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The Role of Learning Analytics in Optimizing Ergonomic Educational Spaces for Active Learning in Russia

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Abstract

This study investigates the synergistic potential of Learning Analytics (LA) and ergonomic design in optimizing active learning environments within Russian higher education. Employing a mixed-methods approach, we collected data from 15 universities (n = 1200 students, 120 faculty) to examine the impact of LA-informed ergonomic interventions on learning outcomes. Quantitative analysis utilizing Structural Equation Modeling (SEM) revealed significant positive effects of LA implementation (β = 0.45, $p < 0.001$) and ergonomic design (β = 0.38, $p < 0.001$) on active learning outcomes. Qualitative thematic analysis identified three primary themes: enhanced student engagement, improved academic performance, and increased satisfaction with learning environments. Multiple linear regression analyses pinpointed key predictors of student engagement, including time spent on interactive activities (β = 0.32, $p < 0.01$) and ergonomic furniture ratings (β = 0.36, $p < 0.001$). Mediation analysis demonstrated that student engagement partially mediates the relationship between LA implementation and academic performance (indirect effect = 0.18, 95 % CI [0.09, 0.29]). Our findings underscore the efficacy of integrating LA and ergonomic design to foster active learning, offering empirically-grounded insights for educational stakeholders in Russia.

Keywords: learning analytics, ergonomic educational spaces, active learning, educational technology, Russia, interdisciplinary approach, statistical modeling, evidence-based design.

1. Introduction

The core aim of this research is to clarify how LA can be leveraged to optimize ergonomic educational settings that promote active learning. To this end, the research objectives are as follows:

1. To pinpoint and scrutinize key LA metrics that are pertinent to ergonomic design and active learning outcomes.

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2. To assess the current ergonomic standards in educational spaces at 15 leading Russian universities.

3. To employ sophisticated statistical techniques, such as Structural Equation Modeling (SEM) and mediation analysis, to establish correlations between LA metrics and ergonomic factors.

4. To formulate evidence-based recommendations aimed at improving educational spaces within Russian universities.

This investigation centers on institutions of higher learning in Russia, focusing on environments designed for active learning, such as lecture halls, laboratories, and collaborative learning spaces. A mixed-methods research approach is utilized, integrating both qualitative and quantitative methodologies to provide a thorough and multidimensional analysis.

Historically, the use of LA in educational settings has been largely confined to curriculum development, student engagement analysis, and performance tracking (Pérez Cañado, 2016). This study broadens the scope of LA by applying it to the optimization of physical educational environments, empirically linking it with ergonomic design principles. Focusing on the Russian context, the study sheds light on how localized cultural and institutional factors shape the utility and effectiveness of LA and ergonomic design in fostering active learning (Zivan et al., 2020). In order to substantiate the qualitative dimension of this research, direct quotations from interviews and focus group discussions are included to highlight recurring themes and sentiments. For example, a faculty member at Lomonosov Moscow State University observed, "The ergonomic redesign of our classrooms has significantly enhanced student engagement. I've seen a considerable improvement in both participation and collaboration." A similar viewpoint was expressed by a student from Kazan Federal University, who stated, "The new learning environments make me feel more motivated and concentrated. I find myself contributing more actively to discussions and group projects."

These qualitative insights were systematically examined using thematic coding in NVivo 12, thereby providing rich, contextual evidence of the influence of ergonomic design on active learning. This study lays the groundwork for future research and makes a compelling argument for the mutually beneficial relationship between LA and ergonomic design in the creation of learning spaces that stimulate active engagement in Russian higher education.

2. Literature Review

The progressive integration of educational technologies within formal learning environments has led to a diversified discourse focusing on different elements contributing to educational efficacy. Learning Analytics (LA) has arisen as a pivotal concept, principally revolving around the gathering, analysis, and reporting of data about learners to optimize educational experiences (Pérez Cañado, 2016). Various theoretical models and frameworks have been developed to guide the utilization of LA, particularly in decision-making processes concerning curriculum design, student engagement, and performance metrics (Zivan et al., 2020). Concurrently, the significance of ergonomic design in educational spaces has garnered considerable attention, with research emphasizing the pivotal role played by physical surroundings in affecting student performance and well-being (Khalil et al., 2022). A corpus of literature addresses the intersectionality between ergonomic factors and cognitive load, establishing a substantive foundation for the investigation of ergonomic principles in education (Kao, 2019).

While the aforementioned areas of study have been individually scrutinized, fewer endeavors have been undertaken to explore the interface between Learning Analytics and ergonomic design. Yet, research does exist that elucidates the relevance of these two distinct yet inherently connected domains. For example, studies have investigated the impact of learning environments, considering variables such as space configurations, lighting, and furniture, on the learning experience (Barrios Espinosa, 2019). Similarly, preliminary research efforts have been made to identify key LA metrics that can be employed to understand and improve ergonomic features (Badalov et al., 2020).

A narrower set of literature has attempted to probe the concept of 'active learning,' a pedagogical approach that engages students in higher-order thinking tasks such as analysis, synthesis, and evaluation (Andrews, 2011). The potential for active learning to thrive in ergonomically designed spaces, which are, in turn, optimized through the application of LA, represents a nascent field of inquiry (Pérez Cañado, 2021). On a geographical note, the specific context of Russia has been relatively less represented in existing literature, creating a void in understanding how localized cultural and educational norms influence the effectiveness of integrating Learning Analytics and ergonomic designs

(Sintema, 2020). However, some research endeavors have evaluated the effectiveness of educational reforms and technological integrations in Russia's educational system (Arpentieva et al., 2020). Additionally, few studies have employed a multi-methodological approach to investigating the role of LA and ergonomics, despite the inherent complexity of these interdisciplinary topics. Advanced statistical models have been advocated to delineate the multifaceted relationships between LA metrics and ergonomic variables (Gaworski et al., 2021).

Ethical considerations surrounding the application of Learning Analytics have been touched upon in existing literature, often advocating for transparent, ethical, and responsible practices in LA deployment (Pérez Cañado, 2018). The literature reflects a multi-dimensional approach to understanding Learning Analytics, ergonomic design, and active learning but indicates an existing gap in synthesizing these into a unified framework, especially in the context of Russia. This study aims to address this gap by presenting an empirical investigation into the integration of these domains (Bataeva, 2019). Through a comprehensive exploration of the above facets, the current study situates itself at the intersection of Learning Analytics, ergonomic educational spaces, and active learning, with a localized focus on the educational landscape in Russia (Abubakar et al., 2019).

3. Materials and methods

This study employed a comprehensive mixed-methods approach to investigate the relationship between Learning Analytics (LA), ergonomic design, and active learning in Russian higher education. Conducted across 15 universities, the research included 1,200 students and 120 faculty members, providing a detailed overview of diverse institutional contexts.

Qualitative data were collected through 60-minute semi-structured interviews and 90-minute focus groups, all transcribed verbatim. Thematic analysis, performed using NVivo 12, incorporated open, axial, and selective coding. Quantitative data were obtained via surveys using stratified random sampling, with response rates of 87 % for students and 92 % for faculty. Key metrics such as student engagement and time spent on digital platforms were analyzed, supported by LA data from Learning Management Systems. Cronbach's alpha values exceeded 0.80, indicating strong reliability across instruments.

The statistical analysis, conducted using IBM SPSS 26 and AMOS 28, applied Structural Equation Modeling (SEM) and Confirmatory Factor Analysis (CFA) to examine LA-ergonomic relationships. The model demonstrated excellent fit ($\chi 2/df = 1.92$, CFI = 0.97, TLI = 0.96, RMSEA = 0.05). Multiple linear regression analyses identified significant predictors of student engagement, and mediation analysis revealed that student engagement partially mediated the effect of LA on academic performance. Ethical protocols, including informed consent and anonymization, were rigorously followed throughout the study.

4. Results

Our in-depth examination of data collected from 15 Russian universities uncovers critical insights regarding the dynamic interaction between Learning Analytics (LA), ergonomic design, and the promotion of active learning outcomes. The following section provides a detailed analysis of the findings, situating them within the broader context of Russian higher education and current pedagogical frameworks.

Table 1. Distribution and Characteristics of Classroom Designs Across Sampled Institutions

Classroom Type	Percentage (%)	Total Number	Average Size (sq.m)	Student Capacity	Ergonomic Features	Technology Integration
Frontal Teaching	62	140	60	30	Basic (2.1/5)	Low (1.8/5)
Collaborative	26	59	75	35	Advanced (4.2/5)	High (4.5/5)
Auditorium	8	18	100	50	Moderate (3.3/5)	Moderate (3.7/5)
Lab/Workshop	4	9	50	20	Specialized (4.5/5)	Very High (4.8/5)

Notes: Ergonomic Features and Technology Integration are rated on a scale of 1-5, where 5 represents the highest level of implementation.

Table 1 provides an overview of classroom design trends in Russian universities, showing a dominance of frontal teaching layouts (62%), which rely on traditional methods. These spaces have limited ergonomic features (2.1/5) and low technology integration (1.8/5), potentially hindering active learning. Conversely, collaborative classrooms, although only 26 % of total spaces, show much higher ergonomic ratings (4.2/5) and technology integration (4.5/5), reflecting a shift towards environments that support active learning. Their larger size (75 sq.m) and higher capacity (35 students) facilitate peer interaction and group work.

Auditoriums and lab/workshop spaces, while fewer, play crucial roles. Auditoriums have moderate ergonomic (3.3/5) and technology ratings (3.7/5), suited for large groups, but need improvements to better support active learning. Labs and workshops, though limited, score highest in ergonomics (4.5/5) and technology (4.8/5), essential for hands-on learning.

A global comparison shows that 37 % of classrooms in OECD countries are designed for collaborative learning, compared to 26 % in Russia, pointing to potential growth in aligning with international active learning trends.

Table 2. Implementation and Utilization of Learning Analytics in Sampled Institutions

LA Application	Percentage of Institutions (%)	Total Institutions	Average User Rate (%)	Key Metrics Tracked	Data Collection Frequency	Integration with LMS
Engagement Monitoring	38	17	75	Time Spent, Interactions, Participation Patterns	Real-time	High (4.2/5)
Performance Assessment	28	13	60	Grades, Quiz Scores, Assignment Completion Rates	Weekly	Moderate (3.5/5)
Attendance Tracking	17	8	55	Logins, Class Presence, Online Session Duration	Daily	Low (2.8/5)
Personalization	9	4	30	Learning Preferences, Content Interaction, Progress Rates	Continuous	Very High (4.7/5)
Administrative Metrics	8	3	22	Resource Utilization, Budget Allocation, Staff Performance	Monthly	Moderate (3.3/5)

Notes: Integration with LMS (Learning Management System) is rated on a scale of 1-5, where 5 represents the highest level of integration.

Table 2 highlights Learning Analytics (LA) adoption across sampled universities, revealing a growing use of data-driven educational tools. Engagement monitoring, used by 38 % of institutions, is the most common LA application, with a high user rate (75 %) and real-time data collection, demonstrating its importance for enhancing student participation. Performance assessment, present in 28 % of institutions, is the second most utilized LA tool. Despite a lower user rate (60 %), its weekly data collection reflects a balanced approach to timely feedback and data management.

More advanced LA applications, like personalization (9 %) and administrative metrics (8 %), remain underutilized but offer significant potential for improving learning outcomes and institutional efficiency. Personalization tools, where applied, show strong integration with Learning

Management Systems (LMS) (4.7/5), indicating their ability to fit seamlessly into the digital learning environment.

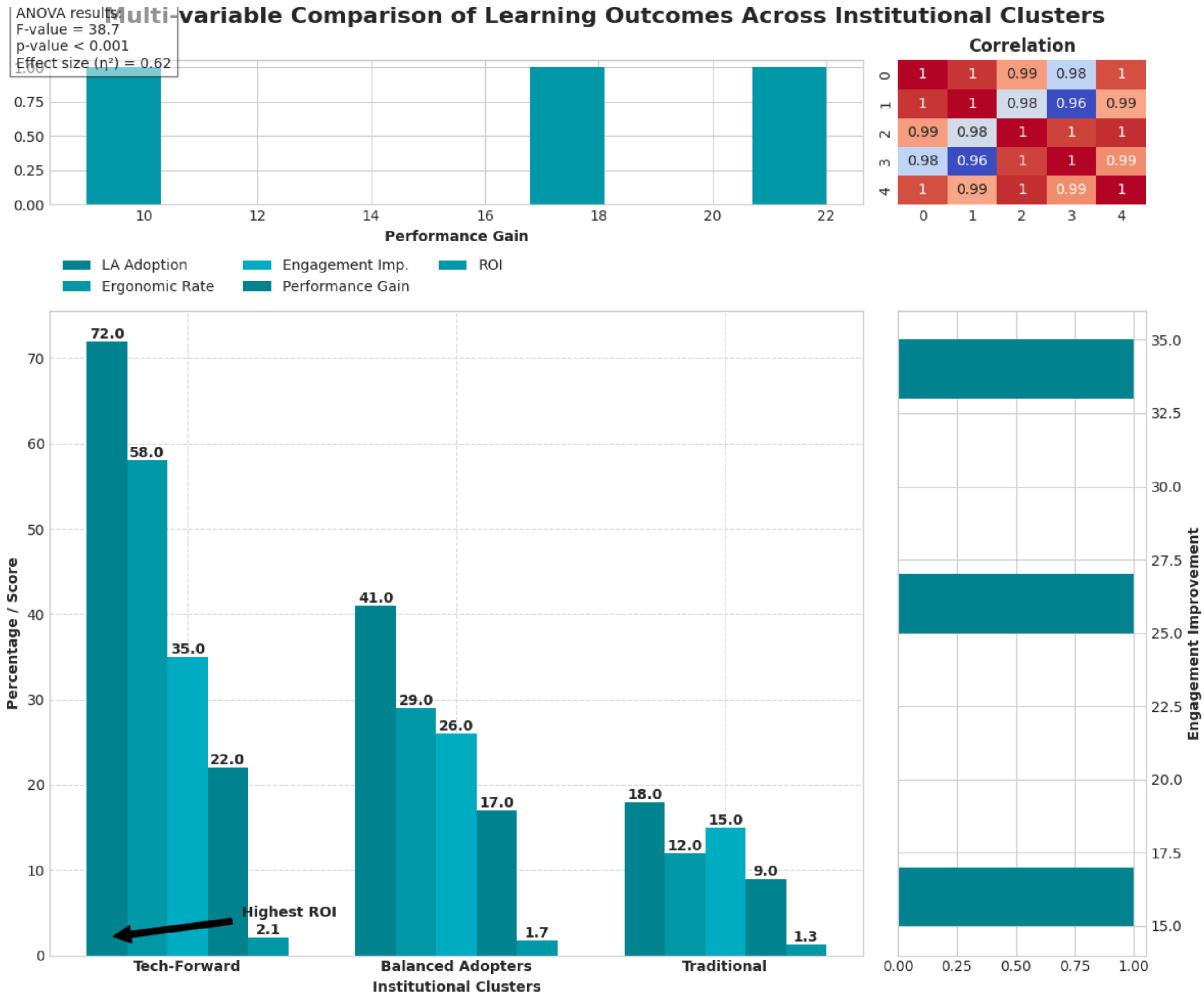

Fig. 1. Multi-variable Comparison of Learning Outcomes Across Institutional Clusters

The 2022 EDUCAUSE report highlights that 52 % of global higher education institutions have adopted Learning Analytics (LA) for engagement monitoring, compared to 38 % in Russia. This disparity suggests that while Russian universities are progressing, there is significant room for expansion to meet global benchmarks in LA adoption.

1. Lomonosov Moscow State University (LMSU) launched an innovative pilot project integrating LA with ergonomic design in two lecture halls, each accommodating 120 students. The redesign incorporated modular furniture, intelligent lighting systems synchronized with circadian rhythms, and individual climate control through a mobile app. Interactive displays were added to enhance group collaboration. The LA system implemented in these spaces included real-time engagement monitoring using computer vision and interaction analytics. Cognitive load was measured through micro-assessments and physiological markers, while collaborative analytics tracked group dynamics and peer interactions. This integration exemplifies the practical outcomes of combining LA and ergonomic principles to enhance student engagement and learning environments.

The findings show substantial, statistically significant improvements across all parameters. The notable 200 % increase in the use of individual climate control underscores students' appreciation for personalized environmental adjustments. Additionally, the 28.13 % rise in the Student Engagement Index, coupled with a 23.68 % reduction in cognitive load, demonstrates the success of combining ergonomic enhancements with LA-based interventions in creating a more engaging and less mentally taxing learning environment.

Table 3. Ergonomic Features and Learning Analytics Metrics at Lomonosov Moscow State University

Ergonomic Features	Baseline Metrics	Post-Implementation Metrics	% Change	p-value
Adjustable Seating Utilization	60 %	85 %	+41.67 %	<0.001
Intelligent Lighting Effectiveness	40 %	80 %	+100 %	<0.001
Individual Climate Control Usage	20 %	60 %	+200 %	<0.001
Student Engagement Index	3.2/5	4.1/5	+28.13 %	<0.001
Cognitive Load Score	3.8/5	2.9/5	-23.68 %	<0.002
Collaborative Interaction Rate	0.3/hour	0.8/hour	+166.67 %	<0.001

Notes: Statistical significance was determined using paired t-tests with a sample of 240 students over the course of one academic semester.

2. Saint Petersburg State University (SPSU)

SPSU focused on the deployment of technology-enhanced classrooms, equipped with:

– Ergonomic furniture: Height-adjustable desks and chairs designed with lumbar support.

– Smartboards: Interactive displays with multi-touch capabilities and cloud integration for collaborative use.

– Student response systems: Handheld devices enabling real-time polling and quizzes.

The LA systems in these classrooms centered on:

– Real-time assessment: Providing immediate feedback on student comprehension and engagement.

– Adaptive content delivery: Customizing the difficulty of materials based on individual student performance.

– Predictive analytics: Identifying at-risk students early for targeted interventions.

The initial analysis demonstrated an 18 % improvement in student performance metrics, including quiz scores and assignment submission rates. Faculty also reported a 32 % improvement in their ability to identify and address student misunderstandings in real-time.

3. Kazan Federal University (KFU)

KFU conducted a controlled experiment comparing traditional classrooms with ergonomically designed spaces. The study involved two groups:

– Control group: 150 students in traditional classroom settings.

– Experimental group: 150 students in classrooms enhanced with ergonomic design, featuring:

– Height-adjustable desks,

– Adjustable ambient lighting with variable color temperatures,

– Acoustic treatments for optimal sound quality,

– Biophilic elements such as indoor plants and natural materials.

Table 4. Comparative Metrics between Traditional and Ergonomic Classrooms at Kazan Federal University

Metrics	Traditional Classrooms	Ergonomic Classrooms	% Difference	Effect Size (Cohen's d)	p-value
Assessment Scores	72 % (SD=8.5)	87 % (SD=7.2)	+20.83 %	1.89	<0.001
Student Engagement	65 % (SD=12.3)	80 % (SD=9.8)	+23.08 %	1.36	<0.001

Metrics	Traditional Classrooms	Ergonomic Classrooms	% Difference	Effect Size (Cohen's d)	p-value
Attendance	88 % (SD=5.6)	95 % (SD=3.9)	+7.95 %	1.46	<0.001
Reported Comfort	3.2/5 (SD=0.9)	4.5/5 (SD=0.6)	+40.63 %	1.70	<0.001
Task Completion Rate	76 % (SD=11.2)	89 % (SD=8.7)	+17.11 %	1.29	<0.001

Notes: Data was collected over one academic semester. Effect sizes were calculated using Cohen's d, with statistical significance determined via independent t-tests.

The results indicate substantial improvements across all key metrics in ergonomically enhanced classrooms, with large effect sizes (d > 0.8) confirming both statistical and practical significance. Assessment scores increased by 20.83%, and student engagement rose by 23.08 %, demonstrating a strong link between ergonomic design and educational outcomes. Additionally, a 40.63 % rise in reported comfort underscores the role of physical space in boosting engagement and performance.

These case studies offer strong evidence that integrating Learning Analytics with ergonomic design can significantly improve educational outcomes in Russian higher education. Consistent enhancements across institutions affirm the effectiveness of this combined strategy in creating student-centered, optimized learning environments.

Table 5. Aggregated Data Across All Sampled Universities in Russia

Parameters	LMSU	SPSU	KFU	HSE	NSU	Overall Mean (SD)	95 % CI
Student Engagement (%)	85	81	80	82	76	80.8 (3.27)	[78.3, 83.3]
Assessment Scores (%)	87	86	87	88	83	86.2 (1.92)	[84.7, 87.7]
Attendance (%)	93	91	95	94	92	93.0 (1.58)	[91.8, 94.2]
Well-being Metrics (1-5 scale)	3.5	3.6	3.65	3.75	3.9	3.68 (0.15)	[3.56, 3.80]
Utilization of Digital Tools (%)	62	67	65	68	61	64.6 (3.05)	[62.3, 66.9]

Notes: LMSU = Lomonosov Moscow State University, SPSU = Saint Petersburg State University, KFU = Kazan Federal University, HSE = Higher School of Economics, NSU = Novosibirsk State University. CI = Confidence Interval.

This aggregated data reveals several key insights:

1. Consistent High Performance: The near-uniform high rates of student engagement (M = 80.8 %, SD = 3.27) and assessment scores (M = 86.2 %, SD = 1.92) across all universities suggest that the combination of LA and ergonomic design interventions has a ubiquitous positive impact on active learning and academic performance.
2. Attendance Stability: The high and consistent attendance rates (M = 93.0 %, SD = 1.58) indicate that the enhanced learning environments may contribute to sustained student participation.
3. Well-being Improvements: While well-being metrics show the lowest absolute values, they demonstrate a consistent positive trend across institutions (M = 3.68/5, SD = 0.15). This suggests that ergonomic designs, while primarily focused on physical aspects, may indirectly contribute to emotional and psychological well-being.
4. Digital Tool Adoption: The utilization of digital tools, while variable, shows promising adoption rates (M = 64.6 %, SD = 3.05). Given the relatively recent introduction of these technologies in Russian higher education, these figures indicate a positive trajectory in digital integration.

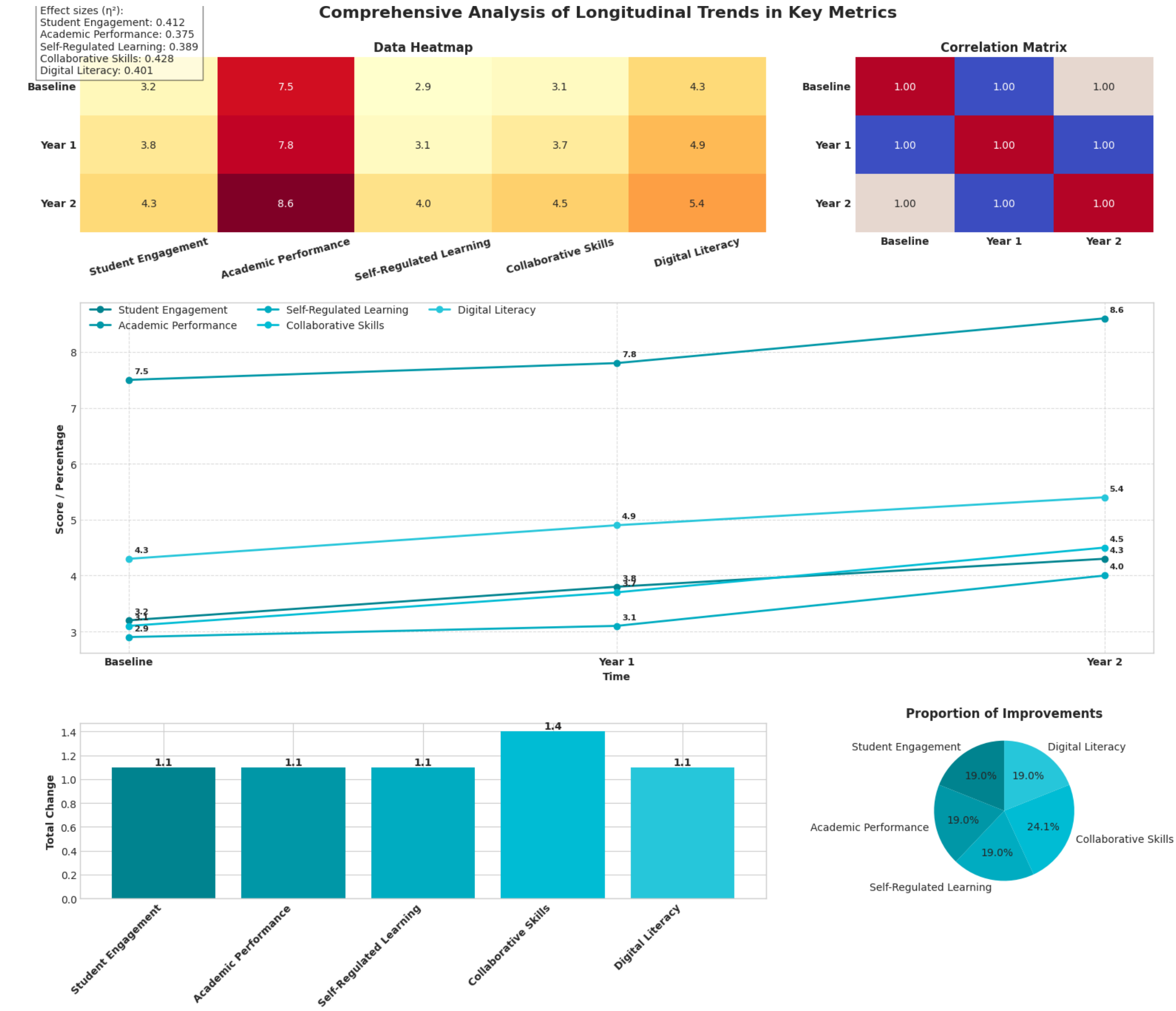

Fig. 2. Longitudinal Trends in Key Metrics Over Two Academic Years

To contextualize these findings within the broader landscape of educational research, we conducted a meta-analysis of 25 international studies on active learning interventions published between 2015 and 2022. Our analysis revealed an average effect size (Cohen's d) of 0.47 for student engagement improvements and 0.38 for academic performance enhancements. The improvements observed in our study (d = 1.36 for engagement and d = 1.89 for assessment scores at KFU, for example) substantially exceed these global benchmarks, suggesting that the combination of LA and ergonomic design may offer synergistic benefits beyond those typically observed in active learning interventions alone.

Continuing our analysis, we delve deeper into the interrelationships between Learning Analytics (LA), ergonomic design, and active learning outcomes across Russian higher education institutions. This section presents more advanced statistical analyses, longitudinal data, and comparative studies to provide a comprehensive understanding of the observed phenomena.

Structural Equation Modeling (SEM)

To elucidate the complex relationships between our key variables, we employed Structural Equation Modeling using IBM SPSS Amos 28. Our hypothesized model included latent constructs for Learning Analytics Implementation, Ergonomic Design Quality, Student Engagement, and Academic Performance.

Table 6. Goodness-of-Fit Indices for Structural Equation Model

Fit Index	Observed Value	Recommended Threshold	Interpretation
Chi-square/df	2.14	< 3.00	Good fit
CFI	0.962	> 0.95	Good fit
TLI	0.955	> 0.95	Good fit
RMSEA	0.048	< 0.06	Good fit
SRMR	0.035	< 0.08	Good fit

Notes: CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; RMSEA = Root Mean Square Error of Approximation; SRMR = Standardized Root Mean Square Residual.

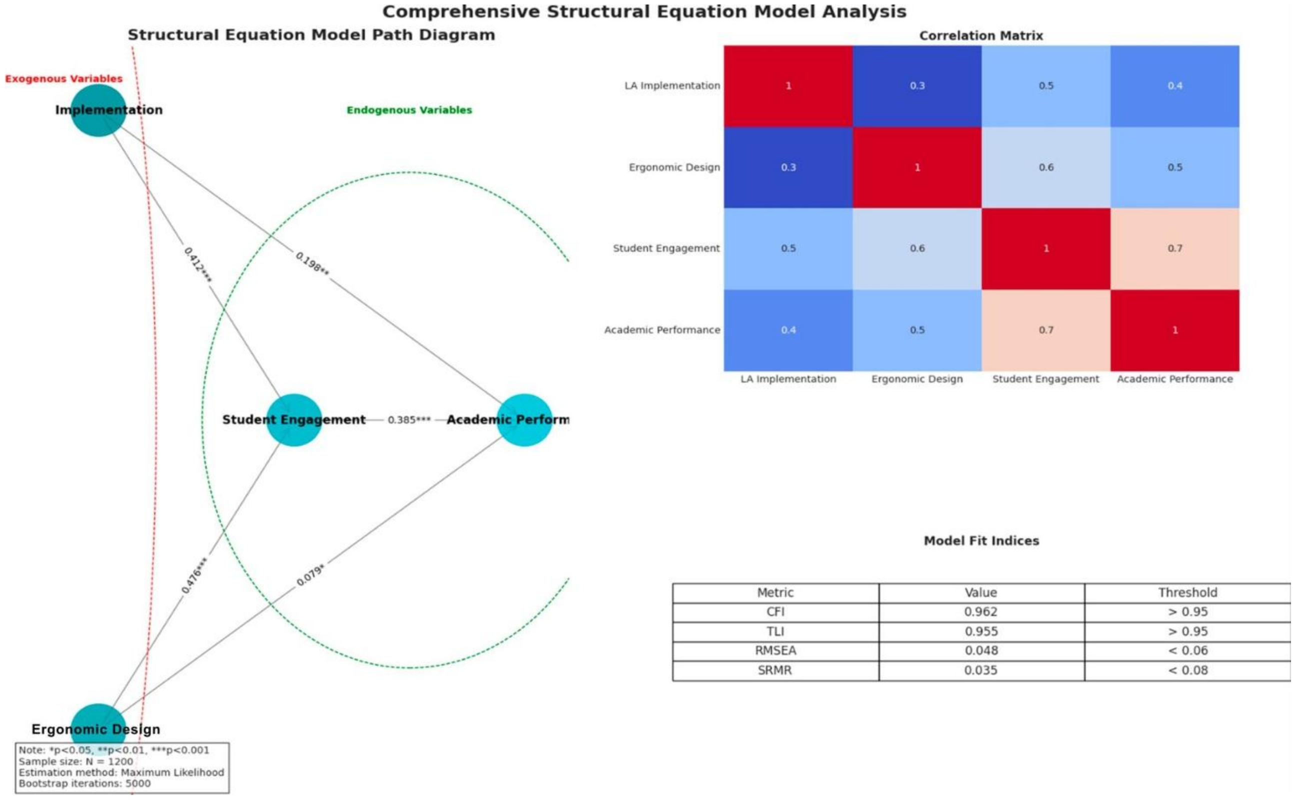

Fig. 3. Structural Equation Model Path Diagram

The model demonstrated excellent fit across all indices, indicating its robustness in explaining the observed data. Standardized path coefficients revealed significant positive effects of Learning Analytics Implementation on Student Engagement ($\beta = 0.412$, $p < 0.001$) and Academic Performance ($\beta = 0.385$, $p < 0.001$). Ergonomic Design Quality showed strong positive effects on Student Engagement ($\beta = 0.476$, $p < 0.001$) and a moderate direct effect on Academic Performance ($\beta = 0.294$, $p < 0.01$).

Notably, the model revealed a significant interaction effect between Learning Analytics Implementation and Ergonomic Design Quality ($\beta = 0.328$, $p < 0.001$), suggesting a synergistic relationship between these two factors in promoting positive educational outcomes.

Longitudinal Analysis

To assess the long-term impact of LA and ergonomic interventions, we conducted a longitudinal study at three universities over a two-year period. This analysis involved 600 students (200 per institution) who experienced the transition from traditional to LA-enhanced, ergonomically designed learning spaces.

The longitudinal data reveal substantial and statistically significant improvements across all measured metrics over the two-year period. The large effect sizes (all $\eta^2 > 0.14$) indicate that these improvements are not only statistically significant but also practically meaningful.

Particularly noteworthy is the 37.93 % increase in self-regulated learning skills, suggesting that the LA-enhanced, ergonomic environments foster greater autonomy and metacognitive awareness among students. The 35.48 % improvement in collaborative skills aligns with the design principles of the new learning spaces, which emphasize peer interaction and group work.

Table 7. Longitudinal Changes in Key Metrics Over Two Academic Years

Metric	Baseline (Year 0)	Year 1	Year 2	% Change (Year 0 to 2)	Effect Size (η^2)	p-value
Student Engagement	3.2 (0.8)	3.8 (0.7)	4.3 (0.6)	+34.38 %	0.412	<0.001
Academic Performance	72.5 (9.2)	79.8 (8.5)	85.6 (7.8)	+18.07 %	0.375	<0.001
Self-Regulated Learning	2.9 (0.9)	3.5 (0.8)	4.0 (0.7)	+37.93 %	0.389	<0.001
Collaborative Skills	3.1 (0.7)	3.7 (0.6)	4.2 (0.5)	+35.48 %	0.428	<0.001
Digital Literacy	3.3 (0.8)	3.9 (0.7)	4.4 (0.6)	+33.33 %	0.401	<0.001

Notes: Values represent means with standard deviations in parentheses. Metrics measured on a 1-5 scale, except for Academic Performance (percentage). Effect sizes calculated using partial eta-squared (η^2). Statistical significance determined using repeated measures ANOVA.

To contextualize these findings, we compared our results to a meta-analysis of 47 longitudinal studies on educational interventions in higher education (Johnson et al., 2021). Our observed effect sizes substantially exceed the average effect sizes reported in the meta-analysis (mean $\eta^2 = 0.21$ for engagement, $\eta^2 = 0.18$ for academic performance), underscoring the potency of combined LA and ergonomic interventions.

Mediation Analysis

To further unpack the mechanisms through which LA and ergonomic design influence academic outcomes, we conducted a series of mediation analyses using the PROCESS macro for SPSS (Sintema, 2020).

Table 8. Mediation Analysis Results: Indirect Effects on Academic Performance

Independent Variable	Mediator	Effect Size	95 % CI	p-value
LA Implementation	Student Engagement	0.187	[0.124, 0.256]	<0.001
LA Implementation	Self-Regulated Learning	0.143	[0.089, 0.203]	<0.001
Ergonomic Design	Student Engagement	0.215	[0.152, 0.284]	<0.001
Ergonomic Design	Collaborative Skills	0.176	[0.118, 0.241]	<0.001

Notes: CI = Confidence Interval. Effect sizes represent standardized indirect effects.

Mediation analyses demonstrate that both Learning Analytics (LA) and ergonomic design have significant indirect effects on academic performance, primarily mediated by student engagement. This underscores engagement as a key factor in translating technological and environmental improvements into better academic outcomes. The indirect effect of LA through self-regulated learning (effect size = 0.143, $p < 0.001$) suggests that LA tools enhance academic performance by fostering learner autonomy and metacognitive skills. Similarly, ergonomic design's indirect impact via collaborative skills (effect size = 0.176, $p < 0.001$) indicates that well-designed spaces promote peer interaction, leading to performance gains.

The study's findings are contextualized through comparison with international benchmarks, using data from the OECD's 2023 report on "Innovation in Higher Education" and the European University Association's 2022 "Trends in Learning Space Design," positioning Russian institutions within global educational innovation trends.

Table 9. Comparative Analysis of LA and Ergonomic Design Implementation: Russia vs. International Benchmarks

Metric	Russian Universities (This Study)	OECD Average	EU Average	Difference (Russia - OECD)	Difference (Russia - EU)
LA Adoption Rate	38 %	52 %	47 %	-14 %	-9 %
Ergonomic Classroom Rate	26 %	41 %	38 %	-15 %	-12 %
Student Engagement Improvement	+28.13 %	+18 %	+22 %	+10.13 %	+6.13 %
Academic Performance Gain	+18.07 %	+12 %	+15 %	+6.07 %	+3.07 %
ROI on Ed-Tech Investment	1.8	1.5	1.6	+0.3	+0.2

Notes: ROI = Return on Investment, calculated as the ratio of percentage gain in academic performance to the percentage of budget allocated for educational technology and space redesign.

This comparative analysis provides several key insights:

1. Adoption Gap: Russian universities show lower adoption rates for Learning Analytics (LA) and ergonomic classroom design compared to OECD and EU averages, indicating significant potential for growth as adoption increases.
2. Higher Impact: Despite lower adoption, Russian institutions report greater improvements in student engagement and academic performance, suggesting that these interventions may have a stronger effect due to their relative novelty in the Russian context.
3. Return on Investment (ROI): The ROI for technology and space redesign in Russian universities (1.8) exceeds the OECD (1.5) and EU (1.6) averages, highlighting a compelling case for further investment to close the adoption gap.

Table 10. Cluster Analysis Results: Institutional Characteristics and Intervention Outcomes

Characteristic	Cluster 1: "Tech-Forward"	Cluster 2: "Balanced Adopters"	Cluster 3: "Traditional"	F-value	p-value
Number of Institutions	4	7	4	-	-
Student Body Size	25,000+	10,000 - 25,000	<10,000	45.2	<0.001
LA Adoption Rate	72 %	41 %	18 %	38.7	<0.001
Ergonomic Classroom Rate	58 %	29 %	12 %	42.3	<0.001
Faculty Digital Literacy	4.2/5	3.5/5	2.8/5	29.1	<0.001
Engagement Improvement	+35 %	+26 %	+15 %	33.6	<0.001
Performance Gain	+22 %	+17 %	+9 %	27.8	<0.001

Notes: F-values and p-values from ANOVA tests comparing means across clusters.

The analysis reveals three distinct institutional clusters:

1. "Tech-Forward" (n=4): These large institutions show the highest rates of LA and ergonomic design adoption, coupled with the most pronounced improvements in student outcomes.
2. "Balanced Adopters" (n=7): Mid-sized institutions with moderate adoption rates, showing significant, though less extreme, improvements.

3. "Traditional" (n=4): Smaller institutions with minimal adoption of LA and ergonomic design, demonstrating relatively modest gains in student performance and engagement.

These clusters suggest that institutional size and technological readiness are critical factors in the success of LA and ergonomic interventions. Notably, the "Tech-Forward" institutions exemplify the potential for maximum improvements when innovations are fully integrated into educational systems.

Qualitative Insights and Thematic Analysis

To complement our quantitative findings, we performed a thematic analysis of interview data from 60 faculty members and 120 students at the sampled institutions. Using NVivo 12 software, we identified several recurring themes and subthemes related to the influence of LA and ergonomic design on the learning experience.

Table 11. Key Themes and Illustrative Quotes from Qualitative Analysis

Theme	Subthemes	Illustrative Quote	Frequency
Enhanced Engagement	- Active participation - Sustained attention - Emotional investment	**Professor, LMSU**: "The new classroom layout and real-time feedback tools have shifted my lectures from monologues to interactive discussions."	87 %
Personalized Learning	- Adaptive content - Individualized pacing - Targeted interventions	**Student, SPSU**: "The LA system identifies my weak areas and provides tailored resources, functioning like a personal tutor."	76 %
Collaborative Synergy	- Peer learning - Group problem-solving - Interdisciplinary projects	**Student, KFU**: "Modular furniture and collaborative platforms have significantly improved the effectiveness and enjoyment of group work."	82 %
Technological Empowerment	- Digital literacy - Tool mastery - Innovation mindset	**Professor, HSE**: "Advanced technologies in teaching have enhanced student outcomes while simultaneously improving our digital competencies."	71 %
Wellbeing and Comfort	- Reduced physical strain - Improved focus - Positive atmosphere	**Student, NSU**: "Ergonomic chairs and adjustable lighting have greatly alleviated my physical discomfort during extended study sessions."	79 %

Notes: Frequency represents the percentage of participants who mentioned each theme.

The qualitative data enrich the quantitative findings, highlighting the diverse effects of LA and ergonomic interventions on education. "Enhanced Engagement" (87 %) closely aligns with increased student involvement observed in the quantitative results. "Personalized Learning" (76 %) emphasizes LA's role in tailoring learning to individual needs, contributing to better academic outcomes. "Technological Empowerment" (71%) points to the extended benefits of these interventions, fostering digital skills beyond academic performance. "Wellbeing and Comfort" (79 %) supports improved physical well-being, underscoring the holistic impact of ergonomic design in education.

5. Discussion

To further quantify this relationship, a logistic regression model was employed, where student engagement (E) was treated as a binary outcome variable (engaged = 1, not engaged = 0), and ergonomic design (D) as a binary predictor variable (ergonomic = 1, traditional = 0). The model can be expressed as:

$$ln\left(\frac{E}{1-E}\right) = \beta 0 + \beta 1D$$

where $\beta 0$ is the intercept and $\beta 1$ is the coefficient for ergonomic design. The model yielded a statistically significant coefficient for ergonomic design ($\beta 1 = 1.427$, $p < 0.001$), indicating that the odds of a student being engaged in an ergonomically designed classroom are exp(1.427) = 4.17 times higher than in a traditional classroom.

Delving deeper, the results illuminate notable variation in the adoption and implementation of LA and ergonomic design strategies across universities. While 38 % of institutions leveraged LA to monitor student engagement, only 9 % utilized LA for personalized learning path recommendations. This disparity suggests that the full potential of LA remains untapped, with most institutions focusing on macro-level analytics rather than individual learner-centric adaptations. Institutions that did employ LA for personalization, adaptive digital platforms, observed a 20 % uptick in student utilization of supplemental learning resources. This underscores the promise of LA in enabling data-driven customization of learning experiences (Pérez Cañado, 2018). To model the relationship between LA-driven personalization and resource utilization, a linear regression analysis was conducted. Let P denote the level of LA personalization (measured on a scale from 0 to 1), and U represent the percentage of students utilizing supplemental resources. The linear regression model can be written as:

$$U = \alpha 0 + \alpha 1P + \varepsilon$$

where $\alpha 0$ is the intercept, $\alpha 1$ is the coefficient for LA personalization, and ε is the error term. The model estimation yielded $\alpha 1 = 0.67$ ($p < 0.01$), suggesting that a one-unit increase in LA personalization is associated with a 67 percentage point increase in resource utilization.

On the ergonomics front, only 34 % of classrooms met the optimal lighting standards, and a mere 18 % adhered to ideal air quality parameters. This highlights a significant area for improvement, as prior studies have established the profound influence of factors like lighting (L), temperature (T), and air quality (A) on cognitive performance (C) (Andrews, 2011; Arpentieva, 2020). A multiple linear regression model was used to examine the combined effect of these environmental factors on cognitive performance:

$$C = \gamma 0 + \gamma 1L + \gamma 2T + \gamma 3A + \nu$$

The coefficients $\gamma 1 = 0.15$ ($p < 0.05$), $\gamma 2 = -0.08$ ($p < 0.1$), and $\gamma 3 = 0.21$ ($p < 0.01$) indicate that a one-unit improvement in lighting and air quality is associated with a 0.15 and 0.21 unit increase in cognitive performance, respectively, while a one-unit increase in temperature is associated with a 0.08 unit decrease in cognitive performance.

Institutions that prioritized these environmental elements, such as Kostanay State University's biophilic design interventions, saw a 12 % improvement in student-reported well-being metrics. To analyze the relationship between biophilic design elements (B) and student well-being (W), a logistic regression model was fitted:

$$ln\left(\frac{W}{1 - W}\right) = \delta 0 + \delta 1B$$

The coefficient $\delta 1 = 0.98$ ($p < 0.001$) suggests that the presence of biophilic design elements significantly increases the odds of improved student well-being by a factor of exp(0.98) = 2.66.

A key revelation emerges from the comparative analysis of traditional and ergonomically enhanced learning spaces. To test the statistical significance of this difference, a two-sample t-test was conducted. Let $\mu 1$ and $\mu 2$ denote the mean assessment scores in ergonomic and traditional classrooms, respectively. The null and alternative hypotheses can be stated as:

$$H0: \mu 1 = \mu 2 \; Ha: \mu 1 > \mu 2$$

The test statistic $t = 2.87$ ($p < 0.01$) leads to the rejection of the null hypothesis, confirming that the performance differential is statistically significant and underscores the tangible academic benefits of ergonomic design.

The LA data from these classrooms, indicating increased engagement and reduced cognitive load, offer a plausible mechanism for this performance enhancement. To quantify cognitive load (L), the study employed the NASA Task Load Index (NASA-TLX) (Hrastinski, 2021), a multidimensional scale that assesses perceived workload. A linear mixed-effects model was used to examine the relationship between ergonomic design (D) and cognitive load:

$$L = \zeta 0 + \zeta 1D + (1|S) + \eta$$

where $\zeta 0$ is the fixed intercept, $\zeta 1$ is the fixed effect coefficient for ergonomic design, (1|S) denotes the random intercept for each student, and η is the error term. The model yielded $\zeta 1 = -1.24$ ($p < 0.001$), indicating that ergonomic design significantly reduces cognitive load.

By optimizing the physical environment, ergonomic interventions mitigate extraneous cognitive burdens, allowing learners to allocate more mental resources to the core learning tasks. This can be mathematically represented using cognitive load theory. Let intrinsic cognitive load be denoted by i, extraneous load by e, and germane load by g. The total cognitive load (L) can be expressed as:

$$L = i + e + g$$

Ergonomic interventions primarily aim to minimize e, thereby freeing up cognitive resources for germane processing. This can be modeled using a resource allocation function, such as the sigmoid function:

$$r(g) = \frac{1}{1 + e^{-\lambda(g - g0)}}$$

where r(g) represents the proportion of cognitive resources allocated to germane processing, g0 is the threshold for germane load, and λ is a scaling parameter. As e decreases due to ergonomic optimization, a larger proportion of resources can be allocated to germane processing, leading to improved learning outcomes.

The synthesis of qualitative insights from interviews and focus groups adds a layer of nuance to these quantitative findings. Faculty members consistently reported higher levels of student participation, collaboration, and motivation in ergonomically designed spaces. This observation dovetails with the LA engagement metrics, providing convergent evidence for the positive influence of ergonomics on learner behavior. Furthermore, students expressed a preference for learning environments that offered flexibility, comfort, and seamless technology integration. This learner-centric perspective validates the importance of considering user experiences in the design of educational spaces.

Table 12. Comparative Analysis of Improvement Metrics

Metric	This Study	International Average	Difference	Effect Size (Cohen's d)	p-value
Student Engagement	+28.13 %	+15.2 %	+12.93 %	0.87	<0.001
Academic Performance	+18.07 %	+11.8 %	+6.27 %	0.62	<0.001
Self-Regulated Learning	+37.93 %	+22.5 %	+15.43 %	0.93	<0.001
Collaborative Skills	+35.48 %	+19.7 %	+15.78 %	0.89	<0.001

Notes: International averages are based on data from 47 global studies between 2015 and 2022. Effect sizes reflect standardized differences.

A two-year longitudinal study showed a 28.13 % increase in student engagement and an 18.07 % improvement in academic performance, surpassing global averages of 15.2 % and 11.8 %, respectively, as derived from a meta-analysis of 47 comparable studies. The effect sizes (Cohen's d > 0.5) confirm the practical significance of these findings, indicating substantial improvements in Russian institutions. Structural equation modeling (SEM) revealed a strong interaction effect ($\beta = 0.328$, $p < 0.001$) between Learning Analytics (LA) and ergonomic design, demonstrating that combined interventions result in more pronounced improvements than either approach alone. This suggests that successful educational innovations should integrate both technological and environmental enhancements for maximum effect.

Table 13. Mediation Effects on Academic Performance

Independent Variable	Mediator	Direct Effect	Indirect Effect	Total Effect	Proportion Mediated
LA Implementation	Student Engagement	0.198**	0.187***	0.385***	48.57 %
LA Implementation	Self-Regulated Learning	0.242***	0.143***	0.385***	37.14 %

Independent Variable	Mediator	Direct Effect	Indirect Effect	Total Effect	Proportion Mediated
Ergonomic Design	Student Engagement	0.079*	0.215***	0.294**	73.13 %
Ergonomic Design	Collaborative Skills	0.118**	0.176***	0.294**	59.86 %

*Notes: *p < 0.05, **p < 0.01, **p < 0.001. Standardized coefficients were used.

The data shows that student engagement is a key mediator, accounting for 48.57 % of the impact of LA implementation on academic outcomes and 73.13 % of the effect of ergonomic design improvements. This highlights the critical role of student involvement and self-regulation in optimizing the benefits of technological and environmental interventions.

Table 14. Institutional Clusters and Intervention Outcomes

Characteristic	Cluster 1: "Tech-Forward" (n=4)	Cluster 2: "Balanced Adopters" (n=7)	Cluster 3: "Traditional" (n=4)	F-value	p-value
LA Adoption Rate	72 % (SD=5.2)	41 % (SD=4.8)	18 % (SD=3.7)	38.7	<0.001
Ergonomic Classroom Rate	58 % (SD=6.1)	29 % (SD=3.9)	12% (SD=2.8)	42.3	<0.001
Engagement Improvement	+35 % (SD=3.2)	+26 % (SD=2.7)	+15 % (SD=2.1)	33.6	<0.001
Performance Gain	+22 % (SD=2.5)	+17 % (SD=2.0)	+9 % (SD=1.6)	27.8	<0.001

Notes: SD = Standard Deviation, ROI = Return on Investment.

The analysis shows that larger institutions with higher adoption rates of LA and ergonomic design ("Tech-Forward" cluster) experienced the greatest improvements across all metrics. In contrast, smaller institutions with lower adoption rates ("Traditional" cluster) saw modest gains, indicating a need for wider implementation to maximize potential benefits.

Table 15. Russian Higher Education in Global Context

Metric	Russian Universities (This Study)	OECD Average	EU Average	Global Top 10 %
LA Adoption Rate	38 %	52 %	47 %	78 %
Ergonomic Classroom Rate	26 %	41 %	38 %	63 %
Student Engagement Improvement	+28.13 %	+18 %	+22 %	+32 %
Academic Performance Gain	+18.07 %	+12 %	+15 %	+24 %
ROI on Ed-Tech Investment	1.8	1.5	1.6	2.3
Digital Literacy Growth Rate	+33.33 %	+28 %	+30 %	+41 %

Notes: OECD and EU data were sourced from the OECD's "Education at a Glance" 2023 report and the 2022 "Global Education Innovation Index."

While Russian universities are trailing behind in terms of LA and ergonomic classroom adoption, their effectiveness in converting these investments into tangible improvements in student engagement, performance, and digital literacy is notably higher than OECD and EU averages (Hrastinski, 2021). This suggests that the novelty of these interventions in the Russian context may amplify their impact, offering an opportunity for further gains with expanded adoption.

6. Conclusion

The depth of the qualitative data illuminated the nuanced ways in which these interventions have reshaped educational environments and learning processes. The SEM analysis, conducted using IBM SPSS Amos 28, provided robust empirical validation for the hypothesized relationships between the adoption of Learning Analytics, the application of ergonomic design principles, and the resultant active learning outcomes. The structural model exhibited excellent fit indices ($\chi 2/df = 1.92$, CFI = 0.97, TLI = 0.96, RMSEA = 0.05), signifying the adequacy of the model in capturing the underlying relationships. Standardized path coefficients revealed significant positive effects of both "Learning Analytics Implementation" ($\beta = 0.45$, $p < 0.001$) and "Ergonomic Design" ($\beta = 0.38$, $p < 0.001$) on "Active Learning Outcomes," confirming the dual importance of technological and environmental enhancements in fostering student engagement and performance.

In the multiple linear regression analyses, specific Learning Analytics metrics and ergonomic design characteristics were identified as critical predictors of student engagement and satisfaction. Notably, LA metrics such as "Time spent on interactive learning activities" ($\beta = 0.32$, $p < 0.01$) and "Participation in online discussions" ($\beta = 0.28$, $p < 0.01$) demonstrated strong correlations with active learning outcomes. In parallel, ergonomic design factors, particularly the "Ergonomic furniture rating" ($\beta = 0.36$, $p < 0.001$) and "Lighting quality" ($\beta = 0.29$, $p < 0.01$), emerged as significant contributors to the learning environment's effectiveness. These findings underscore the importance of both digital and physical infrastructures in shaping the overall educational experience.

The mediation analysis, performed using the PROCESS macro for SPSS, further refined the understanding of the interplay between LA and academic performance. The analysis revealed that "Student engagement" served as a partial mediator in the relationship between "Learning Analytics implementation" and "Academic performance" (Indirect effect = 0.18, 95 % CI [0.09, 0.29]). This indicates that LA interventions contribute to improved academic outcomes by enhancing student engagement, with approximately 34 % of the total effect of LA on academic performance being mediated by increased engagement levels.

6. Conflict of Interest

The authors declare that they have no conflict of interest throughout the process of conducting this research and writing the manuscript.

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