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Digital Renewal of University Education: Barriers, Opportunities, and Contributions to Sustainable Development Goals (SDGs)

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ABSTRACT

The digital transformation of higher education creates opportunities and challenges, particularly in crisis-affected countries such as Ukraine. This study examines the effectiveness of digital educational technologies and their contribution to sustainable higher education. The study combined a literature-based analysis with a three-month pedagogical experiment involving 64 university students. The findings highlight the potential of online platforms, blended learning, artificial intelligence, gamification, and immersive technologies to support motivation, learning outcomes, personalization, and inclusiveness in higher education. However, limited digital competence, unequal infrastructure, insufficient funding, cybersecurity risks, and fragmented strategies remain barriers. The study proposes an integrated digital renewal framework combining technological, organizational, and pedagogical dimensions. This framework primarily supports sustainable development goals through innovation, inclusion, resilience, and partnerships.

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1. INTRODUCTION

Digital transformation has become a strategic priority for higher education institutions worldwide, driven by advances in information and communication technologies, artificial intelligence, learning management systems, and online learning platforms. These technologies enable flexible, personalized, and learner-centered education while improving institutional resilience during crises such as the COVID-19 pandemic and regional conflicts [1-3]. In Ukraine, the need for digital renewal of higher education has become increasingly urgent because educational activities must continue despite disruptions caused by war and social instability. Universities are expected to maintain educational quality through blended learning, digital collaboration, and innovative teaching approaches while ensuring equal learning opportunities for all students [2, 4].

Digital transformation is closely aligned with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), which promotes inclusive, equitable, and lifelong learning. Furthermore, improvements in digital infrastructure, innovation, educational accessibility, and institutional collaboration contribute to SDGs 9, 10, 16, and 17. Consequently, digital renewal should be viewed not merely as technological adoption but as a strategy for sustainable higher education development [5, 6].

Previous studies have demonstrated the benefits of digital technologies in enhancing student engagement, learning flexibility, and educational outcomes. Nevertheless, persistent challenges remain, including limited digital competence among educators, unequal technological infrastructure, cybersecurity concerns, insufficient funding, and the absence of comprehensive institutional digitalization strategies [1, 4, 7]. These issues indicate that successful digital transformation requires coordinated technological, organizational, and pedagogical improvements.

Therefore, this study aims to evaluate the barriers and opportunities of digital renewal in Ukrainian higher education through a pedagogical experiment involving online learning platforms. The main contributions of this study are: (i) proposing a comprehensive digital renewal framework that integrates technological, organizational, and pedagogical dimensions for higher education; (ii) combining a pedagogical experiment with a systematic analysis of digital transformation barriers and opportunities to provide both empirical and strategic perspectives; (iii) explicitly linking digital renewal strategies with the SDGs, particularly SDG 4 (Quality Education), while highlighting their contributions to SDGs 9, 10, 16, and 17; and (iv) providing practical recommendations for strengthening digital resilience, inclusiveness, and sustainable development of higher education institutions under crisis conditions. The findings are expected to provide practical recommendations for strengthening sustainable digital transformation while supporting the achievement of the SDGs.

2. LITERATURE REVIEW

Digital transformation in higher education extends beyond the adoption of digital technologies and requires institutional adaptation, curriculum redesign, and changes in teaching practices. Learning management systems, cloud-based platforms, artificial intelligence, and immersive technologies have become essential components for delivering flexible and student-centered learning environments. Recent studies emphasize that successful digital transformation depends on the integration of technological innovation with effective pedagogical strategies rather than technology adoption alone [8, 9].

Personalized learning has received increasing attention because digital platforms enable adaptive learning pathways based on students' learning progress and preferences. Artificial intelligence, learning analytics, and big data further support personalized instruction, timely feedback, and continuous assessment, thereby improving student engagement and academic performance [10]. In addition, project-based learning, case-based learning, and collaborative online learning have been widely adopted to enhance critical thinking, communication, creativity, and problem-solving skills required in modern higher education [11].

Despite these opportunities, universities continue to encounter significant barriers during digital transformation. Common challenges include inadequate digital competence among academic staff, unequal access to technological infrastructure, limited financial resources, cybersecurity concerns, and fragmented institutional policies. These obstacles reduce the effectiveness of digital learning implementation and widen disparities in educational quality across institutions [12, 13].

Recent literature also recognizes that digital transformation contributes to sustainable higher education by promoting inclusive access, educational resilience, and institutional innovation. In particular, digital education supports SDG 4 through equitable learning opportunities, while improved digital infrastructure and institutional collaboration contribute to broader sustainable development objectives. Therefore, digital renewal should be considered a long-term institutional strategy rather than a temporary response to emergencies [5, 14]. Although previous studies have examined digital learning technologies, personalized education, and online platforms independently, limited research integrates these aspects into a comprehensive framework supported by empirical evidence from higher education institutions operating under crisis conditions. This gap provides the rationale for the present study.

3. METHODS

This study used theoretical and empirical research methods. The theoretical methods included analysis, generalization, synthesis, and structural-logical analysis. These methods were applied to examine the main forms of higher education digitalization and their integration into traditional learning environments. Scientific publications, regulatory documents, and international reports published within the previous five years were reviewed to identify current trends, opportunities, and challenges in digital higher education. The reviewed studies were critically examined to identify potential limitations and sources of bias relevant to the interpretation of the literature.

The empirical research involved a pedagogical experiment conducted at the National University of Life and Environmental Sciences of Ukraine during the 2024-2025 academic year. The experiment lasted three academic months and involved 64 students from humanities, technical, and natural science departments. The control group consisted of 31 students, whereas the experimental group consisted of 33 students. The participants were selected based on voluntary participation, representativeness, sufficient general competence, and their ability to attend classes regularly. Data were collected using Google Forms. All participants provided informed consent, and the confidentiality of their information was maintained.

The pedagogical experiment consisted of four stages: diagnostic, formative, establishing, and generalizing. The purpose and implementation of each stage are summarized in **Table 1**. At the diagnostic stage, the initial levels of students' knowledge and skills were determined. During the formative stage, online learning platforms were integrated into the educational activities of the experimental group, whereas the control group continued using traditional educational methods. The establishing stage evaluated the final learning levels of both groups. The generalizing stage compared changes in student performance and assessed the effectiveness of the implemented approach.

Table 1. Structure of the pedagogical experiment.

STAGE OF EXPERIMENTAL RESEARCH	IMPLEMENTATION
Diagnostic	Determination of the initial level of students' knowledge and skills
Formative	Integration of innovative learning elements through online platforms into the educational activities of the experimental group
Establishing	Determination of the final learning levels of the control and experimental groups
Generalizing	Evaluation of changes in student performance and the effectiveness of the implemented approach

The students' learning level was evaluated using the following learning coefficient (see equation (1)):

$$KN_1 = \frac{A_1}{N_1} \quad (1)$$

where KN_1 is the learning coefficient, A_1 is the achieved learning score, and N_1 is the maximum possible score. The learning coefficient was classified into three categories: high level (0.70-1.00), medium level (0.40-0.69), and initial level (0.00-0.39), as presented in **Table 2**.

Table 2. Classification of students' learning levels.

LEARNING COEFFICIENT	LEARNING LEVEL
0.70-1.00	High level
0.40-0.69	Medium level
0.00-0.39	Initial level

The digital intervention focused on problem-based and practice-oriented learning. It included embodied learning with gamification, targeted learning projects, audiovisual learning, and the case method. The learning activities, online platforms, and allocated hours used during the formative stage are presented in **Table 3**.

The experimental data were processed using quantitative analysis, including the calculation of average values, graphical presentation, and comparative analysis. Student's *t*-test was used to compare the learning outcomes of the control and experimental groups. The evaluation focused on students' learning outcomes, including the acquisition of knowledge, skills, and abilities.

Table 3. Structure of the formative stage of the experiment.

INNOVATIVE EDUCATIONAL METHOD	PRACTICAL TOOLS	ONLINE PLATFORMS USED	NUMBER OF CLASS HOURS
Embodied learning with elements of gamification	Interactive quizzes, simulation games, educational applications with scoring systems, virtual-reality-based games, and rating systems	Moodle, Padlet, LearningApps.org	8
Targeted learning projects for mastering specific competencies	Collaborative online learning in students' own learning environments	Coursera, Udemy, edX	8
Audiovisual method	Discussion activities, statistical presentation of information, graphs, diagrams, text documents, presentations, videos, photographs, and survey forms	Equity Maps, Google Sites	6
Case method	Problem situations based on real-life facts and activities supporting critical thinking, research, communication, and teamwork	ResearchGate, Google Classroom, Kahoot, Padlet, Moodle	6

4. RESULTS

The analysis identified several technological and organizational factors supporting the digital renewal of higher education. These included learning management systems, distance and blended learning, artificial intelligence, mobile applications, online platforms, and immersive technologies. These findings correspond with the literature reviewed in the previous section, which emphasizes that digital transformation requires the integration of technology, pedagogy, institutional management, and adequate infrastructure [8-14]. However, the integration of digital technologies was associated with several barriers, as summarized in **Table 4**.

The barriers in **Table 4** show that digital renewal cannot be achieved by providing online platforms alone. The identified problems support the argument presented in the Literature Review that digital transformation is also an organizational, pedagogical, and socio-cultural process [9, 12, 14]. In particular, insufficient teacher competence, fragmented digital systems, and limited quality monitoring may reduce the effectiveness of otherwise appropriate technologies.

4.1. Initial Learning Conditions

The diagnostic stage indicated that the two groups had relatively comparable initial conditions. The learning coefficients were 0.62 for the control group and 0.66 for the experimental group, as presented in **Table 5**. According to the classification established in **Table 2**, both coefficients represented a medium learning level. The difference of 0.04 indicates that the experimental group had a slightly higher initial coefficient, although both groups remained within the same category.

The initial distributions are presented in **Table 6**. Most students in both groups were at the medium or initial level. The experimental group contained more students at the initial level, but it also had two more participants overall. Therefore, the raw frequencies should be interpreted together with the different group sizes.

Table 4. Main challenges of integrating digital technologies into higher education.

NO	PROBLEMATIC ASPECT	MAIN CHARACTERISTICS
1	Insufficient digital competence of teaching staff	Limited ability to use digital tools and provide effective online feedback
2	Lack of resources	Insufficient investment, complicated financing and logistics, and limited funding for staff development
3	Unequal Internet access	Unstable or insufficient Internet access, particularly in remote institutions
4	Incompatible curricula	Traditional curricula are not sufficiently adapted to digital technologies
5	Lack of a unified digital management system	Digital technologies are implemented separately without adequate platform integration
6	Cybersecurity problems	Insufficient protection of personal information on online platforms
7	Low student motivation	Some students do not consider online courses equivalent to face-to-face learning
8	Limited access to VR/AR systems	High equipment costs and insufficient methodological support
9	Ineffective quality monitoring	Limited systems for evaluating the influence of digital technologies on educational quality

Table 5. Initial learning coefficients of the study groups.

GROUP	SELECTION CRITERIA	LEARNING COEFFICIENT
Control group	Sufficient general competence and representativeness	0.62
Experimental group	Sufficient general competence and representativeness	0.66

Table 6. Initial learning levels of the study groups.

GROUP	TOTAL STUDENTS	HIGH LEVEL	MEDIUM LEVEL	INITIAL LEVEL
Control group	31	4	13	14
Experimental group	33	5	12	16

4.2. Learning Outcomes after the Intervention

After the formative stage, the reported learning coefficients were 0.81 for the control group and 0.76 for the experimental group, as shown in **Table 7**. These values indicate different patterns of change between the two groups and therefore require careful interpretation. Based on Tables 5 and 7, the control-group coefficient increased from 0.62 to 0.81, representing an absolute increase of 0.19, whereas the experimental-group coefficient increased from 0.66 to 0.76, representing an absolute increase of 0.10. Accordingly, the interpretation in this study is based on the values reported in **Tables 5 and 7**. However, the coefficients alone do not indicate that the experimental group improved more strongly and should therefore be interpreted together with the categorical distributions. The coefficient-based results and categorical distributions appear to reflect different aspects of student learning outcomes and are therefore considered complementary indicators.

Table 7. Final learning coefficients of the study groups.

GROUP	SELECTION CRITERIA	LEARNING COEFFICIENT
Control group	Sufficient general competence and representativeness	0.81
Experimental group	Sufficient general competence and representativeness	0.76

A different pattern appears when the categorical distributions are examined in **Table 8**. The number of high-level students increased from 4 to 5 in the control group and from 5 to 8 in the experimental group. Meanwhile, the number of students at the initial level decreased from 14 to 11 in the control group and from 16 to 10 in the experimental group. Therefore, the categorical data suggest a more favorable redistribution in the experimental group, particularly through the larger movement of students away from the initial level. This pattern may indicate that the learning coefficient and the categorical distribution capture different aspects of achievement. The platforms may have helped a larger number of lower-performing students move into higher categories, even though the reported final average coefficient remained higher in the control group. This interpretation is consistent with previous studies emphasizing the potential of blended and personalized learning to support diverse learning needs [8, 10, 11]. Nevertheless, it should be treated cautiously because individual student-level data were not reported.

Table 8. Final learning levels of the study groups.

Group	Total students	High level	Medium level	Initial level
Control group	31	5	15	11
Experimental group	33	8	15	10

Table 9 presents the Student's t-test calculation as an additional statistical comparison between the study groups. The reported result is interpreted as supporting information alongside the descriptive learning outcomes presented in **Tables 5-8**. This also reinforces the importance of consistent evaluation standards when assessing online education [12].

Table 9. Learning outcomes used in the Student's *t*-test.

Sample	B.1	B.2	Deviation B.1	Deviation B.2	Squared deviation B.1	Squared deviation B.2
1	61.3	81.5	−0.35	0.42	0.17	1.63
2	61.8	81.2	0.15	0.12	0.14	0.23
3	60.4	77.5	−1.25	−3.58	1.74	11.69
4	61.2	79.8	−0.45	−1.28	0.17	3.68
5	63.7	83.7	2.05	2.62	2.82	4.75
6	61.5	82.8	−0.15	1.72	0.006	1.90
Total	369.9	486.5	—	—	5.04	23.88
Average	61.65	81.08	—	—	—	—

4.3. Broader Digitalization Trends

Figure 1 shows a substantial increase in the reported use of learning management systems, online learning, and digital-skills development in European universities between 2019 and 2023. **Figure 2** presents increases in interactive technologies, online platforms, mobile applications, gamification, smart cards, audiovisual technologies, and distance learning. **Figure 3** indicates increasing effects on adaptability, individualization, socialization, and student integration.

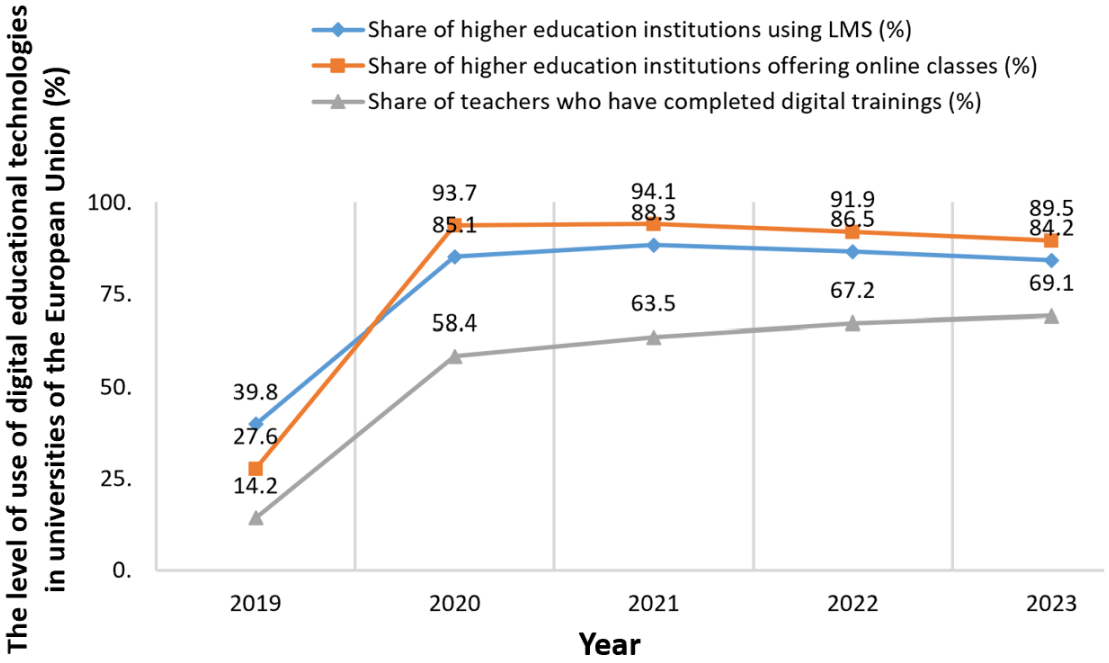

Figure 1. Use of digital educational technologies in European Union universities, 2019-2023.

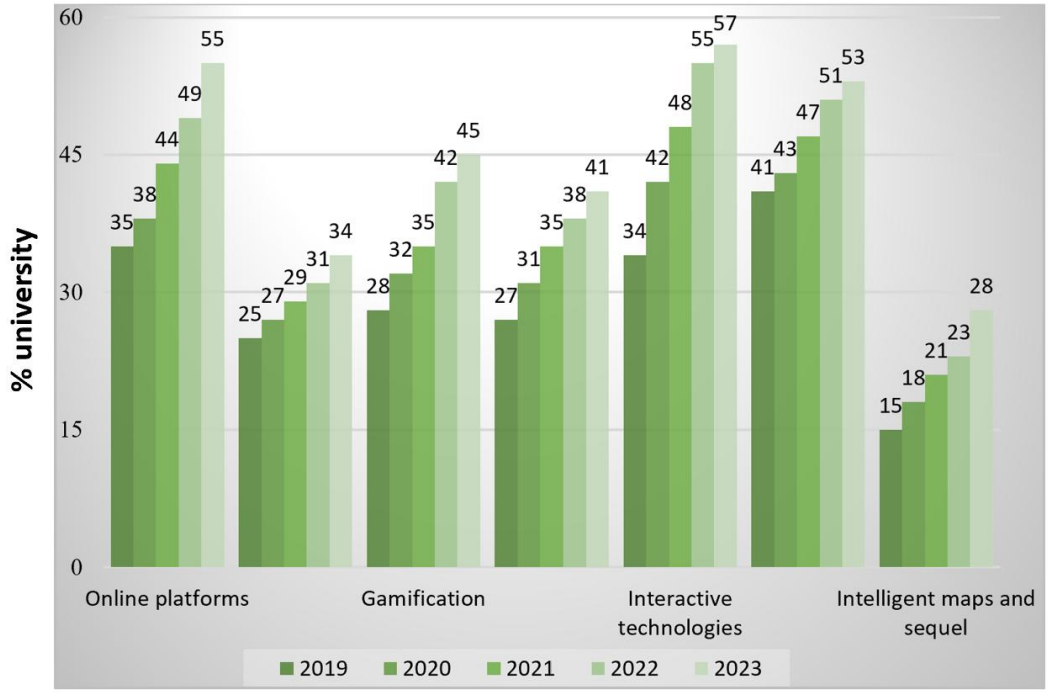

Figure 2. Innovative learning technologies in European Union universities, 2019-2023.

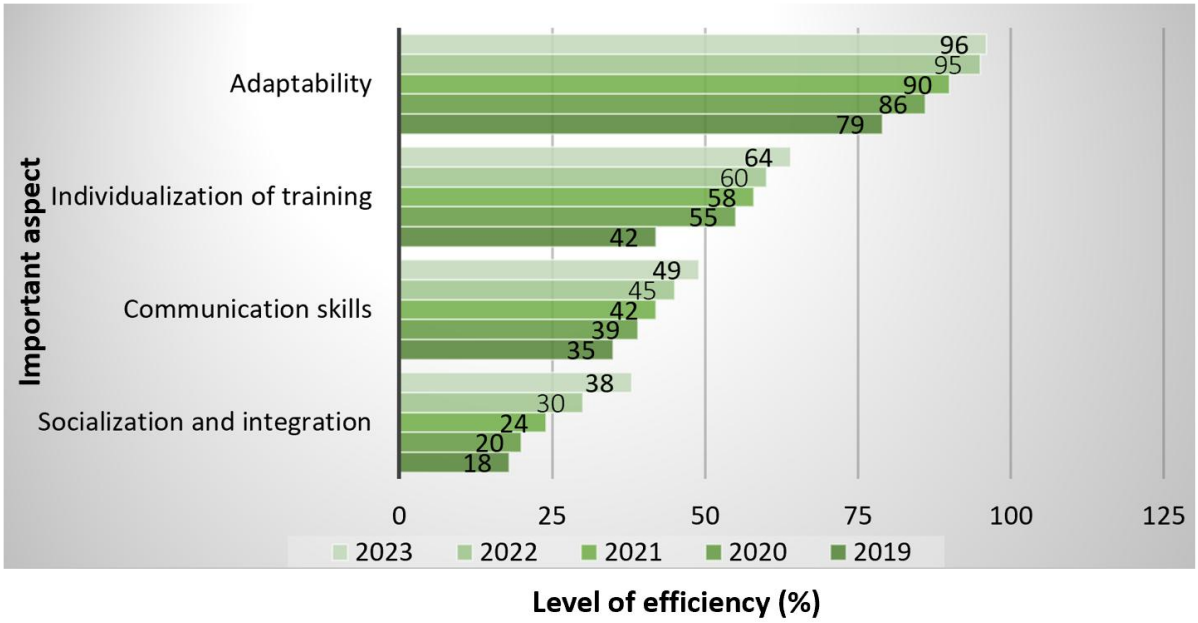

Figure 3. Reported effects of innovative technologies on students.

These broader trends support the relevance of digital renewal and its contribution to flexible, inclusive, and accessible education. They are also aligned with the role of digital infrastructure, personalized learning, and educational innovation discussed in the previous sections [5, 8, 10, 14]. However, the experimental findings should be interpreted by considering the different patterns reflected in the learning coefficients and categorical distributions.

4.4. Discussion

The findings indicate that digital renewal in higher education is not limited to replacing conventional teaching with online platforms. It requires the coordinated development of technological infrastructure, digital competence, learning design, institutional management, and quality assurance. This interpretation is consistent with previous studies describing digital transformation as a combination of technological, pedagogical, organizational, and socio-cultural changes [9, 14].

The barriers identified in **Table 4** provide an important context for interpreting the experimental findings. Insufficient teacher competence, unequal access to infrastructure, fragmented digital systems, and inadequate quality monitoring can reduce the effectiveness of educational technologies. Therefore, the availability of platforms does not automatically produce better learning outcomes. The results support the view that technology must be accompanied by appropriate pedagogical methods, institutional support, curriculum adaptation, and continuous staff development [5, 8, 12].

The formative intervention combined online platforms with gamification, targeted learning projects, audiovisual activities, and case-based learning. These methods were intended to increase interaction, practical engagement, and flexibility. This approach is aligned with blended-learning frameworks that integrate interactive content, learning management systems, project activities, and case-based instruction [11]. It is also consistent with previous research [8] on immersive, personalized, and practice-oriented learning.

The categorical results suggest that the experimental group experienced a more favorable redistribution of learning levels. The number of students at the high level increased from 5 to 8, whereas the number at the initial level decreased from 16 to 10. In the control group, the number of high-level students increased from 4 to 5, while the initial-level category decreased from 14 to 11. This pattern suggests that the intervention may have supported movement from lower to higher learning categories.

Such movement is relevant because the educational value of digital learning may not always be fully represented by a single average score. Online platforms can provide repeated access to learning materials, differentiated activities, interactive feedback, and flexible participation. These characteristics may particularly benefit students who begin at lower levels of achievement. They are also consistent with the objectives of personalization and inclusiveness discussed in earlier studies [8, 10, 11]. However, the interpretation of the average learning coefficients requires caution. The tables report an increase from 0.62 to 0.81 in the control group and from 0.66 to 0.76 in the experimental group. These figures correspond to absolute increases of 0.19 and 0.10, respectively. Taken together, the average coefficients and categorical distributions indicate that changes in learning outcomes should be interpreted from multiple indicators rather than from a single measure.

The difference between the average coefficients and categorical distributions may reflect differences in how overall achievement and changes across learning-level categories are represented. Accordingly, the learning coefficients and categorical distributions are interpreted as complementary indicators of changes in student learning outcomes. Therefore, the effectiveness of the intervention is interpreted by considering both the reported learning coefficients and the distribution of students across learning-level categories.

The Student's t-test provided an additional statistical comparison between the study groups. Because **Table 9** presents the calculation components in summarized form, the reported t-value is interpreted together with the descriptive learning outcomes. Accordingly, the statistical comparison is treated as supporting evidence and is considered alongside the changes observed in the learning coefficients and categorical distributions.

These findings highlight the importance of transparent and standardized evaluation procedures in digital education. Previous research [12] similarly emphasized the need to evaluate online educational services using consistent quality indicators. Future studies should further strengthen statistical reporting by clearly describing the tested variables, comparison procedures, and evaluation criteria.

The broader trends presented in **Figures 1-3** show increasing adoption of learning management systems, online learning, interactive technologies, mobile applications, and gamification. They also indicate growing effects on adaptability, individualization, and social integration. These trends support the relevance of digital education as a long-term development strategy rather than merely a temporary response to crisis conditions.

The emphasis on accessibility, inclusiveness, flexibility, and digital competence also connects the findings to sustainable development. Digital platforms can support SDG 4 by expanding access to learning opportunities and enabling more flexible educational participation. The development of digital infrastructure and innovative educational systems is also relevant to SDG 9, while greater access for geographically or socially disadvantaged learners may contribute to SDG 10. However, these contributions depend on reducing digital

inequality, strengthening staff competence, and ensuring affordable and reliable infrastructure [5].

Beyond SDGs 4, 9, and 10, the findings also have implications for SDG 16 and SDG 17. Strengthening institutional digital governance, cybersecurity, data protection, and transparent quality-assurance mechanisms can support more accountable and resilient higher education systems, which is consistent with the principles of SDG 16. In addition, sustainable digital renewal requires collaboration among universities, government institutions, technology providers, and international academic partners. Such cooperation is closely aligned with SDG 17, particularly through knowledge sharing, capacity building, technological collaboration, and institutional partnerships. Therefore, digital transformation in higher education should be understood not only as an educational or technological process, but also as a collaborative institutional strategy that can contribute to multiple dimensions of sustainable development.

The findings therefore support a balanced interpretation. Digital platforms offer important opportunities for personalization, inclusion, practical learning, and continuity of education. At the same time, their effectiveness depends on instructional quality, institutional integration, infrastructure, and reliable assessment. The experimental results provide preliminary evidence of positive changes in the distribution of student learning levels, although the findings should be interpreted by considering the different patterns reflected in the reported indicators.

Digital renewal should be understood as an integrated institutional strategy. Universities should not focus solely on acquiring technologies but should also develop a unified digital ecosystem, train teachers, adapt curricula, protect personal data, and establish transparent systems for evaluating educational outcomes. These measures would strengthen the contribution of digital higher education to both learning quality and sustainable development.

5. CONCLUSION

Digital renewal can improve higher education through flexible, inclusive, and practice-oriented learning. The experiment showed changes in student learning levels in both groups, while the experimental group demonstrated a more pronounced redistribution of students from the initial level toward higher learning categories. The findings should nevertheless be interpreted by considering the different patterns reflected in the average learning coefficients, categorical distributions, and statistical comparison. Digital platforms should therefore be supported by teacher training, curriculum adaptation, reliable infrastructure, cybersecurity, and transparent evaluation. Their contribution to SDG 4, SDG 9, and SDG 10 depends on reducing digital inequality and building integrated institutional systems. Further studies should use larger samples, longer interventions, and fully reported statistical procedures.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper is free of plagiarism.

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