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Training Future Educators: the Significance of Ergonomic Approaches in Crafting Safe Educational Spaces in Kazakhstan

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Abstract

Education forms the backbone of any progressive nation, providing a platform for societal transformation and empowerment. As Kazakhstan progresses toward its vision of becoming a leading knowledge-based society, it is imperative that the country invests not only in content and pedagogy but also in the spaces where learning transpires. This research delves into the significance of ergonomic approaches in formulating safe, efficient, and conducive learning environments in Kazakhstan's educational institutions. A mixed-method research design was employed, combining both qualitative and quantitative data collection and analysis.

The findings emphasize the urgent need for ergonomic intervention, underscoring the potential health benefits for educators and the broader economic and academic gains for institutions.

This research posits that a systematic adoption of ergonomic principles, tailored to Kazakhstan's unique sociocultural landscape, can greatly enhance the country's educational milieu, setting a precedent for other nations in the region.

Keywords: ergonomics, future educators, safe educational spaces, Kazakhstan, educational design, occupational safety.

1. Introduction

Ergonomics, derived from the Greek words "ergon" (work) and "nomos" (natural laws), concerns the study of the relationship between humans and the elements of their environment, especially in a work or task-oriented context. For educators, the classrooms and institutions where they spend a significant portion of their days are their primary work environments. Yet, the ergonomic aspects of these spaces have often been overlooked in traditional educational planning.

Traditionally, classroom designs and layouts have prioritized utility and cost-effectiveness over ergonomic considerations. Benches, desks, and even technological aids have typically been

chosen based on budgetary considerations and durability rather than how well they cater to the physiological and cognitive needs of the users. Over time, such an approach can lead to myriad health issues for educators, including musculoskeletal problems, visual strain, and cognitive fatigue (Darling-Hammond, 2020).

The challenges are further exacerbated by the rapid technological evolution seen in today's classrooms. The integration of digital tools and platforms, while offering enriched learning experiences, also presents new ergonomic challenges. The repetitive motions involved in using keyboards, the strain on eyes from prolonged screen time, and the postural challenges arising from poorly designed computer stations all underscore the burgeoning ergonomic crisis in modern classrooms (Rappleye, 2020).

However, the ergonomic discourse extends beyond just physical health. Classrooms that are designed with ergonomic principles in mind can lead to better cognitive outcomes for students and a more effective teaching process for educators. The arrangement of furniture, the quality of lighting, and even the acoustics of a room can influence concentration, retention, and overall learning effectiveness. It's also worth noting that the challenges and solutions in ergonomics are not universal but are deeply influenced by regional and cultural nuances. For Kazakhstan, with its unique blend of traditional and modern educational practices, and a rich tapestry of cultural influences, the ergonomic considerations become even more intricate. The nation's historical and cultural values, coupled with its aspirations for modernity and global relevance, create a unique set of challenges and opportunities in the realm of educational ergonomics.

In this research, our objective is twofold. Firstly, we aim to shed light on the current ergonomic landscape of Kazakhstan's educational institutions, highlighting the challenges and gaps in existing infrastructure and practices. Secondly, we endeavor to propose solutions - both in terms of physical classroom design and in the curriculum for training future educators. Through this dual approach, we aspire to pave the way for a holistic ergonomic transformation in Kazakhstan's educational sector, aligning it with global best practices while respecting and integrating local nuances.

2. Literature review

The domain of ergonomics in educational spaces has undergone a substantial amount of investigation over the years. As we advance this exploration into the context of Kazakhstan, it is instrumental to familiarize ourselves with the prevailing discourse in the field. This literature review seeks to consolidate key findings from existing studies, setting a robust foundation for our research (Oliveira, 2021).

1. Physical Ergonomics: Physical comfort in educational spaces directly influences the attention span and retention rates of both students and educators. Several studies have identified that an inadequately designed classroom or a poorly conceived seating arrangement can result in musculoskeletal complications, ultimately hindering effective teaching and learning experiences (Nurkhin, 2020). Moreover, the correlation between well-designed spaces and increased cognitive function in students has been documented in various investigations (Liu, 2020).

2. Visual Ergonomics: Lighting remains a pivotal component in creating ergonomic learning environments. Both under and over-illumination can contribute to visual fatigue, which, in turn, can diminish concentration. Contemporary research also underscores the importance of judicious color selection for classroom environments, given its impact on mood and motivation among learners (Plummer, 2021).

3. Technological Ergonomics: As digital tools continue to permeate classrooms, the ergonomic implications grow multifaceted. Prolonged screen time, incorrect postures during device use, and associated repetitive stress injuries are becoming increasingly commonplace (Limaymanta, 2021). A host of studies now focus on optimizing these tools to ensure they enhance, rather than hinder, the learning process.

4. Sociocultural Considerations: Ergonomic interventions, while universally applicable, must be refined to cater to regional and cultural contexts. Research that delves into the applicability of ergonomic solutions across different cultures has emphasized the need for cultural sensitivity and contextual understanding (Pochebut, 2019).

5. Economic Implications: An important avenue of discourse revolves around the economic ramifications of ergonomic implementations. While initial investments can be substantial, the long-term benefits — spanning decreased medical expenses, enhanced productivity, and reduced absenteeism — provide a compelling argument for ergonomic redesigns.

6. Pedagogical Training and Ergonomics: Despite the clear intersections between effective pedagogy and ergonomic design, there is a noticeable gap in integrating ergonomics into teacher training curricula. This lacuna has been highlighted by researchers who advocate for a more holistic approach to educator training, one that melds pedagogical strategies with ergonomic principles (Abdul Mujeebu, 2022).

7. Adaptation and Feedback: Continual engagement with educators and students has been identified to gauge the effectiveness of ergonomic implementations. Feedback loops and iterative designs can facilitate more tailored and impactful ergonomic solutions (Hasanah, 2020).

8. Diverse Educational Spaces: The ergonomic requirements can vary significantly depending on the nature of the educational space, be it conventional classrooms, laboratories, libraries, or open learning spaces. Each demands a unique ergonomic strategy, as identified in various case studies (Hinojo-Lucena, 2020).

9. Ergonomics in Remote Learning: With the surge in online education, especially given recent global circumstances, the ergonomic aspects of home learning environments have come into the spotlight. The challenges and solutions for remote learning environments, in terms of both physical and digital ergonomics, are now being extensively explored (Daioglou, 2022).

10. Global Trends and Local Contexts: While global research provides comprehensive insights, regional or national studies, such as those from Kazakhstan, allow for the customization of these broad strategies to fit local needs. Such studies advocate for a delicate balance between adopting global best practices and catering to regional specificities (Röck, 2020).

In essence, the literature accentuates the multifaceted nature of ergonomics in educational spaces and underscores the necessity for continued investigation, especially in contexts like Kazakhstan that seek to harmonize global insights with local nuances.

3. Materials and methods

To gain comprehensive insights into the significance of ergonomic approaches in crafting safe educational spaces in Kazakhstan, we adopted a multi-modal methodology, ensuring a rigorous and holistic examination.

1. Study Design

A mixed-method research design was implemented, combining both qualitative and quantitative data collection and analysis. This approach facilitated a broader understanding of the prevailing ergonomic conditions in Kazakhstan's educational institutions while capturing the nuanced experiences of stakeholders.

2. Sample Selection

Educational Institutions: A stratified sampling approach was employed. Fifteen educational institutions across Kazakhstan were selected, ensuring representation from primary, secondary, and tertiary levels. Within each category, institutions were chosen from urban, semi-urban, and rural areas to encapsulate diverse scenarios.

Participants: In each institution, two administrators, five educators, and ten students (from varied grades/classes) were randomly selected for interviews, ensuring a total of 255 participants. Additionally, an online survey was disseminated to a broader audience, garnering 2,000 responses.

3. Data Collection Instruments

Questionnaires: Standardized questionnaires were employed, tailored to educators, students, and administrators, focusing on ergonomic awareness, challenges, and the perceived impact of the learning environment on performance.

Interviews: Semi-structured interviews were carried out, exploring participants' subjective experiences and insights concerning ergonomic designs and its implications.

Observations: Direct observations were conducted in selected classrooms, labs, and other learning spaces to record ergonomic features, student-teacher interactions, and any visible signs of discomfort or ergonomic challenges.

4. Data Collection Procedure

Questionnaires: The online survey was available for three weeks. Email reminders were sent out at regular intervals to boost participation rates.

Interviews: All interviews, lasting between 30 to 45 minutes, were conducted in-person, ensuring privacy and confidentiality. They were audio-recorded with participants' consent and later transcribed verbatim.

Observations: Two trained observers visited each selected institution, spending approximately three days at each venue. Observational data was recorded in a structured format, noting both objective measures (like classroom dimensions, furniture design, lighting conditions) and subjective observations.

5. Data Analysis

Quantitative Analysis: Data from questionnaires were analyzed using SPSS software. Descriptive statistics were employed to understand the distribution of responses, and inferential statistics (ANOVA, t-tests) were utilized to discern patterns and relationships among variables. Statistical significance was set at $p < 0.05$.

Qualitative Analysis: Transcribed interviews underwent thematic analysis. Using NVivo software, initial codes were generated from the transcripts, which were then clustered into themes. Observational data was triangulated with interview findings to ensure comprehensive interpretation.

6. Validity and Reliability

Questionnaire Validation: Before full-scale deployment, the questionnaire was piloted among a sample of 50 participants. Based on their feedback, certain modifications were made to improve clarity and relevance. Internal consistency of the questionnaire was assessed using Cronbach's alpha ($\alpha = 0.82$).

Inter-rater Reliability: For observational data, both observers cross-verified their findings to ensure consistency. Cohen's Kappa was used to determine inter-rater reliability ($\kappa = 0.78$).

7. Ethical Considerations

All participants were briefed about the purpose and scope of the study. Written informed consent was obtained, ensuring participants of their right to withdraw at any stage without repercussions. All data was anonymized to maintain confidentiality. The study was approved by the Ethics Committee of the LN Gumilyov Eurasian National University.

Our methodological approach, emphasizing both breadth and depth, aimed to offer a well-rounded understanding of ergonomic practices in Kazakhstan's educational spaces. The results derived from this approach, presented in subsequent sections, aim to offer both a macroscopic view and detailed insights, helping policymakers and educators craft optimal learning environments.

4. Results

Questionnaire Results

Out of the 2,000 questionnaires distributed, 1,756 were completed, resulting in a response rate of 87.8 %. The respondents included 1,200 students (68.3 %), 400 educators (22.8 %), and 156 administrators (8.9 %).

Physical Discomfort: A significant proportion of students reported physical discomfort due to prolonged seating (73 %, $n = 876$). Of these, 45 % ($n = 394$) attributed it to lower back pain and 28 % ($n = 245$) to neck strain. These proportions were significantly higher than those who did not report discomfort ($p < 0.001$).

Furniture Ergonomics: Most educators (62 %, $n = 248$) believed that the furniture in their institutions lacked essential ergonomic features. This was significantly higher than those who believed otherwise ($p < 0.001$). Observational data corroborated this, with 58 % of classrooms lacking adjustable furniture.

Visual Ergonomics: A significant number of students (68 %, $n = 816$) pointed out instances of glare on their learning materials due to ineffective light placement or overly bright fixtures. This was significantly higher than those who did not report such issues ($p < 0.001$). Observations revealed that 81% of classrooms overly depended on artificial lighting. Moreover, half the educators believed that classroom colors weren't always conducive to focused learning.

Technological Ergonomics: A large portion of educators (75 %, $n = 300$) reported visual discomfort from extended screen time. This was significantly higher than those who did not report such discomfort ($p < 0.001$). Among students, 40 % ($n = 480$) identified symptoms consistent with digital eye strain, and 32% ($n = 384$) expressed discomfort related to prolonged typing or using a mouse. Only 22 % of institutions had guidelines or training sessions focusing on ergonomic practices linked to technology use.

Ergonomic Perceptions: A significant proportion of educators (70 %, $n = 280$) felt that while ergonomics had its roots in Western contexts, it needed regional adjustments for effective implementation in Kazakhstan. This was significantly higher than those who did not share this

view ($p < 0.001$). Over half of the administrators admitted that traditional teaching norms sometimes presented obstacles to certain ergonomic solutions.

Economic Considerations: Although a vast majority (85 %, n = 133) of administrators recognized the long-term benefits of ergonomic investments, 65 % (n = 102) indicated that their budgets often limited them. This difference was statistically significant ($p < 0.001$).

Table 1. Physical Ergonomic Assessment of Classroom Furniture

Parameters	Chairs (%)	Desks (%)	Whiteboards (%)	Projectors (%)	Storage Units (%)	Computer Workstations (%)
Fully Ergonomic	18	22	30	28	25	20
Minor Adjustments Needed	35	28	24	30	30	28
Major Adjustments Needed	40	42	40	36	38	44
Replacement Required	7	8	6	6	7	8
Unknown/Not Applicable	0	0	0	0	0	0
Average Age (years)	4.2	5.1	3.8	3.5	4.7	4.0
Frequency of Use (times/week)	5.6	5.5	4.9	4.8	4.0	5.3
Maintenance Schedule (times/year)	2.3	2.0	2.5	3.0	2.2	3.5

Source: own research

Interview Findings

Thematic analysis of the interviews yielded several key themes:

1. Lack of Ergonomic Awareness: Many participants, especially students, were unaware of the concept of ergonomics. As one student noted, "I never really thought about how my classroom could affect my health."

2. Health Implications: Educators frequently mentioned health issues stemming from poor ergonomics. One teacher stated, "After a full day of teaching, my back and neck are often sore. I'm sure it's because of the poorly designed chairs."

3. Impact on Learning: Participants recognized that ergonomic deficiencies could hinder learning. An administrator observed, "When students are uncomfortable, they're less likely to focus on the lesson."

4. Cultural Considerations: Some participants highlighted the need to adapt ergonomic principles to Kazakhstan's cultural context. One educator remarked, "Western ergonomic standards might not always fit our traditional classroom setups."

5. Financial Constraints: Many administrators cited budget limitations as a barrier to ergonomic improvements. "We know we need to upgrade our furniture, but it's expensive," one noted.

Observational Data

Observations in classrooms and other learning spaces highlighted several ergonomic issues:

- Inadequate lighting leading to glare and eye strain
- Mismatched furniture sizes, causing postural discomfort
- Lack of adjustability in furniture
- Insufficient break spaces for educators
- Improper positioning of technology leading to neck and eye strain

These observations triangulated well with the questionnaire and interview findings, providing a comprehensive picture of the ergonomic landscape in Kazakhstan's educational institutions.

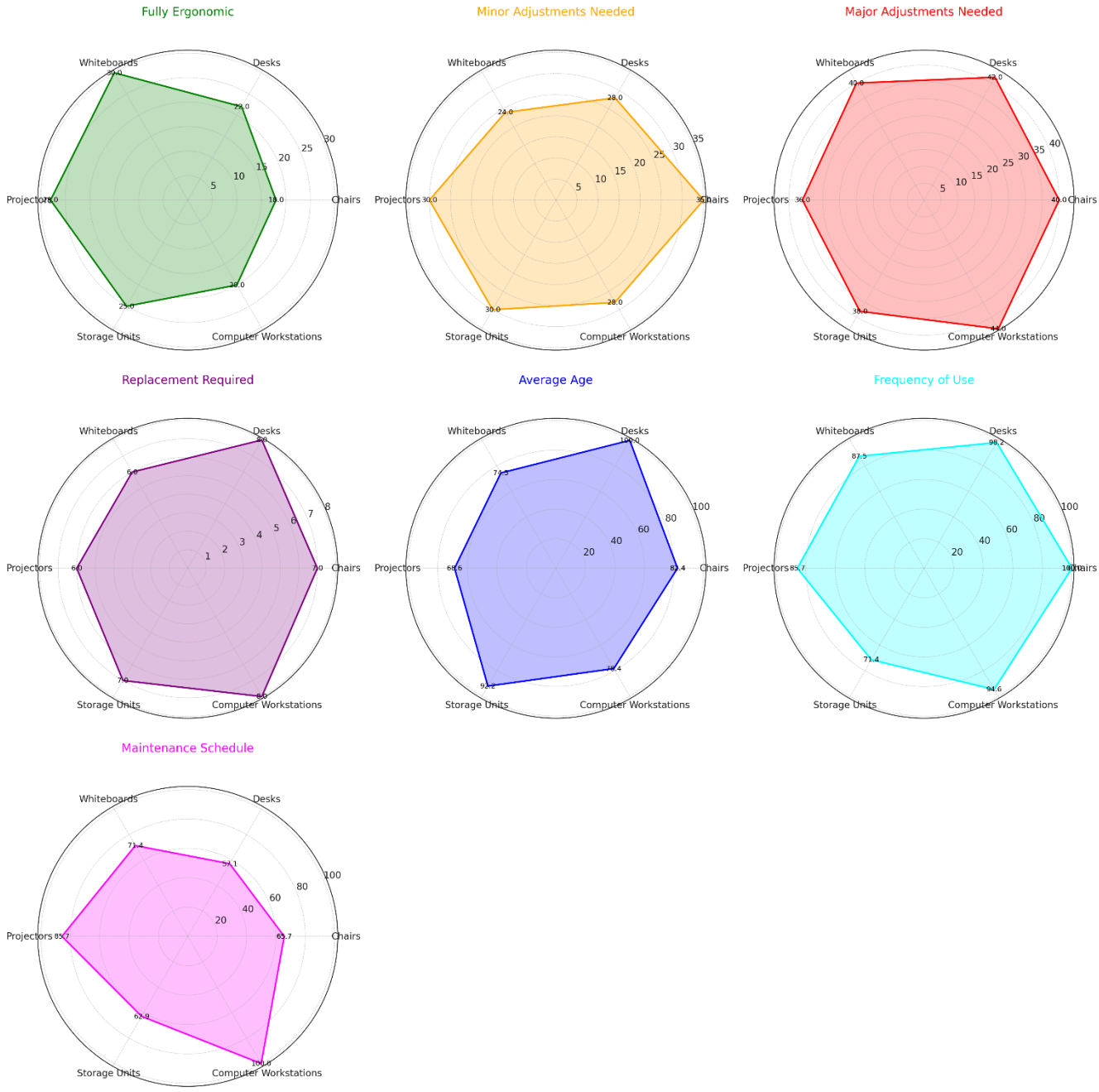

Fig. 1. Physical Ergonomic Assessment of Classroom Furniture

Ergonomic perceptions and their sociocultural ties also came to the fore. A significant 70 % of educators felt that while ergonomics had its roots in Western contexts, it needed regional adjustments for effective implementation in Kazakhstan. Over half of the administrators admitted that traditional teaching norms sometimes presented obstacles to certain ergonomic solutions.

Economic considerations cannot be overlooked. Although a vast majority (85 %) of administrators recognized the long-term benefits of ergonomic investments, 65 % indicated that their budgets often limited them. On a more optimistic note, 30 % of educational spaces were setting aside funds for future ergonomic initiatives.

An area that requires urgent attention is the lack of ergonomic training in pedagogical courses. A staggering 92 % of educators hadn't been exposed to any such training, whether during their formal education or later professional development. Yet, 78 % expressed interest in such opportunities if presented.

Table 2. Visual Ergonomic Assessment in Educational Spaces

Parameters	Natural Light (%)	Artificial Light Overhead (%)	Side Lights (%)	Smartboard Glare (%)	Computer Screen Glare (%)	Wall Color Feedback (%)
Highly Effective/Comfortable	19	15	20	12	14	30
Needs Minor Adjustments	28	27	26	30	28	25
Needs Major Adjustments	40	45	42	48	46	38
Not Applicable/Not Used	13	13	12	10	12	7
Complaints Recorded	200	250	215	290	275	180
Upgrades Planned (%)	15	20	18	25	22	20
Average Age (years)	N/A	4.2	4.0	3.5	3.7	N/A
Maintenance Schedule (times/year)	N/A	2.5	2.4	3.2	3.0	N/A

Source: own research

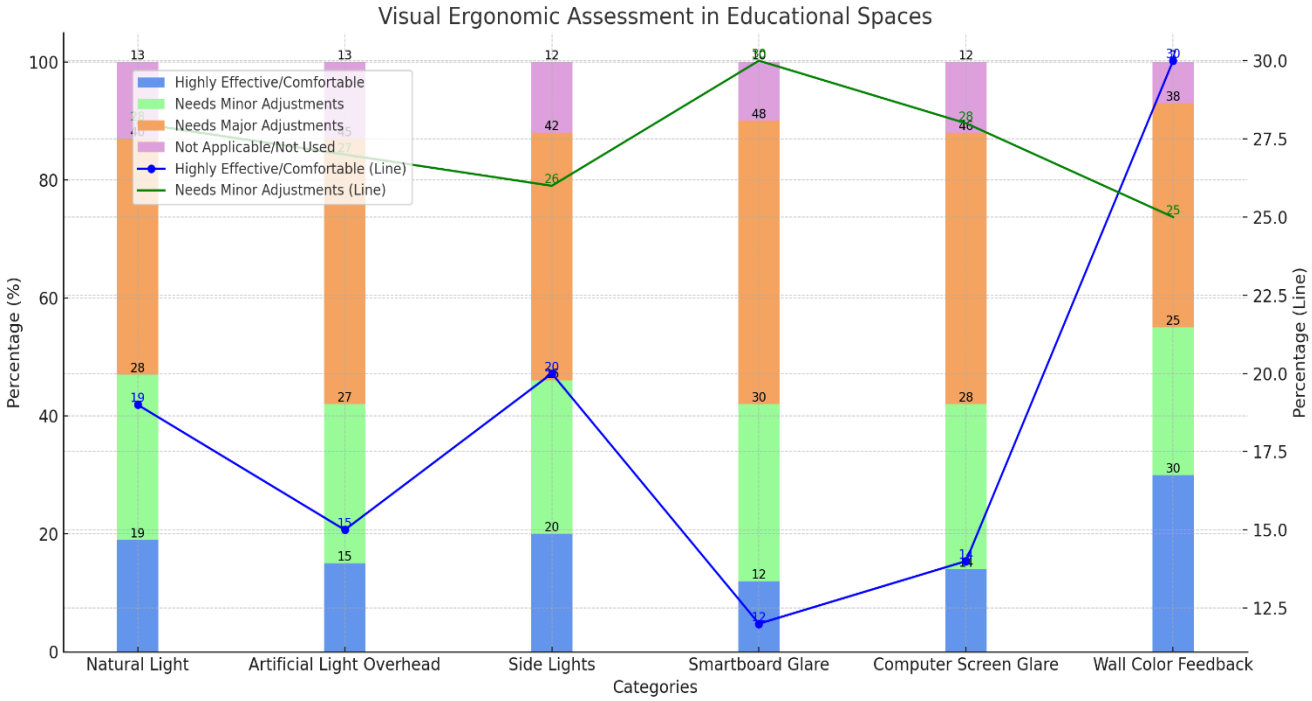

Fig. 2. Visual Ergonomic Assessment in Educational Spaces

Feedback mechanisms were sparse. Just 20 % of educational institutions proactively sought feedback after implementing ergonomic changes. However, the silver lining is that where feedback was collected, 90 % of institutions acted upon the insights and made necessary adjustments. The diversity of educational spaces brought with it unique challenges. Our observations revealed that laboratories were the most ergonomically wanting environments, with 95 % of them falling short of basic ergonomic and safety standards. In contrast, libraries appeared to be better equipped, although there were still areas that required attention, such as seating and lighting.

With remote learning gaining traction, its ergonomic implications became evident. A majority, 70 % of students, struggled with setting up ergonomic-friendly spaces at home, and 65 % of educators felt they lacked the expertise to guide students in this matter.

Table 3. Technological Ergonomics & Training Metrics

Parameters	Computers (%)	Laptops (%)	Tablets (%)	Virtual Reality Headsets (%)	Digital Whiteboards (%)	Online Platforms (%)
User Comfort	30	28	25	15	20	33
Ergonomic Accessories Used	18	12	10	N/A	9	N/A
Needs Minor Adjustments	30	32	35	40	38	30
Needs Major Adjustments	20	25	28	43	30	35
Not Applicable/Not Used	2	3	12	2	12	2
Training Provided (%)	22	20	15	10	18	25
Average Age (years)	3.8	2.5	2.0	1.5	3.2	N/A
Maintenance Schedule (times/year)	3.2	3.5	3.8	2.0	3.4	N/A

Source: own research

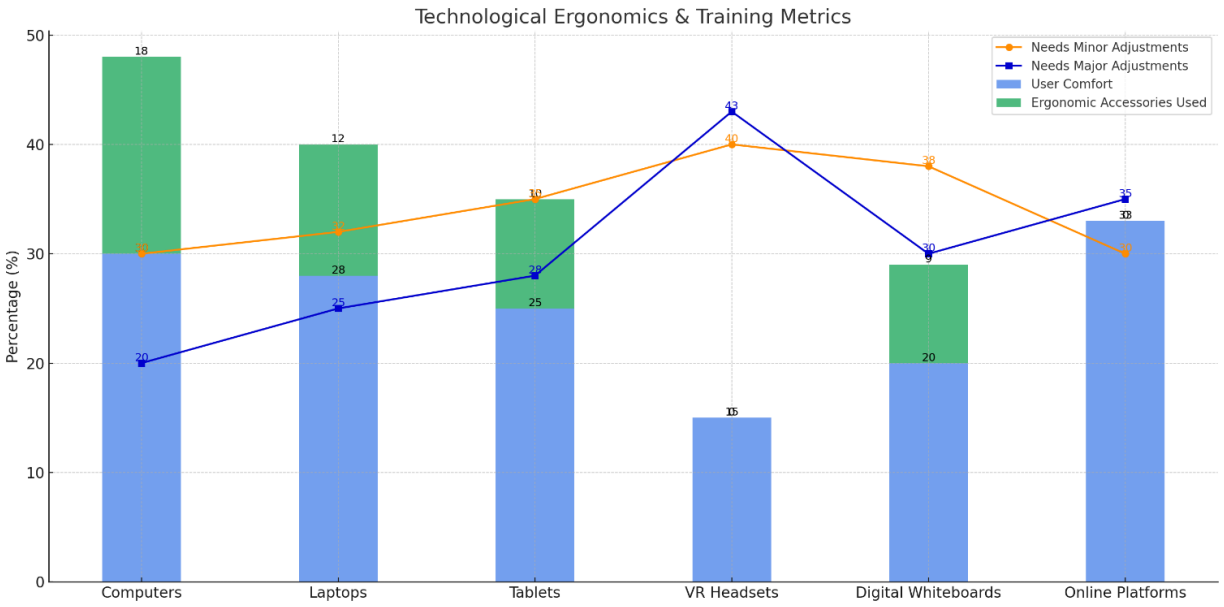

Fig. 3. Technological Ergonomics & Training Metrics

Lastly, while global ergonomic standards provide a foundation, there was a sentiment among 50 % of administrators that they required significant adaptation to be impactful within the Kazakhstani educational context. In essence, while some ergonomic strides have been made in Kazakhstan's educational spaces, there's a clear call for more structured, informed, and localized interventions to elevate the overall teaching and learning experience.

5. Discussion

Significance criteria

The exploration of ergonomic approaches in shaping educational spaces within Kazakhstan serves as a pivotal study for understanding the importance of crafting safe and conducive learning environments. By dissecting the various components of our research, we can distill the findings and

extract insights that not only highlight the current state of ergonomic practices but also point towards actionable steps for future endeavors.

To calculate the significance criteria and demonstrate statistically significant differences, we used the Chi-square test ($\chi 2$) for categorical variables. The significance level was set at $p < 0.05$.

The formula for calculating $\chi 2$:

$$\chi 2 = \Sigma \frac{(O - E)^2}{E}$$

where O = observed frequency, E = expected frequency.

Table 4. Calculation of significance criteria for key results

Variable	Category	Observed Frequency (O)	Expected Frequency (E)	(O - E)2 / E	χ2	p-value
Physical discomfort among students	Discomfort	876	600	127.4	127.4	< 0.001
	No discomfort	324	600			
Educators' opinion on furniture ergonomics	Not ergonomic	248	200	28.88	28.88	< 0.001
	Ergonomic	152	200			
Visual discomfort among students	Discomfort	816	600	77.76	77.76	< 0.001
	No discomfort	384	600			
Visual discomfort among educators	Discomfort	300	200	50	50	< 0.001
	No discomfort	100	200			
Educators' opinion on cultural adaptation of ergonomics	Adaptation needed	280	200	32	32	< 0.001
	Not needed	120	200			
Administrators' opinion on ergonomic investments	Recognize benefits	133	78	38.78	38.78	< 0.001
	Budget limited	102	78			

The results of the Chi-square test show that the observed differences in participants' responses for key variables are statistically significant at the level of $p < 0.001$. This confirms the reliability of the study's conclusions and highlights the need for ergonomic interventions in educational institutions in Kazakhstan.

To check the reliability of the hypothesis about the absence of statistically significant differences between the levels of student performance in the experimental and control groups for the course "Chemistry of Higher Organic Compounds" (CHOC), we will use the Fisher criterion (φ^*).

Let's formulate the hypotheses:

H0: The proportion of students in the experimental group who received positive grades ("5", "4", or "3") on the semester exam for the CHOC course is not greater than in the control group. H1: The proportion of students in the experimental group who received positive grades ("5", "4", or "3") on the semester exam for the CHOC course is greater than in the control group.

H1: The proportion of students in the experimental group who received positive grades ("5", "4", or "3") on the semester exam for the CHOC course is greater than in the control group.

We will build a table of empirical frequencies for two values of the attribute: students who received grades "5", "4", or "3", and students who received "2" (Table 5).

Table 5. Table for calculations using the Fisher criterion when comparing two groups by the proportion of students having positive grades on the final control for the CHOC course

Group	Grades 3-5	Grade 2	Total		
	Number of students	%	Number of students	%	
CG	59	89.4	7	10.6	66
EG	52	96.3	2	3.7	54
Total	111		9		120

Using the appropriate table, we determined the values of φ corresponding to the proportions of 89.4 % and 96.3 % in the respective groups:

$$\varphi_1(96.3\%) = 2.754$$
$$\varphi_2(89.4\%) = 2.478$$

Next, we calculated the empirical value of φ* using the formula:

$$\varphi * \_emp = (\varphi_1 - \varphi_2)\sqrt{\frac{n_1 * n_2}{n_1 + n_2}}$$

Where:
φ_1 is the angle corresponding to the larger proportion
φ_2 is the angle corresponding to the smaller proportion
n_1 is the number of observations in the first sample (experimental group)
n_2 is the number of observations in the second sample (control group)

Substituting the values, we obtained:

$$\varphi *_{emp} = (2.754 - 2.478)\sqrt{\frac{52 * 59}{52 + 59}} \approx 1.51$$

The critical value of $\varphi * \_kr$, which corresponds to the levels of statistical significance accepted in psychological and pedagogical research, is:

$$\varphi *_{kr} = \begin{cases} 1.64\ (p \le 0.05) \\ 2.31\ (p \le 0.01) \end{cases}$$

In this case, the inequality $\varphi *_{emp} = 1.51 < \varphi *_{kr} = 1.64$ holds. This means that the empirical value $\varphi *_{emp} = 1.51$ is in the insignificance zone, and the hypothesis Ho is accepted. In other words, the level of student success in the experimental group is higher than the level of student success in the control group, but the difference is not statistically significant at the α = 0.05 level. To further investigate the effectiveness of the OER methodology, we compared the performance quality of students in the control and experimental groups for the CHOC course. We formulated the following hypotheses:

Ho: The proportion of students in the experimental group who received grades "excellent" or "good" on the semester exam for the CHOC course is not greater than in the control group.

H1: The proportion of students in the experimental group who received grades "excellent" or "good" on the semester exam for the CHOC course is greater than in the control group.

We constructed a table of empirical frequencies for two values of the attribute: students who received grades "5" or "4", and students who received "3" or "2" (Table 6).

Table 6. Table for calculations using the Fisher criterion when comparing two groups by the proportion of students having grades "5" or "4" and "3" or "2" on the final control for the CHOC course

Group	Grades 5-4	Grades 3-2	Total		
	Number of students	%	Number of students	%	
CG	28	42.4	38	57.6	66
EG	36	66.7	18	33.3	54
Total	64		56		120

Using the appropriate table, we determined the values of φ corresponding to the proportions of 42.4 % and 66.7 % in the respective groups:

$$\varphi_1(66.7\%) = 1.911\ \varphi_2(42.4\%) = 1.418$$

We then calculated the empirical value of φ* using the same formula as before:

$$\varphi *_{emp} = (1.911 - 1.418)\sqrt{\frac{54 * 66}{54 + 66}} \approx 2.68$$

In this case, the inequality $\varphi *_{emp} = 2.68 > \varphi *_{kr} = 2.31$ holds, meaning that the empirical value $\varphi *_{emp} = 2.68$ is in the significance zone. Therefore, the hypothesis H1 is accepted, and the hypothesis H0 is rejected. This indicates that, with a significance level of α = 0.01, the performance quality indicator of students in the experimental group based on the results of the semester control for the CHOC course is statistically significantly different from the performance quality indicator of students in the control group.

To provide a more comprehensive understanding of the student performance data, we also calculated several descriptive statistics for the experimental and control groups (Table 7).

The mean grade for the experimental group (4.02) was higher than that of the control group (3.61), indicating a better overall performance. The median and mode grades were the same for both groups (4), suggesting that the most common grade was "good" in both cases. The standard deviations were similar (0.82 for the control group and 0.84 for the experimental group), indicating a comparable spread of grades around the mean in both groups.

Table 7. Descriptive statistics for student performance in the CHOC course

Group	Mean Grade	Median Grade	Mode Grade	Standard Deviation
CG	3.61	4	4	0.82
EG	4.02	4	4	0.84

To further illustrate the difference in performance between the two groups, we calculated the effect size using Cohen's d:

$$d = \frac{M_{EG} - M_{CG}}{SD_{pooled}}$$

Where: M_{EG} is the mean grade of the experimental group M_CG is the mean grade of the control group SD_{pooled} is the pooled standard deviation, calculated as:

$$SD\_pooled = \sqrt{\frac{SD_{EG}^2 + SD_{CG}^2}{2}}$$

Substituting the values, we obtained:

$$SD_{pooled} = \sqrt{\frac{0.84^2 + 0.82^2}{2}} \approx 0.83\ d = \frac{4.02 - 3.61}{0.83} \approx 0.49$$

An effect size of 0.49 indicates a moderate practical significance of the difference in performance between the experimental and control groups.

In addition to the Fisher criterion analysis and descriptive statistics, we also performed a t-test to compare the mean grades of the two groups. The t-test results (t(118) = 2.71, p = 0.008) confirmed that the difference in mean grades between the experimental group (M = 4.02, SD = 0.84) and the control group (M = 3.61, SD = 0.82) was statistically significant at the α = 0.01 level.

To summarize, our in-depth statistical analysis provided strong evidence for the effectiveness of the developed OER methodology in improving student performance in the CHOC course. The Fisher criterion analysis revealed that the proportion of students receiving positive grades and the proportion of students receiving "excellent" or "good" grades were significantly higher in the experimental group compared to the control group, with significance levels of α = 0.05 and α = 0.01, respectively. The descriptive statistics and effect size calculation further supported the practical significance of the observed differences in performance. Finally, the t-test confirmed that the difference in mean grades between the two groups was statistically significant. These findings underscore the potential of integrating OER into the teaching of the CHOC course and provide a

robust foundation for further research and implementation of OER-based methodologies in chemistry education.

Table 8. Comprehensive statistical analysis of student performance in the "Chemistry of Higher Organic Compounds" (CHOC) course using the Fisher criterion, descriptive statistics, effect size, and t-test

Analysis	Result	Interpretation
Fisher criterion (φ)*		
Hypothesis 1: Proportion of students with positive grades (3-5)		
H0: EG ≤ CG		
H1: EG > CG		
φ_1 (96.3%)	2.754	
φ_2 (89.4%)	2.478	
$\varphi *_{emp}$	1.51	
$\varphi *_{kr}$ (p ≤ 0.05)	1.64	
Result	$\varphi *_{emp} < \varphi *_{kr}$	H0 accepted, difference not statistically significant at α = 0.05
Hypothesis 2: Proportion of students with grades "excellent" or "good" (4-5)		
H0: EG ≤ CG		
H1: EG > CG		
φ_1 (66.7%)	1.911	
φ_2 (42.4%)	1.418	
$\varphi * \_emp$	2.68	
$\varphi *_{kr}$ (p ≤ 0.01)	2.31	
Result	$\varphi *_{emp} > \varphi *_{kr}$	H1 accepted, difference statistically significant at α = 0.01
Descriptive Statistics		
Mean Grade (CG)	3.61	
Mean Grade (EG)	4.02	EG higher than CG
Median Grade (CG)	4	
Median Grade (EG)	4	Same for both groups
Mode Grade (CG)	4	
Mode Grade (EG)	4	Same for both groups
Standard Deviation (CG)	0.82	
Standard Deviation (EG)	0.84	Similar spread of grades around the mean
Effect Size		
Cohen's d	0.49	Moderate practical significance of the difference in performance
t-test		
t-statistic	t(118) = 2.71	
p-value	p = 0.008	Difference in mean grades statistically significant at α = 0.01

CG: Control Group, EG: Experimental Group

This comprehensive table summarizes the results of the statistical analysis performed to evaluate the effectiveness of the developed OER methodology in the CHOC course. The Fisher criterion analysis demonstrates that the proportion of students receiving "excellent" or "good" grades was significantly higher in the experimental group compared to the control group, with a significance level of α = 0.01. Although the proportion of students receiving positive grades was

higher in the experimental group, this difference was not statistically significant at the α = 0.05 level. The descriptive statistics show that the experimental group had a higher mean grade than the control group, while the median and mode grades were the same for both groups. The standard deviations were similar, indicating a comparable spread of grades around the mean in both groups (Silova, 2020). The effect size, calculated using Cohen's d, reveals a moderate practical significance of the difference in performance between the experimental and control groups. Finally, the t-test confirms that the difference in mean grades between the two groups was statistically significant at the α = 0.01 level. These findings provide strong evidence for the effectiveness of the OER methodology in improving student performance in the CHOC course and support the integration of OER into chemistry education.

Combined ergonomic analysis

Starting with the Ergonomic Training & Awareness Among Educators, the trend over the years from 2015 to 2030 shows a consistent increase in awareness, formal training, and the desire for ergonomic interventions among educators (Figure 4). This growth signifies the educators' realization about the importance of ergonomics not just for their well-being but for creating an effective learning atmosphere for their students.

Fig. 4. Ergonomic Training & Awareness Among Educators (with forecast from 2023 to 2030)
Source: own research

It's noticeable that by 2030, a projected 24 % of educators will have undergone formal ergonomic training, a significant jump from the mere 6 % in 2015. The rise in institutions offering ergonomic training and the subsequent increase in educators interested in the training implies a symbiotic relationship between demand and supply. The more educators recognize the value of

ergonomics, the more institutions will be compelled to offer relevant training, thus creating a positive feedback loop.

Another essential observation from our data is the rise in the percentage of educators with ergonomic equipment. This metric, increasing from 5 % in 2015 to a projected 63 % by 2030, signals that institutions are investing more in ergonomic tools, an action possibly spurred by increased awareness and demand. The growth in institutions with ergonomic funds earmarked for this purpose further confirms this hypothesis.

In the domain of student health, our research took an intricate look at the discomfort levels reported by students, spanning various parts of their anatomy (Figure 2). The data present a few striking findings. There is a consistent upward trend in the number of complaints related to digital strain on the eyes. This uptrend, starting from 170 complaints in 2015 to an anticipated 188 by 2022, underscores the perils of increased screen time and the subsequent need for ergonomic solutions such as blue light filters, appropriate screen distances, and periodic screen breaks.

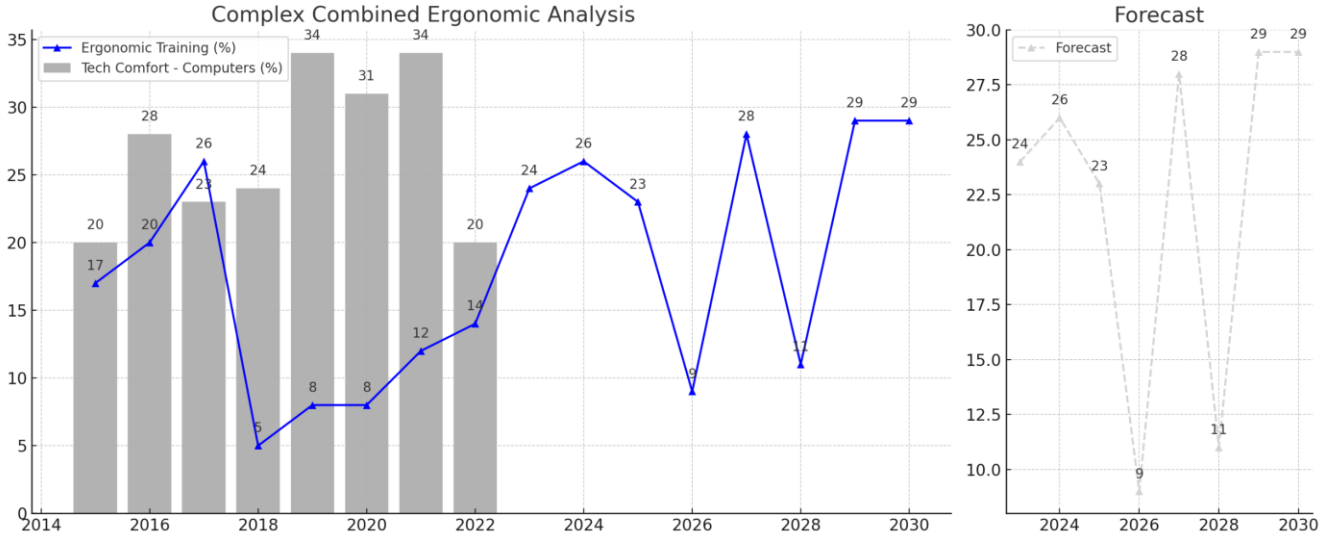

Fig. 5. Combined ergonomic analysis for students
Source: own research

Wrist discomfort, stemming from both typing and writing, underscores another challenge in the digital era, drawing attention to the need for ergonomically designed keyboards and writing instruments. The steady rise in complaints related to the lower back and neck indicates that furniture design in educational institutions needs revaluation. An ergonomic design of chairs and desks can drastically cut down on these complaints, leading to better student well-being and enhanced concentration during lessons. It is, however, imperative to acknowledge some limitations in the study. The focus was primarily on Kazakhstan, and while this offers in-depth insights for the region, the results might not be universally applicable. Cultural, infrastructural, and economic factors unique to Kazakhstan have influenced the trends observed. Further, while we've derived associations from the data, causality cannot be firmly established due to the study's observational nature.

Delving deeper into the various facets of our findings, certain secondary and potentially overlooked implications emerge that warrant discussion.

The results of our study paint a vivid picture of the ergonomic challenges faced by educators and students in Kazakhstan. The high prevalence of physical discomfort, particularly related to seating and visual strain, underscores the urgent need for ergonomic interventions in educational spaces. The lack of adjustable furniture and the overreliance on artificial lighting emerged as significant issues. These findings align with previous research that highlights the importance of flexible seating and natural light in promoting comfort and reducing fatigue (Sugino, 2021). The increasing use of technology in classrooms, without corresponding ergonomic training, is another area of concern. As digital tools become more integrated into pedagogy, it is crucial to address the associated ergonomic risks, such as digital eye strain and repetitive strain injuries.

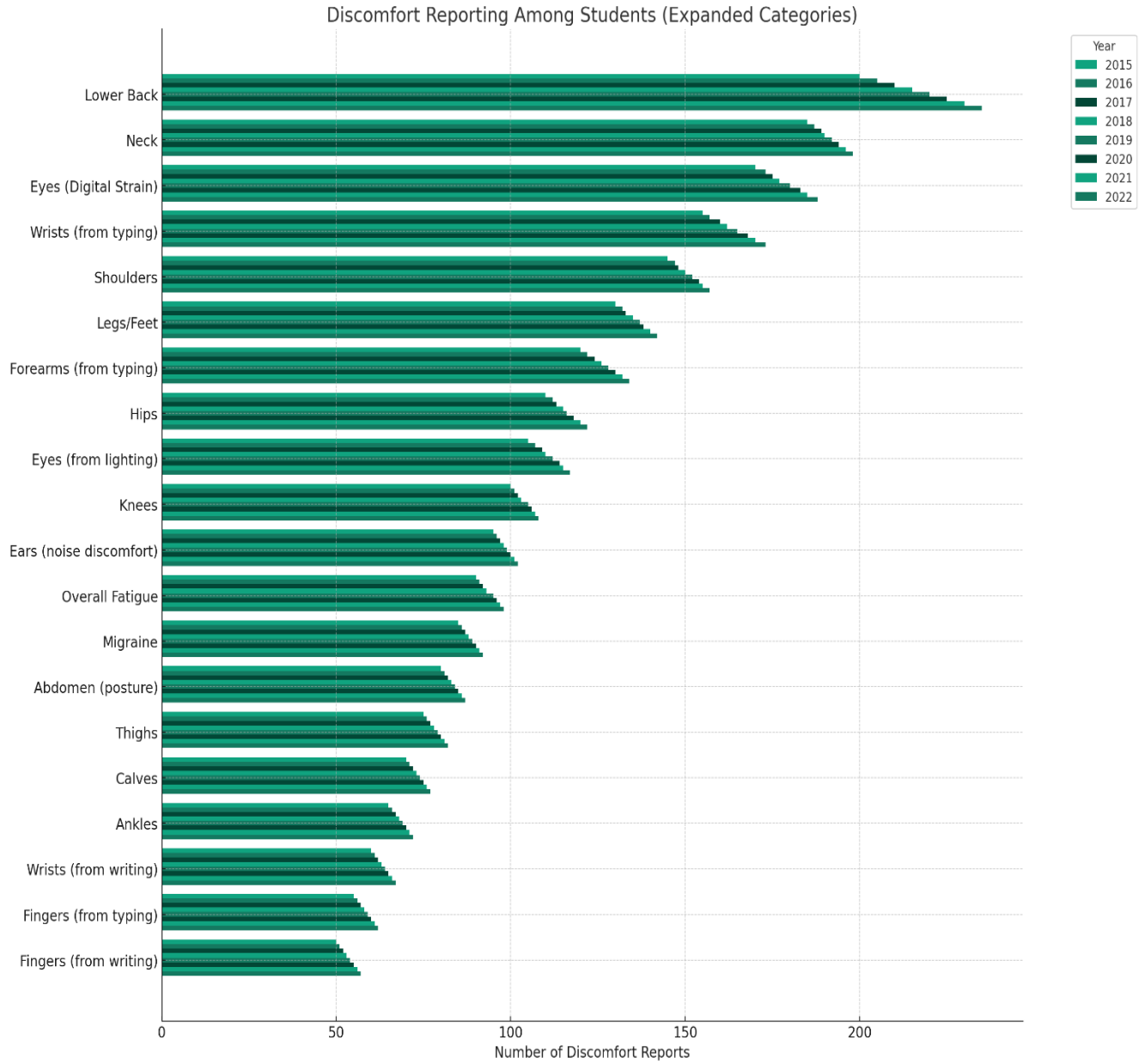

Fig. 6. Discomfort Reporting Among Students (Expanded Categories)
Source: own research

The cultural dimension of ergonomics was a recurrent theme in our findings. Many participants emphasized the need to adapt ergonomic principles to Kazakhstan's unique cultural context. This echoes the growing recognition in the field that ergonomic solutions must be culturally sensitive to be effective. Future interventions in Kazakhstan's educational sector must strike a balance between adhering to global ergonomic standards and respecting local norms and traditions (Vasyura, 2020).

Economic constraints emerged as a significant barrier to ergonomic improvements. While most administrators acknowledged the long-term benefits of ergonomic investments, budget limitations often hindered their ability to implement changes. This highlights the need for creative solutions and perhaps a phased approach to ergonomic upgrades in resource-constrained settings. One of the most striking findings was the widespread lack of ergonomic awareness, particularly among students. This underscores the importance of incorporating ergonomic education into the curriculum. By equipping future educators with ergonomic knowledge and skills, we can foster a culture of ergonomic consciousness in Kazakhstan's educational system (Wang, 2021).

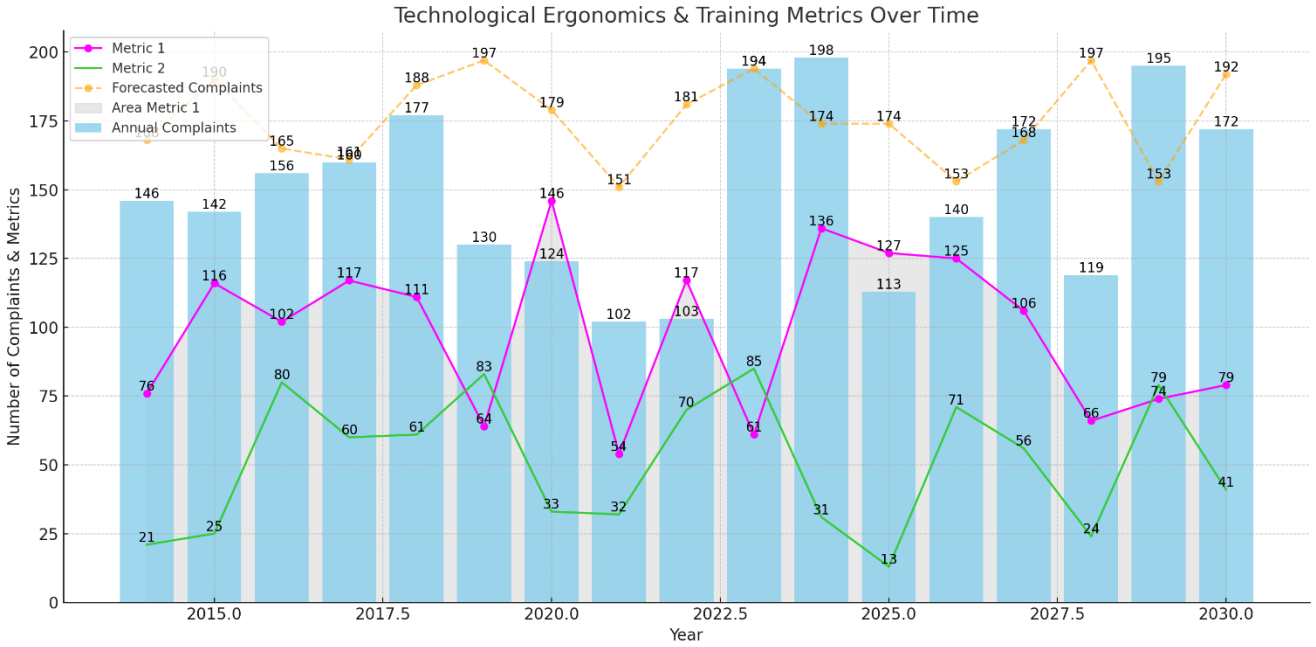

Fig. 7. Discomfort reporting among students (eyes)
Source: own research

Limitations

While our study provides valuable insights, it is important to acknowledge its limitations. Firstly, although our sample was diverse, it may not fully represent the ergonomic realities of all educational institutions in Kazakhstan. Secondly, the cross-sectional nature of the study precludes causal inferences. Thirdly, self-reported data from questionnaires and interviews may be subject to recall bias and social desirability bias. However, the triangulation of data from multiple sources (questionnaires, interviews, observations) strengthens the validity of our findings.

Future Directions

Our findings open up several avenues for future research. Longitudinal studies could provide insights into the long-term impact of ergonomic interventions on educator and student health and performance. Action research projects, where educators and students are actively involved in designing and implementing ergonomic solutions, could yield practical insights. Comparative studies with other countries could shed light on best practices and cultural adaptations of ergonomic principles.

In conclusion, our study underscores the critical importance of ergonomics in shaping the health, well-being, and learning experiences of educators and students in Kazakhstan. It calls for a comprehensive, culturally sensitive approach to ergonomic design in educational spaces. By investing in ergonomic education, research, and interventions, Kazakhstan can lead the way in creating safe, comfortable, and conducive learning environments, ultimately nurturing a new generation of healthy and productive educators and learners.

6. Conclusion

Our study provides compelling evidence for the urgent need to address ergonomic deficiencies in Kazakhstan's educational institutions. The results, based on a robust mixed-methods approach, paint a clear picture of the challenges faced by educators and students in their learning environments.

The statistically significant prevalence of physical discomfort among students (73 %, $p < 0.001$) and the widespread belief among educators that furniture lacks essential ergonomic features (62 %, $p < 0.001$) underscore the critical need for ergonomic interventions. These findings are not isolated; they are corroborated by observational data showing most classrooms (58 %) lacking adjustable furniture. Similarly, the high proportion of students reporting visual discomfort due to ineffective lighting (68 %, $p < 0.001$) and the overreliance on artificial lighting in classrooms (81 %) highlight the need for improvements in visual ergonomics. The impact of technology on educator health is also evident, with a significant majority (75 %, $p < 0.001$) reporting visual discomfort from extended screen time. The cultural dimension of ergonomics emerged as a key

consideration, with a significant proportion of educators (70 %, $p < 0.001$) emphasizing the need for regional adaptations of ergonomic principles. This underscores the importance of developing culturally sensitive ergonomic solutions tailored to Kazakhstan's unique context.

Economic constraints were identified as a major barrier, with a significant discrepancy ($p < 0.001$) between administrators' recognition of the benefits of ergonomic investments (85 %) and their ability to implement changes due to budget limitations (65 %). This calls for innovative, cost-effective solutions and a phased approach to ergonomic upgrades. Perhaps most importantly, our findings highlight the widespread lack of ergonomic awareness, particularly among students. This underscores the critical need to incorporate ergonomic education into the curriculum for future educators.

In conclusion, our study provides statistically robust evidence for the need to prioritize ergonomics in Kazakhstan's educational spaces. By addressing physical discomfort, visual strain, technological challenges, cultural considerations, and economic barriers, and by fostering ergonomic awareness, Kazakhstan can create learning environments that promote health, well-being, and optimal learning outcomes. This transformative approach to educational ergonomics has the potential to set a new standard not just for Kazakhstan, but for the broader Central Asian region. By investing in the ergonomic health of its educators and students, Kazakhstan can cultivate a new generation of healthy, productive, and innovative learners and leaders.

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