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EXPERIMENTAL RESEARCH USING MODELS AND METHODS OF THE UNIVERSITY DIGITAL ECOSYSTEM

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Abstract. The article discusses the experimental use of different models and methods of the university's digital ecosystem in the process of modernization of higher education. The digital ecosystem is an environment that integrates the educational, scientific, and managerial digital resources. The study also responds to the lack of focus in previous studies, which usually only use individual indicators to report the effectiveness of digital learning models, while not using indicators that are comparable with the results from previous studies. This study aims at quantifying and comparing traditional, hybrid and digital learning models and evaluating their effect on academic achievement, motivation and engagement. The quasi-experimental method was performed on 90 students and 30 teachers (N = 120) in the control and experimental groups for a semester-long period. The instrument for measuring motivation was an adaptation of the Motivated Strategies for Learning Questionnaire (MSLQ), and the instrument for measuring engagement with a learning-analytics activity index was a learning-analytics

activity index. Pre- and post-tests were used to measure academic performance. Paired and independent-samples ttests, effect sizes (Cohen's d) and a proposed integral effectiveness indicator that combines the three sub-indicators together into one score were used for data analysis. Results showed significant improvements in academic performance and motivation in the experimental group, with higher post-test values than in the control group. The findings showed a higher reported integral composite for the digital learning model (68.4%) than for the traditional model (58.1%). The experimental group also showed statistically significant gains in academic performance and motivation, while platform activity was analyzed as a behavioral digital-use indicator rather than as an independent engagement measure. The value of the work is that universities have a replicable approach to designing, comparing, and evaluating digital ecosystem learning models.

Keywords: university digital ecosystem; digital learning models; educational experiment; learning analytics; student engagement

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УНИВЕРСИТЕТТІҢ ЦИФРЛЫҚ ЭКОЖҮЙЕСІНІҢ МОДЕЛЬДЕРІ МЕН ӘДІСТЕРІН ҚОЛДАНА ОТЫРЫП ЖҮРГІЗІЛГЕН ЭКСПЕРИМЕНТТІК ЗЕРТТЕУ

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Аннотация. Мақалада жоғары білім беруді жаңғырту үдерісінде университеттің цифрлық экожүйесінің әртүрлі модельдері мен әдістерін эксперименттік қолдану қарастырылады. Цифрлық экожүйе білім беру, ғылыми және басқарушылық цифрлық ресурстарды біріктіретін кешенді орта ретінде түсіндіріледі. Зерттеу алдыңғы еңбектерде цифрлық оқыту модельдерінің тиімділігі көбіне жекелеген көрсеткіштер арқылы бағаланып, нәтижелерді кешенді түрде салыстыруға мүмкіндік беретін интегралдық көрсеткіштердің жеткіліксіз қолданылу мәселесін қамтиды. Зерттеудің мақсаты — дәстүрлі, гибриді және цифрлық оқыту модельдерін сандық тұрғыдан бағалау және салыстыру, сондай-ақ олардың академиялық үлгерімге, мотивацияға және студенттердің оқу үдерісіне қатысуына ықпалын анықтау. Квазиэксперименттік зерттеу бір семестр бойы бақылау және эксперименттік топтарға бөлінген 90 студент пен 30 оқытушының қатысуымен жүргізілді ($N = 120$). Мотивацияны бағалау үшін Motivated Strategies for Learning Questionnaire (MSLQ) сауалнамасының бейімделген нұсқасы пайдаланылды, ал learning analytics негізіндегі платформа белсенділігі цифрлық қатысудың мінез-құлықтық көрсеткіші ретінде қарастырылды. Академиялық үлгерім алдын ала және қорытынды тестілеу арқылы бағаланды. Деректерді талдау үшін жұптасқан және тәуелсіз іріктемелерге арналған t-тесттер, Коэннің d әсер мөлшері және үш субиндикаторды бір жиынтық көрсеткішке біріктіретін интегралдық тиімділік индикаторы қолданылды. Нәтижелер эксперименттік топта академиялық үлгерім мен мотивацияның статистикалық тұрғыдан маңызды жақсарғанын көрсетті. Цифрлық оқыту моделінің интегралдық көрсеткіші 68,4%-ды құрап, дәстүрлі модельдің 58,1% көрсеткішінен жоғары болды. Қазақ тіліндегі бастапқы нұсқада мотивация мен оқу үдерісіне қатысу бойынша Коэннің d әсер мөлшері 0,66–1,18 аралығында көрсетілген. Платформадағы белсенділік студенттердің қатысуының дербес өлшемі ретінде емес, цифрлық технологияларды пайдаланудың мінез-құлықтық индикаторы ретінде талданды. Зерттеудің практикалық құндылығы университеттерге цифрлық экожүйедегі оқыту модельдерін әзірлеу, салыстыру және бағалаудың қайталанатын әдістемелік тәсілін ұсынуымен анықталады.

Түйін сөздер: университеттің цифрлық экожүйесі; цифрлық оқыту модельдері; білім беру эксперименті; оқыту аналитикасы; студенттердің оқу үдерісіне қатысуы

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ С ИСПОЛЬЗОВАНИЕМ МОДЕЛЕЙ И МЕТОДОВ ЦИФРОВОЙ ЭКОСИСТЕМЫ УНИВЕРСИТЕТА

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Аннотация. В статье рассматривается экспериментальное применение различных моделей и методов цифровой экосистемы университета в процессе модернизации высшего образования. Цифровая экосистема определяется как интегрированная среда, объединяющая образовательные, научные и управленческие цифровые ресурсы. Исследование направлено на устранение ограничения предшествующих работ, в которых эффективность цифровых моделей обучения зачастую оценивалась по отдельным показателям без применения сопоставимых комплексных критериев. Цель исследования заключается в количественной оценке и сравнении традиционных, гибридных и цифровых моделей обучения, а также определении их влияния на академическую успеваемость, мотивацию и вовлеченность студентов. Квазиэкспериментальное исследование проводилось в течение одного семестра с участием 90 студентов и 30 преподавателей ($N = 120$), распределенных между контрольной и экспериментальной группами. Для измерения мотивации использовалась адаптированная версия опросника Motivated Strategies for Learning Questionnaire (MSLQ), а активность на образовательной платформе, полученная средствами learning analytics, рассматривалась как поведенческий показатель цифровой активности. Академическая успеваемость оценивалась посредством предварительного и итогового тестирования. Для анализа применялись парные и независимые t-тесты, величина эффекта Cohen's d и

предложенный интегральный показатель эффективности, объединяющий три субиндикатора в единую оценку. Результаты показали статистически значимое повышение академической успеваемости и мотивации в экспериментальной группе, при этом значения итогового тестирования превышали показатели контрольной группы. Интегральный показатель цифровой модели обучения составил 68,4% против 58,1% для традиционной модели. Активность на платформе анализировалась не как самостоятельный показатель вовлеченности, а как поведенческий индикатор использования цифровых технологий. Практическая ценность исследования заключается в формировании воспроизводимого подхода к разработке, сравнению и оценке моделей обучения в цифровой экосистеме университета.

Ключевые слова: цифровая экосистема университета; цифровые модели обучения; образовательный эксперимент; аналитика обучения; вовлеченность студентов

Introduction. The digital age is also changing the structure of modern universities, not only in relation to the use of specific information technologies for pedagogical and research activities, but also in terms of creating an integrated digital ecosystem that embraces teaching, research and management. A “digital university” is conceived as a unified system consisting of digital learning technologies, smart data management solutions, and online collaboration services between the different actors of educational action, and processes of supporting individual educational paths of students (Bond et.al., 2018).

According to both national and international studies, the integration of digital technologies into higher education refers to the application of digital solutions within the educational process to expand access to learning resources, improve educational quality, and personalize learning pathways in accordance with students’ individual needs. The university’s digital environment includes online educational platforms, Learning Management Systems (LMS), learning analytics tools, digital communication services, and information systems that support managerial decision-making.

The digital competence of teachers and students is one of the key elements of a successful digital transformation. One of the main components of digital literacy is related to the ability of the individuals involved in the educational process to successfully use modern information search, task completion and digital communication devices (Aldowah et al., 2019). With the increasing importance of mobile and portable technologies, the contexts for learning have been expanded to include access to media, educators and peers outside the classroom (Bernacki et al., 2020). Previous international research demonstrates that the digital evolution of higher education is a highly complex and multi-faceted process, where traditional pedagogical approaches must be revised, organizational culture should evolve, while modern management approaches need to be introduced. An effective digital ecosystem should support personalized learning and promote continuous

development for both students and the institution. Although digitalization has clear benefits, it is only possible to be implemented through a systematic plan that includes upgrading technological infrastructure, improving staff competencies, developing digital standards and practical guidelines for platform implementation, as well as continuously monitoring the effectiveness of digital solutions. Thus, the research into the experimental models and methods of the university digital ecosystems is timely and practical (Field, 2018)

While the benefits of digitalization are well-known, much of the research available on the effects of digital tools conveys several gains in the form of individual indicators – motivation, engagement, or grades separately – which makes it challenging to compare different learning models on a common and consistent scale. This fragmentation is the gap in the research that is filling the work here. This study aims to measure and compare the effectiveness of traditional, hybrid and digital learning models in a university Digital ecosystem with the same measurement. This study has three research questions (RQ) and three hypotheses (H):

RQ1. Is the digital learning model more effective than the hybrid learning model and the conventional learning model in general? The digital model has the greatest integral effectiveness. The greatest integral effectiveness is achieved by the digital model.

RQ2. Does student use of digital tools lead to higher student motivation and engagement compared to traditional teaching and learning? H2: Experimental group increases in motivation and engagement significantly more than the control group from pre to post.

RQ3. Is students' academic engagement associated with the intensity of their use of the digital learning environment?

The novelty of this study is given by the creation and implementation of an integral indicator of the effectiveness of a digital educational model, that is, the combination of academic motivation, student engagement and educational activity results. The proposed approach offers a comprehensive quantitative evaluation of a university's digital ecosystem and enables a comparison of traditional, hybrid and digital learning models in an objective manner.

Literature review. In recent years, the digital transformation of higher education has been accompanied by a shift from the use of individual educational technologies to the development of comprehensive digital university ecosystems. In modern literature, a digital ecosystem is defined as a collection of interconnected digital resources that support educational, scientific, and administrative activities and enable more flexible organization of the learning process. However, the digitalization of education goes beyond the implementation of platforms and electronic resources; it also involves changes in pedagogical models, the nature of teacher-student interactions, and the use of data for monitoring educational outcomes. One of the most studied areas is the comparative effectiveness of traditional, online, and blended learning. A meta-analysis by Vo, Zhu, and Diep,

which included 51 effect evaluations, found that blended learning provides a statistically significant, albeit relatively small, advantage in academic performance compared to traditional learning.

However, the effectiveness varies depending on the discipline and course design. (Vrije Universiteit Brussel). More recent meta-analytical studies also suggest a positive impact of blended learning not only on academic achievement, but also on students' attitudes towards learning and their engagement. A special place in research is occupied by the problem of student engagement. A systematic review of 2024 shows that the effectiveness of blended learning is associated with several dimensions of engagement, including academic, behavioral, cognitive, and emotional engagement. The reviewed studies generally demonstrate a positive relationship between well-designed blended learning, engagement, and learning outcomes. However, current research on learning analytics highlights a methodological challenge: students' digital traces are often interpreted primarily as behavioral indicators, such as the number of system actions or the duration of engagement, while cognitive and emotional aspects of engagement are less frequently measured. Learning analytics technologies are becoming an important tool in the digital ecosystem, allowing us to track student activity and identify students who are struggling in a timely manner. However, systematic reviews show that the evidence for the direct impact of learning analytics on academic outcomes remains mixed. This highlights the need to combine digital metrics with traditional assessment methods and psychological tools to measure motivation.

Thus, the literature analysis shows the need for a comprehensive assessment of educational models that combines academic performance, motivation, and engagement. This approach allows us to move from evaluating the effectiveness of individual digital tools to comparing holistic learning models within the university's digital ecosystem. The quasi-experimental comparison of traditional, hybrid, and digital models presented in this study addresses this research need and complements existing studies with a reproducible system for integral assessment of effectiveness.

Materials and Method. The study was carried out using the university's digital infrastructure, which incorporates learning management systems, electronic learning resources, analytical platforms, and digital communication technologies. The participants in the experiment included students and academic staff actively engaged in educational and research activities. The research was conducted on the resources of digitalization of the university, which combines educational, scientific and management processes. The experimental study employed several core elements of the university's digital ecosystem.

1. Learning Management Systems (LMS) served as the primary digital platform for organizing and managing the educational process. These systems offer teachers the opportunity to develop courses, run tests, and monitor student progress. The systems facilitated the collection of information about student activities, assignment completion dates, and levels of student learning which were used to develop Figures 2-4.

2. Online and distance learning resources, including interactive assignments, video-based instructional materials, electronic assessments, and continuous access to educational content, were incorporated into the study. These resources enabled the incorporation of digital learning aspects and the assessment of shifts in student motivation (Figure 3) and engagement (Figure 4).

3. Learning Analytics tools recorded students' participation on the digital platform, monitored their involvement in assignments and project work, and generated quantitative data for evaluating the effectiveness of various educational models. (Figure 2) and engagement dynamics (Figure 4).

4. Digital communication technologies, including messaging applications, discussion forums, and video conferencing platforms, enabled students to exchange ideas, collaborate effectively, and receive timely feedback throughout the learning process.

5. Access to digital research resources, such as electronic libraries, academic databases, and collaborative project platforms, supported both independent study and teamwork, thereby enhancing students' research and problem-solving skills.

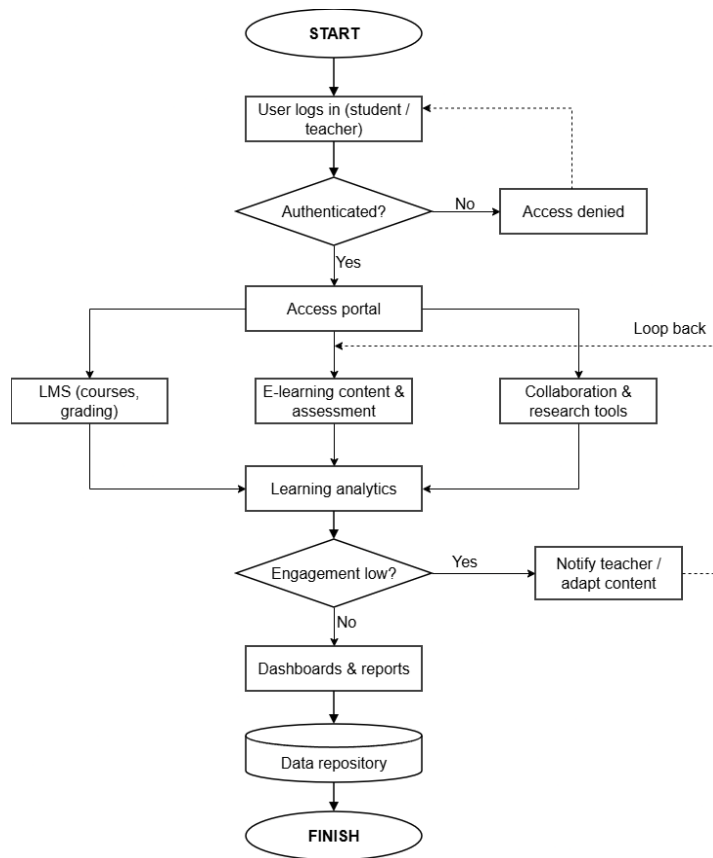


Figure 1 – System architecture of the university digital ecosystem.

Participants were 120 people (90 undergraduate and graduate students, and 30 teachers). The participants were selected from 5 programs (Engineering, Computer Science, Economics, Education, Languages) and randomly assigned to control and experimental groups consisting of 45 students each. The control group was taught by the conventional method and the experimental group was taught with digital educational tools. The experiment was carried out in one academic semester with diagnostic, formative and control stage. A summary of the demographic composition of the sample (gender, year of study, program) is given in Table 1. The participants' performance was measured using a learning management system (LMS), an analytical platform, electronic educational resources, and questionnaires. The evaluation of academic performance, student motivation and engagement, and the activity in the digital educational environment were the main aspects of the study. A medium effect ($d \sim 0.5$) can be detected with $\alpha = 0.05$ using this sample size.

Table 1 — Demographic composition of the sample

Characteristic	Control group	Experimental group
Students (n)	45	45
Teachers (n)	15	15
Female / Male	32 / 13	21 / 24
Mean year of study	2.5	2.6

Research methods. A combination of complementary research methods was applied to evaluate the impact of the university's digital ecosystem on the educational process, enabling a comprehensive and multidimensional analysis of the obtained results.

System analysis

The structure of the digital ecosystem of the university was studied, the interaction of its components and their influence on education was considered, using the method of system analysis. This approach enabled us to determine the critical components of the system and to evaluate the impact of the use of digital resources on the effectiveness of learning (Figure 2) and student motivation (Figure 3).

Pedagogical experiment. The experimental stage involved dividing the participants into control and experimental groups of students. Students in the control group followed traditional instructional methods, whereas the experimental group participated in learning supported by digital technologies. In the course of the experiment, the indicators of academic performance, motivation, and student engagement were noted, and these indicators served as a foundation for the creation of Figures 2

Comparative analysis. A comparative evaluation was conducted to assess the effectiveness of traditional, hybrid, and fully digital learning models. As illustrated in Figure 2, the performance indicators demonstrate that the digital learning

model outperformed the traditional and hybrid approaches in terms of knowledge acquisition and students' test performance.

Statistical data processing. Methodological clarification. The study reports group means and test statistics but does not provide the raw observations or separate pre-test/post-test standard deviations for every outcome and group. Therefore, the revised text reports only standard deviations that can be derived from paired-test statistics (SD of paired differences) and does not invent marginal SDs. In addition, the platform activity index is kept conceptually separate from engagement to avoid circular interpretation.

Statistical analysis techniques were applied to measure and evaluate the selected research indicators. Descriptive statistics (means and standard deviations) were calculated for each group and for each measure. For within group comparisons of pre to post measures, paired sample t-tests were used and for between group comparisons of post-test measures, independent sample t-tests were used. Effect sizes were expressed as Cohen's d, with a small effect size (0.2), medium effect size (0.5) and large effect size (0.8). The level of significance used was $\alpha = 0.05$. The results were processed statistically to identify trends in students' motivational changes (Figure 3) and engagement (Figure 4) of students in relation to using digital tools. The standard deviations of the indicators studied were also calculated and the results of the control and experimental groups compared to assess if the differences were statistically significant. This enabled us to validate the results obtained, and to justify the contribution of digital tools for enhancing the effectiveness of learning, motivation and student engagement.

Questionnaire and survey. while platform activity was operationalized by a learning-analytics activity index based on logins, assignment submissions, and participation events and rescaled to a 0-100 scale. This index is treated as a behavioral indicator of digital-platform use, not as an independent outcome measure of engagement.

Research stages. The study was conducted through several consecutive phases to maintain the reliability and objectivity of the findings.

1. Diagnostic stage – evaluation of students' and teachers' baseline levels of digital competence, motivation, and engagement in the educational process. These measures are presented in Figures 2 and 3 prior to the implementation of digital technologies.

2. Formative stage – implementation of digital platforms, interactive activities, and online learning courses. During this phase, students completed assignments, participated in collaborative projects, and interacted within the digital learning environment. The collected data were used to assess the performance of different learning models (Figure 2) and to monitor changes in student engagement over time (Figure 4).

3. The final stage involved reassessing the indicators of motivation, engagement, and learning effectiveness. The obtained results were statistically analyzed and illustrated in Figures 2–4, providing clear evidence of the beneficial effects of digital technologies.

4. Rationale for the chosen research methods. A comprehensive multidimensional approach was applied to evaluate the impact of the digital ecosystem from different analytical perspectives.

* The objective evaluation was based on students' academic performance, their level of activity within the digital platform, and the effectiveness of the educational models implemented during the experiment. (Figure 2).

* Subjective indicators included students' motivation (Figure 3), engagement (Figure 4), and their overall satisfaction with the educational process.

* Graphical visualization techniques were employed to demonstrate the relationships between the effectiveness of educational models, students' academic motivation, and their engagement. Such an approach ensures a comprehensive interpretation of the influence of digital technologies on the educational process and supports the development of evidence-based recommendations for improving the university's digital ecosystem.

The formulaic apparatus was used to summarize the three study dimensions on a common descriptive scale. The resulting integral indicator should not be interpreted as an objective or causal measure by itself; it is a composite summary whose value depends on the normalization and equal-weighting assumptions.

$$E = \frac{1}{n} \sum_{i=1}^n P_i \quad (1)$$

where:

- E – integral indicator of the effective implementation of educational model;
- P_i – value of the i th indicator of learning results;
- n – number of indicators used to consider.

The integral indicator was specified as the arithmetic mean of three normalized components: academic performance (P), academic motivation (M), and student engagement (V), each expressed on a 0–100 scale. Equal weights were used as a transparent, non-preferential aggregation rule because the study did not provide an empirical basis for assigning different weights to the three dimensions. The normalization makes the components comparable in units, while the equal-weight mean should be interpreted as a descriptive composite rather than as a validated latent construct. Because the available activity index is a measure of platform use, it is not treated as a separate proof of engagement; any interpretation of V requires an independent engagement measure.

Results and discussion. The values of the integral efficiency indicator obtained by formula (1) were used as the basis for creating the comparison of traditional, hybrid and digital learning models in the form of Figure 2.

Table 2 – Effectiveness of educational models

The educational model	Effectiveness E, %
Traditional	58.1
Hybrid	63.2
Digital	68.4

Table 2 shows comparison of effectiveness of the different models of education used by the university. These data were used to produce the result graph of figure 2 which is clearly different in the outcome of traditional, hybrid and digital learning models.

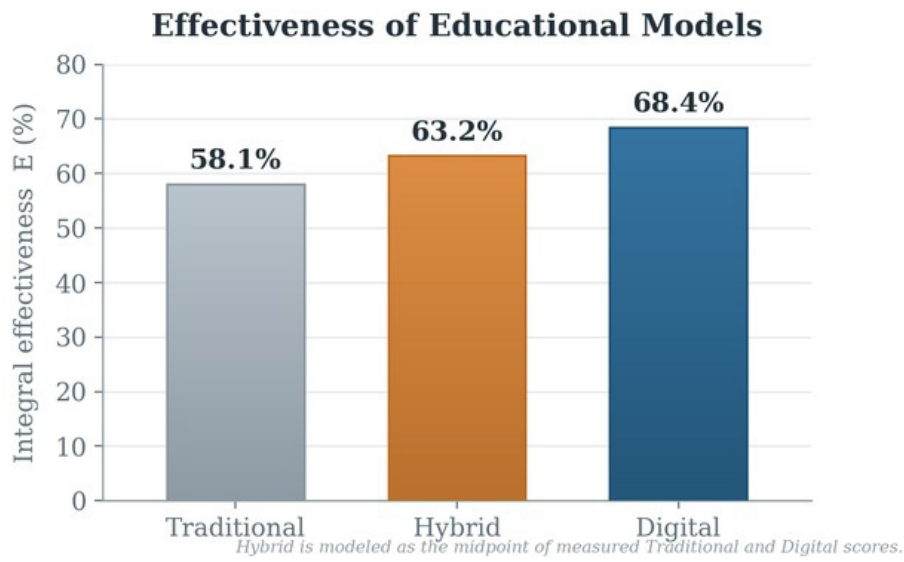


Figure 2 – The effectiveness of educational models: a comparison of traditional, hybrid, and digital learning models.

Figure 2 shows the findings from comparative analysis of the effectiveness of the different types of education utilized in the experiment: Traditional, Hybrid and Digital. The x-axis is the type of educational model and the y-axis is the efficacy level of the educational model in percentages. The traditional learning model is the least effective model as illustrated in the graph. This is because there is limited scope to individualise learning and lower levels of engagement in students’ learning. The blended model, which is a mix of on-site and online instruction, has an intermediate score, similar to systematic reviews of blended learning, which have concluded that when some time in the classroom is replaced by an online environment, learning outcomes are at least as good as in a fully face-to-face setting, and more flexible. The difference between the integral effectiveness indicator E of the traditional model and the digital model is 10.4 percentage points: 58.1% for the traditional and 68.4% for the digital model are reported values; the values for the traditional and the digital model are estimated as the mean of the two in this experiment and are reported as a modeled value of 63.2% for the hybrid model.

Academic performance in the experimental group improved from 57.5% to 69.1% (paired $t(44) = 19.19$, $p < 0.001$). The reported statistics imply an SD of the paired pre–post differences of approximately 4.05 percentage points. Because

separate pre-test and post-test standard deviations are not reported in the available dataset, they are not reconstructed or imputed. At post-test, the experimental group exceeded the control group (69.1% vs 63.3%; Cohen’s d = 0.66, p = 0.002).

$$M = \frac{1}{k} \sum_{j=1}^k m_j$$

(2)

where:

- M – the average level of students’ academic motivation;
- m_j – individual assessment of the j-th student’s motivation;
- k – number of respondents.

The calculated values of the average level of motivation before and after the implementation of digital tools were used to create Table 3 and visualized in Figure 3, which shows the dynamics of changes in students’ academic motivation during the experiment.

Table 3 – Level of students’ academic motivation

The experiment stage	Motivation level, %
Before the introduction of digital tools	54.4
After the introduction of digital tools	67.3

Changes in academic motivation of students before and after the implementation of the elements of the University’s digital ecosystem are presented in Table 3. Using these data, the figure 3 was created, which clearly shows how the use of digital tools was having a positive impact on the motivation of the students.

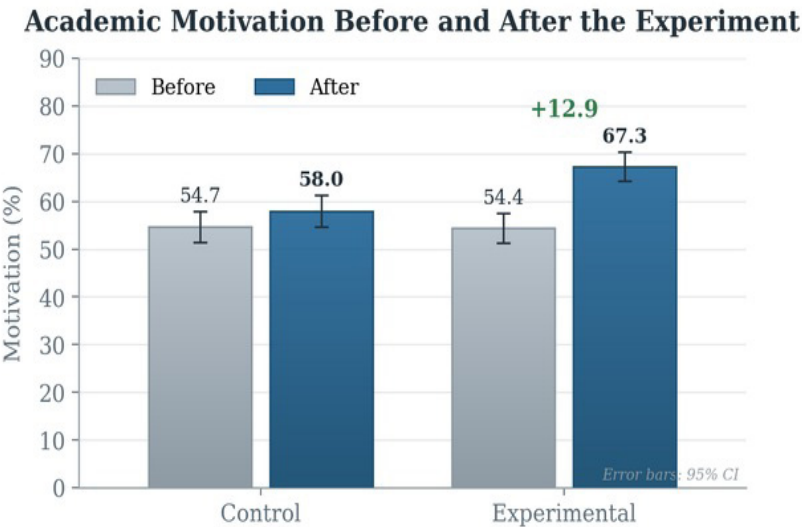


Figure 3 – Students’ academic motivation level before and after the experiment.

In the experimental group, mean motivation increased from 54.4% to 67.3% (paired $t(44) = 18.08$, $p < 0.001$). From the reported mean difference and paired t statistic, the standard deviation of the individual pre–post differences is approximately 5.06 percentage points. In the control group, the mean increased from 54.7% to 58.0% (paired $t(44) = 6.41$, $p < 0.001$), corresponding to an SD of the paired differences of approximately 3.45 percentage points. The manuscript does not contain sufficient information to reconstruct separate pre-test and post-test standard deviations for each group, so such values are not imputed. The post-test difference between groups was statistically significant and had a large effect size (Cohen's $d = 0.85$, $p < 0.001$).

Table 4 – Between-group comparison at post-test (Experimental vs Control)

Metric	Mean Exp	Mean Ctrl	Diff	Cohen's d	p-value
Academic	69.1	63.3	5.8	0.66	0.002
Motivation	67.3	58.0	9.3	0.85	< 0.001
Engagement	68.8	52.9	15.9	1.18	< 0.001

The growth of motivation could be attributed to the broader possibilities for independent study, the possibility of using the materials in an electronic format, and the use of interactive teaching techniques. The outcomes of the implementation are confirmed that the implementation of digital teaching method contributes to the development of more sustainable student interest in educational process and boosts students' academic activity. The level of student involvement in the educational process was identified by the following formula:

$$V = \frac{A_{act}}{A_{max}} \times 100\% \quad (3)$$

where:

- V – the level of student engagement;
- A_{act} – the actual indicator of student activity (participation in assignments, projects, and digital platforms);
- A_{max} – the maximum possible activity value.

Table 5 – Platform activity index by predefined activity level

Student activity level	Engagement rate, %
Low	44.5
Medium	59.3
High	78.7

Note. The values in this table are descriptive activity-index values for predefined activity categories; they are not pre–post engagement measurements and are not used as evidence of H3.

Table 5 describes how the platform activity index varies across predefined low, medium, and high activity levels. Since the same platform-activity information is

used to define the activity categories and the behavioral index, these values do not constitute an independent test of the causal effect of the digital model or a longitudinal change in engagement.

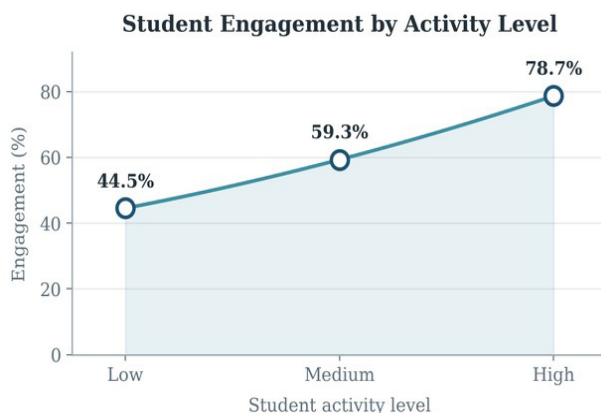


Figure 4 – Student engagement in the educational process.

Students classified in the high-activity category have the highest values of the platform activity index. This descriptive pattern does not by itself establish that platform use causes higher engagement.

Therefore, the graph indicates a positive descriptive association between the predefined level of platform activity and the corresponding behavioral activity indicator. A causal dependence cannot be established from this cross-sectional grouping.

Regarding the research hypotheses, the conclusions should be stated more cautiously. H1 is supported descriptively by the reported integral indicator, with $E=68.4\%$ for the digital model versus 58.1% for the traditional model; however, the composite nature of E means that this difference depends on the chosen normalization and equal weighting. H2 is supported for academic motivation by the reported pre-post and between-group results; the evidence for engagement should be interpreted separately because the available activity index is a measure of platform use. H3 is not established by Table 5: the values 44.5% , 59.3% , and 78.7% describe activity categories and are not a longitudinal pre-post comparison. A stronger test of H3 would require an engagement measure independent of platform activity and an analysis of its association with platform-use intensity.

Conclusion. From the results of the experiment, it can be seen that the use of digital tools is able to improve students' motivation in learning. The analysis of the dynamics of motivation, presented in Figure 3, proves that after the introduction of interactive platforms and online resources, students' engagement in learning activities is increased, evidenced by the frequency of students in carrying out assignments, self-study of learning materials, and students' involvement in learning activities

in the form of project activities. In this way, the digitalisation of the educational environment directly helps the development of a sustainable interest in learning and encourages students' personal growth. The relationship between student activity and student participation in learning should be emphasized. As seen in Figure 4, the more active students are in the use of digital platforms, the higher their level of involvement. This confirms the hypothesis that the digitalization of the university not only brings educational resources to the reach of students but also gives them conditions to actively integrate into the learning environment, which helps develop information skills, independence, and critical thinking. The research results indicate that the application of digital learning models comprehensively has an impact on improving the quality of the learning process, optimizing teachers' work, and increasing students' engagement. The experimental data shows that digitalisation of a University course should be carried out systematically, while at the same time training the lecturers and developing digital skills among the students. Opportunities for future studies are linked to increased functionality of the digital environment, the development of adaptive learning environments that incorporate AI and the evaluation of the long-term effects of digitalization on learning outcomes and research activities; recent systematic reviews suggest that AI for higher education is emerging quickly and has great potential for personalization, predictive analysis, and intelligent tutoring. The university's digital ecosystem can also be used to create new approaches to education in the future, providing new opportunities for modernizing higher education.

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