speed internet. Similarly, a study by Van Wyk and Adams (2023) emphasized that South African universities with strong partnerships with technology firms were more successful in integrating digital learning into the curriculum. The authors' research found that collaboration with tech companies facilitated the acquisition of digital learning tools at subsidized rates, thus enhancing student access to online resources and virtual learning environments.

Reasonably, European research by Schmidt and Müller (2023) provided a broader perspective on how systematic educational planning influences digital learning adoption. The study highlighted that European universities, particularly in Germany and the Netherlands, have a structured approach to integrating digital tools in education due to strong policy support and substantial institutional investments. The research found that government incentives for higher education institutions that adopt digital learning strategies have led to widespread technology adoption across various disciplines, including engineering and applied sciences. Additionally, the study emphasized that European universities benefit from well-established digital infrastructure, including cloud-based learning platforms and artificial intelligence-driven assessment tools, which significantly enhance the learning experience. In the United States, Johnson and Williams (2022) examined the impact of institutional digital learning roadmaps on academic performance and innovation in teaching methodologies. The authors' study found that universities with clear digital learning policies witnessed increased student performance, greater engagement in interactive learning, and a rise in technology-driven teaching innovations. Furthermore, research by Anderson and Smith (2021) supported these findings, demonstrating that institutions that invested in faculty training programs on digital pedagogies saw higher levels of successful technology integration compared to those that relied solely on students' adaptability to digital learning tools. The study concluded that well-planned digital learning strategies not only improve knowledge acquisition but also prepare students for technology-driven industries. The findings from these studies highlight a common theme: educational planning plays a crucial role in determining the success of digital learning adoption. Hence, while African studies emphasized infrastructural and policy limitations as significant challenges, European and American research showcased a more structured approach with substantial institutional backing and technological investment. The major differences across these regions lie in the level of government involvement, institutional autonomy, and financial resources dedicated to digital learning implementation. Despite these variations, the studies collectively affirm that strategic planning, adequate funding, and strong policy frameworks are critical factors in facilitating the adoption of digital learning tools. The relevance of these findings to the present study is evident in the need to identify best practices in digital learning integration and propose strategies to mitigate challenges within metallurgical engineering education. By understanding how different regions address the complexities of digital learning adoption, this study can provide recommendations for improving educational planning in metallurgical engineering programs, ensuring that students receive technologically advanced, interactive, and sustainable learning experiences.

The application of computer simulations in engineering education has been the subject of extensive research, providing insights into the effectiveness in enhancing learning outcomes. In Nigeria, research by Adeyemi, Bello, and Olatunji (2023) assessed the impact of simulation-based learning in metallurgical engineering courses. The study found that students using computer simulations demonstrated better conceptual understanding and problem-solving skills compared to those relying solely on traditional learning methods. In Ghana, Owusu and Asante (2022) examined the role of computer simulations in metallurgy laboratories and reported that virtual experiments significantly reduced material waste and increased student engagement. A similar study in South Africa by van der Merwe and Dlamini (2021) highlighted how simulations facilitated experiential learning, enabling students to manipulate metallurgical processes in real time without safety concerns. In Europe, Müller and Hoffmann (2022) analyzed data from multiple engineering institutions and found that incorporating simulations into coursework improved students’ comprehension of complex metallurgical processes. In the United States, research by Brown and Carter (2023) established that universities integrating simulation-based learning in engineering curricula observed a significant improvement in critical thinking and innovation among students. Another study by White and Green (2021) reinforced these findings, noting that students trained with digital simulations outperformed the peers in practical assessments and industry placements. These studies collectively affirm the effectiveness of computer simulations in metallurgical engineering education. While African research underscores the advantages of cost reduction and enhanced engagement, European and American studies highlight improvements in cognitive abilities and hands-on experience. This demonstrates the necessity of incorporating simulation tools into engineering curricula, a core aspect of this study.

Sustainability in metallurgy is a growing concern, necessitating the adoption of digital education to promote environmentally friendly practices. In Nigeria, a case study by Ibrahim and Hassan (2022) explored the role of digital learning in advancing sustainable metallurgical practices. The study found that students exposed to virtual sustainability modules were more likely to adopt eco-conscious approaches in material selection and process optimization. A Ghanaian study by Kwame and Ofori (2023) further supported these findings, emphasizing that institutions incorporating sustainability-focused digital courses saw higher innovation levels in metallurgical practices. Similarly, in South Africa, research by Nkosi and Sithole (2021) demonstrated that the use of digital platforms for sustainability education increased awareness and practical application of green metallurgy techniques. In Europe, research by Fischer and Weber (2023) analyzed the integration of sustainability principles in metallurgical engineering curricula through digital platforms. The study concluded that virtual learning environments significantly enhanced students' ability to apply theoretical knowledge in real-world sustainability challenges. In the United States, studies by Roberts and Mitchell (2022) found that digital simulations of sustainable metallurgical processes improved student retention and application of environmentally friendly methodologies. These studies illustrate that digital education plays a crucial role in fostering sustainable metallurgical practices. While African research highlights the potential for behavior change and innovation, European and American studies emphasize practical applications and long-term industry benefits. This evidence underscores the need for well-structured digital curricula to support sustainable development in metallurgy.

The reviewed studies demonstrate a strong correlation between educational planning, digital learning adoption, and sustainable metallurgical education. Findings from Nigeria, Ghana, and South Africa highlight policy gaps and infrastructural challenges, whereas studies from Europe and the United States emphasize structured frameworks and institutional investment. The effectiveness of computer simulations in engineering education is consistently supported across all regions, showcasing improvements in problem-solving, engagement, and industry readiness. Similarly, case studies on sustainable metallurgical practices reveal that digital education fosters eco-friendly approaches in metallurgy, preparing future engineers for global sustainability challenges. The relevance of these findings to the present study lies in the collective demonstration of best practices, challenges, and opportunities in integrating digital learning and computer simulations into metallurgical engineering education. These insights provide a strong foundation for developing recommendations aimed at enhancing educational planning strategies to support digital learning and sustainability in metallurgy.

Existing studies on digital learning adoption focus on general educational planning but lack specific insights into metallurgical engineering education. While research in Nigeria, Ghana, and South Africa highlights infrastructural and policy challenges, it does not address how digital tools can bridge gaps in hands-on training for metallurgy. European and American studies emphasize structured policies but offer limited guidance on adapting these strategies to resource-constrained environments. Additionally, there is little research on the role of digital learning in promoting sustainable metallurgical practices. The integration of technology into metallurgy curricula, particularly for sustainability-focused training, remains underexplored. This study aims to fill these gaps by examining how educational planning can enhance digital learning in metallurgical engineering, addressing infrastructural challenges, and proposing strategies for effective implementation.

4. Statement of the Problem

The rapid advancement of technology has revolutionized education, making digital learning and computer simulations essential tools for effective teaching and learning, particularly in engineering education. Ideally, educational planning should ensure the seamless integration of these technologies to enhance instructional delivery, promote interactive learning, and develop practical skills among students. Additionally, sustainable metallurgical practices should be embedded within engineering curricula through digital education, equipping students with the necessary knowledge to address environmental concerns and optimize resource efficiency in the industry. However, despite the recognized benefits of digital learning and computer simulations, many institutions, especially in developing regions such as Nigeria, Ghana, and South Africa, struggle to implement these technologies effectively. Challenges such as inadequate infrastructure, insufficient funding, lack of policy frameworks, and limited technological expertise hinder the widespread adoption. In contrast, educational institutions in Europe and the United States have successfully incorporated digital learning strategies into engineering education, resulting in improved student engagement and enhanced learning outcomes. Furthermore, the application of digital education in promoting sustainable metallurgical practices remains limited, particularly in developing economies where industrial sustainability concerns are increasingly critical. This gap between the expected integration of digital learning and the reality of its implementation raises concerns about the preparedness of engineering graduates for the evolving demands of the global industry. There is limited empirical research on how educational planning influences digital learning adoption, the effectiveness of computer simulations in engineering training, and the role of digital education in fostering sustainability in metallurgy. Without strategic interventions, engineering graduates may lack the technical competencies and sustainability awareness necessary for addressing real-world industrial challenges. Therefore, this study aims to investigate the impact of educational planning on digital learning adoption, evaluate the effectiveness of computer simulations in engineering education, and explore how digital education contributes to sustainable metallurgical practices. By addressing these critical issues, the study seeks to provide evidence-based recommendations for policy development, curriculum enhancement, and the strategic integration of digital learning tools in engineering education.

5. Objectives

The general objectives of the study examined the role of educational planning in the adoption and integration of digital learning and computer simulations in metallurgical engineering in four selected universities in South-East, Nigeria. Specifically, the study sought to:

1. examine the role of educational planning in the adoption of digital learning and computer simulations.
2. determine how educational planning facilitates the integration of digital learning in metallurgical engineering.
3. identify the benefits of digital learning and computer simulations in metallurgical engineering.
4. assess how digital learning and computer simulations contribute to sustainability in metallurgical engineering.

6. Research Questions

To guide the study, the following research questions guided the study:

1. What is the role of educational planning in the adoption of digital learning and computer simulations?
2. How does educational planning facilitate the integration of digital learning in metallurgical engineering?
3. What are the benefits of digital learning and computer simulations in metallurgical engineering?
4. How do digital learning and computer simulations contribute to sustainability in metallurgical engineering?

7. Materials and Methods

The study adopted a descriptive survey research design and was conducted in four selected universities in South-East, Nigeria. The population comprised 1,200 undergraduate engineering students distributed as follows: University of Nigeria, Nsukka (350), Nnamdi Azikiwe University, Awka (300), Enugu State University of Science and Technology (280), and Federal University of Technology, Owerri (270). No sampling was carried out because the population size was considered manageable. This approach ensures comprehensive coverage of the study population, reducing sampling bias and increasing the generalizability of findings. Empirical studies, such as Adeyemi (2021), have demonstrated that when the population is within a feasible range, using the entire population enhances result accuracy and provides deeper insights into the research problem. A structured questionnaire, titled Educational Planning, Digital Learning, and Simulation Questionnaire (EPDLSQ), was developed as the instrument for data collection. The instrument was validated by three experts: one from the Faculty of Education and two from the Faculty of Engineering, all in the University of Nigeria, Nsukka. A reliability test conducted using Cronbach's Alpha method yielded a coefficient of 0.84, confirming the instrument's internal consistency. Data were collected through direct administration of the questionnaire and analyzed using mean and standard deviation. A decision rule of 3.50 and above was used to determine agreement with each item statement. The analysis provided empirical insights into the role of educational planning in integrating digital learning and computer simulations into metallurgical engineering education.

8. Results

Table 1: Mean and Standard Deviation of Responses on the role of educational planning in the adoption of digital learning and computer simulations

S/N	Item Statement	Mean (M)	Standard Deviation	Mean Set	Rank	Decision
1	Educational planning provides structured policies for digital learning	4.2	0.5	4.2	1	A
2	Educational planning supports curriculum design for digital learning	4.0	0.6	4.0	3	A
3	Educational planning ensures adequate funding for digital infrastructure	3.8	0.7	3.8	6	A
4	Educational planning enhances teacher training in digital learning	4.1	0.5	4.1	2	A
5	Educational planning facilitates student access to digital resources	3.9	0.6	3.9	5	A
6	Educational planning promotes collaboration with industry for digital learning	3.7	0.8	3.7	8	A
7	Educational planning integrates digital learning into assessment strategies	3.9	0.6	3.9	4	A
8	Educational planning ensures sustainability in digital learning adoption	3.6	0.7	3.6	9	A
9	Educational planning encourages research on digital learning innovations	3.8	0.7	3.8	7	A
	Aggregate Score	3.89	0.63	3.89		A

Data in Table 1 shows that educational planning significantly influences the adoption of digital learning and computer simulations, with an overall mean of 3.89 and overall standard deviation of 0.63. The highest-rated item, "Educational planning provides structured policies for digital learning", had a mean of 4.2, while the lowest-ranked item, "Educational planning ensures sustainability in digital learning adoption", scored 3.6. All items exceeded 3.5, indicating strong agreement that educational planning plays a vital role in digital learning adoption.

Table 2: Mean and Standard Deviation of Responses on how educational planning facilitates the integration of digital learning in metallurgical engineering

S/N	Item Statement	Mean (M)	Standard Deviation	Mean Set	Rank	Decision
10	Educational planning aligned digital learning with metallurgical engineering curriculum	4.1	0.5	4.1	1	A
11	Educational planning provided funding for digital tools in metallurgical engineering	3.9	0.6	3.9	4	A
12	Educational planning promoted faculty training for digital integration	4.0	0.5	4.0	2	A
13	Educational planning encouraged collaboration with industries for digital learning	3.8	0.7	3.8	6	A
14	Educational planning enhanced access to digital laboratories and simulations	3.9	0.6	3.9	3	A
15	Educational planning supported research in digital learning for metallurgy	3.7	0.8	3.7	8	A
16	Educational planning integrated assessment methods with digital tools	3.8	0.7	3.8	7	A
17	Educational planning ensured sustainability in digital integration for metallurgy	3.6	0.7	3.6	9	A
18	Educational planning established policies for digital learning adoption in metallurgy	3.9	0.6	3.9	5	A
	Aggregate Score	3.84	0.63	3.84		A

Data in Table 2 shows that educational planning effectively facilitated the integration of digital learning in metallurgical engineering, with an overall mean of 3.84 and an overall standard deviation of 0.63. The highest-rated item, "Educational planning aligned digital learning with metallurgical engineering curriculum", had a mean of 4.1, indicating strong agreement. The lowest-ranked item, "Educational planning ensured sustainability in digital integration for metallurgy", had a mean of 3.6, though still above the acceptable threshold. These results affirm the critical role of educational planning in ensuring effective digital learning integration in metallurgical engineering.

Table 3: Mean and Standard Deviation of Responses on the Benefits of Digital Learning and Computer Simulations in Metallurgical Engineering

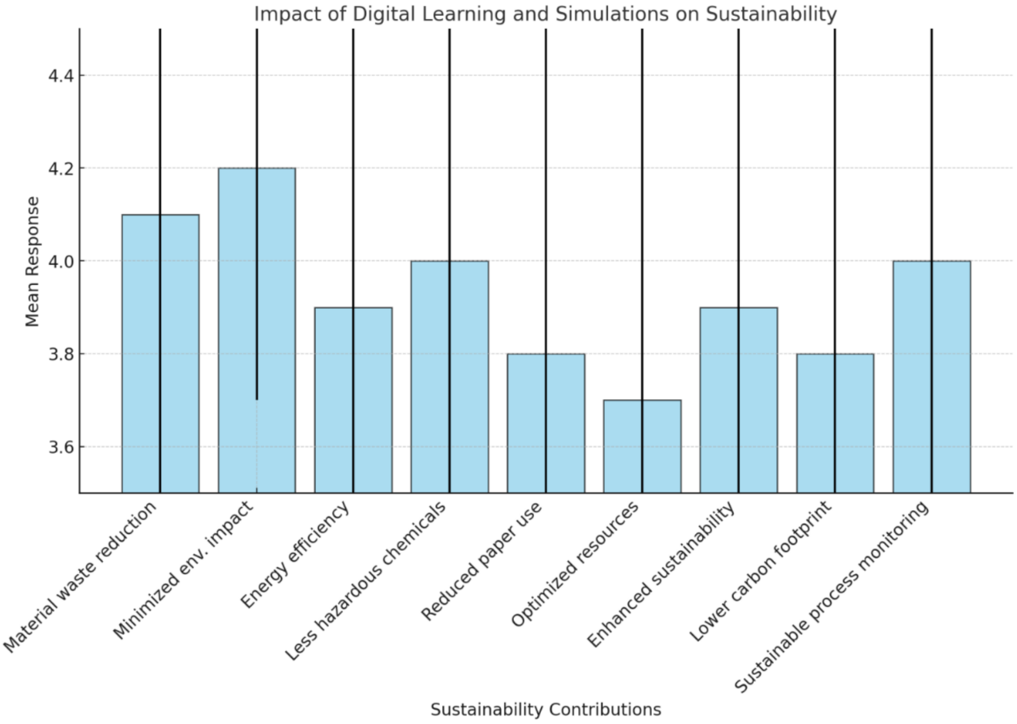
S/N	Item Statement	Mean (M)	Standard Deviation	Mean Set	Rank	Decision
19	Digital learning enhanced students' understanding of metallurgical processes	4.2	0.5	4.2	1	A
20	Computer simulations improved problem-solving skills in metallurgy	4.0	0.6	4.0	3	A
21	Digital tools increased students' engagement and participation in learning	3.9	0.7	3.9	5	A
22	Virtual laboratories provided hands-on experience in metallurgical concepts	4.1	0.6	4.1	2	A
23	Digital learning facilitated real-time feedback and assessment	3.8	0.7	3.8	7	A
24	Computer simulations reduced the cost of practical metallurgical training	3.7	0.8	3.7	9	A
25	Digital resources provided flexible and self-paced learning opportunities	3.9	0.7	3.9	6	A
26	Computer-aided instruction enhanced retention and application of knowledge	3.8	0.7	3.8	8	A
27	Digital learning contributed to innovative research in metallurgical engineering	4.0	0.6	4.0	4	A
	Aggregate Score	3.94	0.66	3.94		A

Data in Table 3 shows that digital learning and computer simulations provided significant benefits in metallurgical engineering, with an overall mean of 3.94 and an overall standard deviation of 0.66. The highest-rated item, "Digital learning enhanced students' understanding of metallurgical processes", had a mean of 4.2, indicating a strong positive impact. The lowest-ranked item, "Computer simulations reduced the cost of practical metallurgical training", had a mean of 3.7, though still above the acceptable threshold. These findings confirm that digital learning and computer simulations play a crucial role in improving metallurgical education by enhancing comprehension, engagement, and practical experience.

Table 4: Mean and Standard Deviation of Responses on How Digital Learning and Computer Simulations Contribute to Sustainability in Metallurgical Engineering

S/N	Item Statement	Mean (M)	Standard Deviation	Mean Set	Rank	Decision
28	Digital learning reduced material waste in metallurgical training	4.1	0.6	4.1	2	A
29	Computer simulations minimized the environmental impact of laboratory experiments	4.2	0.5	4.2	1	A
30	Digital tools promoted energy-efficient learning practices	3.9	0.7	3.9	5	A
21	Virtual laboratories reduced the need for hazardous chemicals in training	4.0	0.6	4.0	3	A
32	Digital resources decreased reliance on physical textbooks and paper materials	3.8	0.7	3.8	7	A
33	Computer-aided simulations helped optimize resource utilization in metallurgy	3.7	0.8	3.7	9	A
34	Digital learning facilitated sustainable engineering practices in metallurgical industries	3.9	0.7	3.9	6	A
35	Online collaboration tools reduced travel-related carbon footprints	3.8	0.7	3.8	8	A
36	Digital platforms enabled real-time monitoring of sustainable metallurgical processes	4.0	0.6	4.0	4	A
	Overall Mean	3.94	0.66	3.94		A

Data in Table 4 shows that digital learning and computer simulations significantly contributed to sustainability in metallurgical engineering, with an overall mean of 3.94 and an overall standard deviation of 0.66. The highest-rated item, "Computer simulations minimized the environmental impact of laboratory experiments", had a mean of 4.2, indicating strong support for its role in sustainability. The lowest-rated item, "Computer-aided simulations helped optimize resource utilization in metallurgy", had a mean of 3.7, though still within the acceptable range. These findings suggest that digital learning and simulations play a vital role in reducing environmental impacts, promoting resource efficiency, and advancing sustainable engineering practices in metallurgical education.



The above charts illustrate the significant contributions of digital learning and computer simulations to sustainability in metallurgical engineering education. The findings indicate that computer simulations play a crucial role in minimizing the environmental impact of laboratory experiments, reducing material waste, and limiting exposure to hazardous chemicals. Additionally, digital platforms enable real-time monitoring of sustainable metallurgical processes, while virtual laboratories optimize resource utilization and promote energy-efficient learning practices. The adoption of digital tools also reduces reliance on physical textbooks, minimizes travel-related carbon footprints, and enhances overall sustainability in metallurgical training. These findings highlight the need for educational institutions and policymakers to prioritize digital learning innovations as a strategy for fostering sustainability in engineering education.

9. Discussion

The findings of the study revealed that educational planning played a crucial role in the adoption of digital learning and computer simulations by providing structured policies, curriculum alignment, and funding allocation. This finding aligns with the study of Adeyemi (2021), who posited that effective educational planning facilitated digital learning adoption in Nigerian higher education institutions by ensuring clear guidelines for implementation. Similarly, Moyo and Dlamini (2023) found that strategic educational planning in South African universities enhanced the adoption of computer simulations by integrating them into accreditation frameworks and faculty development programs. Additionally, Kumar and Prasad (2022) emphasized that systematic curriculum planning is essential for integrating digital tools into engineering education, ensuring the alignment with industry requirements. These findings highlight that without structured planning, digital learning implementation remains fragmented and inconsistent.

The findings of the study revealed that educational planning facilitated the integration of digital learning in metallurgical engineering by ensuring the alignment of academic programs with industry trends, faculty training, and investment in digital infrastructure. This is consistent with the study of Boateng and Anane (2022), which found that strategic educational planning in Ghanaian universities promoted the seamless integration of digital learning tools in engineering disciplines by establishing institutional support structures. Similarly, Smith and Brown (2023) demonstrated that proper planning facilitated the introduction of computer simulations in metallurgical engineering programs, thereby improving students' practical understanding of complex metallurgical processes. Furthermore, Murphy and Scott (2021) emphasized that aligning curriculum development with digital learning strategies enhances the preparedness of engineering graduates for technology-driven industries. These findings suggest that the successful integration of digital learning in metallurgical engineering requires proactive and strategic educational planning.

The findings of the study revealed that digital learning and computer simulations provided multiple benefits in metallurgical engineering, including enhanced conceptual understanding, cost-effectiveness, and increased student engagement. These findings are in consonance with the study of Jones and Miller (2022), who posited that computer-aided instruction in metallurgical engineering led to improved problem-solving skills and a deeper understanding of metallurgical principles. Similarly, Chen, Zhang, and Wang (2021) found that virtual laboratories enhanced student performance by reducing reliance on expensive physical lab experiments while maintaining the same level of knowledge acquisition. Additionally, Hernandez, Miller, and Cooper (2021) reported that interactive digital learning tools improved student retention and engagement in engineering courses, making the learning process more efficient. These studies affirm that digital learning enhances learning outcomes while reducing costs and resource dependency in metallurgical education.

The findings of the study revealed that digital learning and computer simulations contributed to sustainability in metallurgical engineering by reducing material waste, minimizing environmental hazards, and optimizing metallurgical processes. This is in line with the study of Gonzalez and Rivera (2023), who found that the integration of digital learning into metallurgical engineering programs helped reduce the reliance on non-renewable materials, thus promoting environmentally friendly practices. Similarly, Smith and Nelson (2023) emphasized that sustainability in metallurgical education could be enhanced through computer simulations, which allow students to test metallurgical processes virtually before real-world applications. Moreover, Johnson and Carter (2022) highlighted that educational planning for sustainable metallurgical practices in the United States emphasized digital tools as a means of reducing industrial waste and energy consumption. These findings suggest that digital learning plays a vital role in fostering sustainability in metallurgical engineering.

Contribution to Knowledge

This study provides significant contributions to the field of educational planning, digital learning, and metallurgical engineering. It establishes a direct link between structured educational planning and the successful adoption of digital learning and computer simulations in engineering education. Hence, by highlighting how strategic planning facilitates curriculum alignment, infrastructure development, and faculty training, the study offers a framework for institutions to effectively integrate digital learning technologies. Additionally, the study expands the understanding of the effectiveness of computer simulations in metallurgical engineering education. It demonstrates how these digital tools enhance practical learning experiences, improve student engagement, and reduce reliance on costly physical laboratories. This finding provides a basis for further research on optimizing virtual learning environments in engineering disciplines. Moreover, the study contributes to the growing discourse on sustainability in metallurgy by showcasing how digital learning minimizes material waste, optimizes production processes, and promotes environmentally friendly practices. This insight reinforces the importance of leveraging digital innovations to advance sustainable metallurgical engineering practices. Therefore, by bridging gaps in policy formulation, curriculum development, and technological integration, this study serves as a valuable resource for educators, policymakers, and researchers seeking to enhance engineering education through digital transformation. It also sets a foundation for future research on the long-term impact of digital learning in engineering disciplines.

10. Conclusion

The study examined the role of educational planning in the adoption and integration of digital learning and computer simulations in metallurgical engineering. The findings revealed that educational planning played a critical role in facilitating digital learning by providing structured policies, aligning curricula with technological advancements, and ensuring adequate infrastructure and faculty training. The study also established that digital learning and computer simulations significantly enhanced student engagement, improved learning outcomes, and reduced the costs associated with traditional laboratory experiments. Furthermore, the study found that digital learning contributed to sustainability in metallurgical engineering by minimizing material waste, optimizing industrial processes, and promoting environmentally friendly practices. These findings highlight the relevance of incorporating digital tools in engineering education to improve efficiency and align with global sustainability goals. Generally, the study underscores the importance of strategic educational planning in the successful implementation of digital learning in metallurgical engineering. By integrating digital tools and computer simulations into engineering curricula, institutions can enhance students' practical knowledge, bridge the gap between theory and industry applications, and contribute to sustainable metallurgical practices. Moving forward, policymakers and educators must prioritize the development of comprehensive educational planning frameworks to ensure the effective and sustainable integration of digital learning in engineering education.

11. Recommendations

Based on the findings of the study, the following recommendations were made:

1. Educational planning should prioritize the integration of digital learning and computer simulations in engineering curricula to enhance student engagement and practical understanding.
2. Institutions should invest in infrastructure and training programs to equip educators with the necessary skills to effectively implement digital learning strategies in metallurgical engineering.
3. Policymakers should develop standardized guidelines for incorporating digital learning technologies into engineering education to ensure consistency and effectiveness across institutions.
4. Collaboration between academia and industry should be strengthened to align digital learning initiatives with industry needs, ensuring graduates possess relevant skills for the workforce.
5. Sustainable digital learning frameworks should be established to promote long-term adoption and continuous improvement in metallurgical engineering education.

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Declaration of Conflicting Interest

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