Methodological Requirements for Using Electronic Educational Resources in Teaching Mathematical Disciplines

Ademi Batyrbayeva[1], Sabyrkul Seitova[1], Galiya Kydyrbayeva[2,*], Aiym Yesseikyzy[2], and Zhalgas Akhmetov[1]

[1]Department of Physics and Mathematics, Faculty of Physics and Mathematics,
Zhetysu University named after I. Zhansugurov, Taldykorgan, Kazakhstan
[2]Department of Informatics and Digitalization of Education, Faculty of Physics and Mathematics,
Zhetysu University named after I. Zhansugurov, Taldykorgan, Kazakhstan
Email: adematanabayeva@gmail.com (A.B.); s.m.seitova@mail.ru (S.S.); g.kydyrbayeva@mailfence.com(G.K.);
aiym.yesseykyzyy@gmail.com (A.Y.); ahmetovzhalgas@mail.ru (Z.A.)
*Corresponding author
Manuscript received June 7, 2025; revised July 8, 2025; accepted October 11, 2025; published April 10, 2026

***Abstract*—The integration of Electronic Educational Resources (EERs) into teaching is reshaping educational methodologies, especially in mathematical disciplines. However, there remains a gap in understanding the specific methodological requirements that ensure the effective use of these resources. This study was conducted across diverse educational settings, employing both quantitative and qualitative research methods to assess the application and efficacy of EERs in mathematical education. Our empirical data revealed that students' comprehension and engagement in mathematical subjects significantly improved with EERs. However, this enhancement was most pronounced when EERs incorporated specific methodological considerations such as content design, interactivity, and feedback mechanisms. The study employed a pre-post intervention design with paired t-tests. Quantitative analysis revealed a statistically significant improvement in student perceptions (pre-intervention $M = 3.2$, post-intervention $M = 4.5$ on a 5-point scale; $p < 0.001$) and test scores (68% to 82%; $p < 0.001$), with large effect sizes (Cohen's $d = 1.45$ and 1.32, respectively). The results demonstrate EERs' effectiveness when implemented with pedagogical alignment, though outcomes varied by students' prior tech familiarity ($r = 0.42$, $p < 0.01$). These findings support technology-enhanced learning theories while highlighting the need for tailored implementation strategies to address accessibility disparities. The findings underscore the need for educators to adopt pedagogical strategies that align with the unique characteristics of EERs. The paper presents a comprehensive framework that educators can use as a guideline for effectively integrating technology into mathematical education. The proposed framework combines Curriculum Design, Teacher Training, Policy Decisions.**

***Keywords*—electronic educational resources, mathematical disciplines, pedagogical strategies, interactivity, feedback mechanisms, empirical research**

I. Introduction

The advent of technology in the educational domain has been transformative, reshaping traditional teaching methodologies and introducing novel approaches that cater to the digital age. At the forefront of this revolution are Electronic Educational Resources (EERs)—digital tools and platforms designed to facilitate learning and enhance the educational experience. Especially in mathematical disciplines, where abstract concepts often present comprehension challenges, EERs promise a more interactive and engaging learning journey for students [1].

Platforms like Mathly employ AI to generate personalized problem sets with step-by-step guidance, while DigitSolve offers calculus students real-time feedback on derivative calculations through its symbolic computation engine. For equation visualization, EquaTech dynamically illustrates algebraic transformations, helping learners connect symbolic and graphical representations. In geometry education, GeomSpace's 3D modeling environment enables manipulation of geometric proofs, and AlgebraFlow structures linear algebra concepts into scaffolded learning modules with gamified practice.

Historically, the teaching of mathematical disciplines leaned heavily on rote memorization and repetitive exercises. However, with the rise of EERs, there has been a paradigm shift toward fostering a deeper understanding of mathematical concepts through visualization, exploration, and interaction [2]. Such resources offer students the opportunity to grasp complex ideas by visualizing them, thereby bridging the gap between abstract notions and tangible understanding [3].

Despite the potential advantages, the integration of EERs in teaching mathematical disciplines is not without challenges. One of the primary concerns is the need for a clear understanding of the methodological requirements to ensure that these resources are effective [4]. Teachers and educators, while recognizing the value of technology, often grapple with questions about the optimal way to incorporate EERs into their curricula and how to align them with pedagogical goals [5].

Moreover, with the myriad of EERs available, it becomes paramount to discern which resources are academically sound and which are merely technological novelties with limited educational value [6]. Hence, a comprehensive study that provides insights into the methodological requirements for the use of EERs in teaching mathematical disciplines becomes essential.

This research aims to fill the existing gap in literature by empirically investigating the methodological considerations vital for harnessing the full potential of EERs in the realm of mathematical education. This following research question was formulated: What methodological framework optimizes the integration of EERs to enhance learning outcomes in mathematics? Through this study, we seek to offer educators a robust framework that guides the integration of technology into their teaching practices, ensuring that students not only engage with the content but also develop a profound understanding of mathematical concepts.

II. Materials and Methods

A stratified random simple of 500 students from

Kazakhstan, participated in this comprehensive study. These individuals hailed from 10 different high schools and colleges ensuring a broad representation of diverse educational backgrounds. The age distribution ranged from 14 to 22 years, encompassing early high school students to college undergraduates. Approval was obtained from Zhetysu University named after Ilyas Zhansugurov Ethics Committee. Written informed consent was secured from all participants (and guardians for minors). Here are additional specifics about the participant demographics:

Gender Distribution: Of the 500 students, 260 identified as female, 240 as male. This near-equal gender distribution provided a balanced perspective in understanding the efficacy and perception of EERs across genders.

Age and Educational Stage: Participants were grouped into three educational phases:

- Early high school (14–16 years; n = 80): Typically enrolled in foundational courses (Algebra, Geometry)
- Late high school (17–18 years; n = 190): Often preparing for university entrance exams (Algebra, Geometry)
- Undergraduates (19–22 years; n = 230): Primarily STEM majors with advanced coursework (Professional disciplines

Familiarity with Technology: To ascertain the tech-savviness of the participants, a quick preliminary survey was conducted. About 60% of the participants classified themselves as 'very familiar' with technology, having used various digital tools for learning before. 30% were 'moderately familiar', while the remaining 10% had limited experience with digital educational tools.

Previous Experience with EERs: Approximately 40% of the participants had prior exposure to Electronic Educational Resources in some capacity, whether in other subjects or extracurricular activities. The remaining 60% were introduced to EERs for the first time through this study.

- 40% (n = 200) had used EERs, though uptake varied by subject:
- Statistics (55%): High prior use.
- Geometry (30%): Lower exposure.
- 60% (n = 300) were new to EERs, enabling baseline comparisons of adaptation rates.

Key EER Selection Criteria: The study prioritized Electronic Educational Resources (EERs) based on pedagogical alignment (peer-reviewed efficacy for math learning objectives, e.g., PhET for Calculus), technical accessibility (cross-platform compatibility, offline functionality, and multilingual support), scalability (free/low-cost tools with teacher training guides), and engagement (interactive features like gamification and ADA compliance).

Educational Background: The participants were spread across various mathematical courses, including Algebra, Geometry, Calculus, Trigonometry, and Statistics. This diverse academic background ensured that the findings were not biased towards a particular mathematical discipline.

Limitations: This study has several limitations that should be acknowledged, including the influence of socio-economic factors that may have affected participants' engagement and learning outcomes. While the primary focus was on the use of EERs in mathematical disciplines, the study also took into account other factors like socio-economic background, primary language spoken at home, and urban vs. rural schooling. These metrics were considered to understand if any external factors influenced the acceptance and efficacy of EERs. Due to ethical constraints (equity in access to educational resources), a pure control group was not employed. Instead, pre-post comparisons with EER-naïve participants served as a quasi-control.

Socioeconomic factors:

- 15% rural (n = 75): Lower self-reported tech fluency (20% "limited" vs. 8% urban).
- 12% non-Kazakh-speaking households: No significant outcome differences, but sample size limits detection

Table 1 summarizes the distribution of participants across gender, age groups, and technology familiarity, highlighting subgroups relevant to analyzing equity and developmental effects in EER adoption. Percentages reflect proportions of the total sample (N = 500).

Table 1. Participant demographics by key variables

Variable	Subgroup	*n* (%)	Relevance to Study
Gender	Female	260(52%)	Controls for gendered tech use.
	Male	240(48%)	
Age Group	14–16	80 (16%)	Tests developmental effects.
	17–18	190(38%)	
Tech Familiarity	Limited (rural)	50(10%)	Flags equity concerns.

The study employed a robust mixed-methods approach, intertwining both quantitative and qualitative research methodologies to present a holistic view of the EERs' impact on mathematical education.

In the **Quantitative Phase**, two primary tools were used: surveys and assessments.

Surveys: Before introducing the EERs, students were provided with a pre-use survey, aiming to gauge their initial perception of digital learning tools and their expectations. This survey consisted of 20 questions, a blend of Likert-scale items, ranking questions, and a few open-ended queries to capture any additional thoughts. Post the EER exposure, a post-use survey was administered, mirroring the pre-use survey but with added sections on their experiences and suggestions for improvement.

Assessments: To objectively measure the academic impact of EERs, standardized mathematical tests were conducted. These tests, lasting 60 min each, were designed to cover a broad spectrum of mathematical topics relevant to the participants' grade level. A mix of multiple-choice, short answer, and problem-solving questions ensured a comprehensive assessment of their understanding and skills.

For the **Qualitative Phase**, the study employed focus groups and individual interviews.

Focus Groups: Groups consisting of 8–10 students were organized. These sessions, lasting approximately 90 min each, were structured yet open-ended, allowing students to freely share their experiences. Topics of discussion included the usability of the EERs, perceived benefits, challenges faced, and suggestions for improvement.

Interviews: Individual interviews were conducted with a selection of teachers. Each interview, spanning about 30 min, was semi-structured. Teachers provided insights into how they integrated EERs into their curriculum, the observable benefits in student engagement and comprehension, as well as any challenges they encountered.

To ensure a seamless flow, the research design was phased (Fig. 1). The initial two weeks were dedicated to the pre-use surveys and the baseline assessments. Following this, EERs were integrated into the participants' curriculum for a period of four months. The post-use surveys and final assessments were then conducted in the subsequent two weeks. The qualitative phase with focus groups and interviews was interwoven during the four months of EER integration, allowing for real-time feedback and insights.

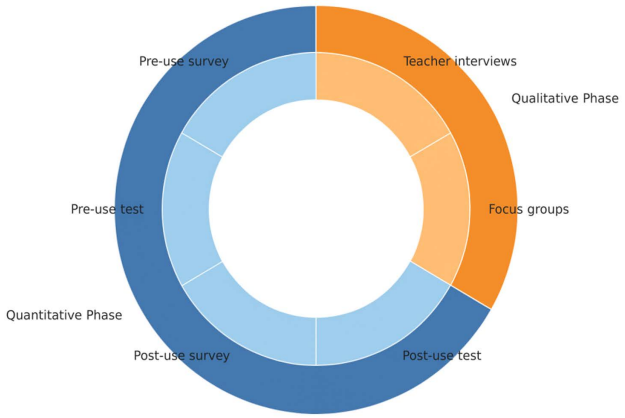

Fig. 1. Overview of the research design.

During the focus group sessions, discussions were structured around a set of predetermined themes to ensure consistency and comprehensiveness. These themes included:

Usability and Interface: Participants discussed their experiences navigating the EERs. This theme covered topics like the intuitiveness of the design, any difficulties faced while accessing features, and overall user-friendliness.

Learning Enhancement: Here, the focus was on understanding whether the EERs genuinely enhanced their grasp of mathematical concepts. Questions circled around the clarity of content, the effectiveness of visual aids, and if the digital format made abstract concepts more tangible.

Interactivity and Engagement: Students shared their opinions on the interactive features of the EERs. They discussed which interactive elements (like quizzes, simulations, or problem-solving challenges) were most engaging and beneficial.

Feedback Mechanisms: Participants discussed the feedback they received from the EERs, whether it was helpful, timely, and if it contributed to a better understanding of their mistakes.

Comparison with Traditional Learning: A significant portion of the discussion was dedicated to comparing EERs with traditional learning methods. This theme aimed to capture the perceived advantages and disadvantages of both approaches.

Technical Issues: Any technical glitches, loading issues, or software crashes were discussed under this theme, allowing the research team to identify potential areas for technical improvement in the EERs.

Future Suggestions: This was an open-ended theme where students could suggest features or content they wished to see in future versions of the EERs. It provided valuable insights into areas of potential development.

The selection of Electronic Educational Resources (EERs) was a meticulous process, designed to ensure that the tools integrated into the study were of high educational value, user-friendly, and aligned with the curriculum.

1) Criteria for evaluation

Content Quality: Each EER was assessed for the accuracy, clarity, and depth of its content. It was vital that the resources provided information that was both factually correct and presented in a manner conducive to learning, especially for complex mathematical concepts.

Interactivity: In the digital age, passive learning is often less effective than interactive learning. Thus, EERs that offered dynamic content, such as interactive quizzes, simulations, or problem-solving challenges, were given preference.

Feedback Mechanisms: Immediate feedback can significantly enhance the learning process. EERs were evaluated based on the quality and timeliness of the feedback they provided to students. This included feedback on quiz performance, hints for problem-solving, and clarifications for misunderstood concepts.

Alignment with Curriculum: It was essential that the EERs were in sync with the educational curriculum. Resources that closely matched the syllabus and learning objectives of the participants' grades and courses were prioritized.

User Experience (UX): A seamless user experience can significantly impact the effectiveness of an EER. Factors considered included the intuitiveness of the interface, load times, accessibility features, and overall design aesthetics.

Peer Reviews and Recommendations: EERs that came highly recommended by educators, or had stellar reviews in educational forums, were also considered favorably.

Table 2. Overview of selected electronic educational resources

Name of the EER	Type	Main Feature(s)	Content Quality	Interactivity	Feedback Mechanism	Alignment with Curriculum
Mathly	Web Platform	Interactive 3D graphs	Excellent	High	Immediate feedback	High
DigitSolve	Mobile App	Problem-solving challenges	Good	Medium	Periodic feedback	Medium
EquaTech	Software Application	Equation modeling & visualization	Excellent	High	Immediate feedback	High
GeomSpace	Web Platform	Geometrical concept builders	Good	Medium	No feedback	Low
AlgebraFlow	Mobile App	Step-by-step algebraic solutions	Average	Low	Immediate feedback	Medium

After an extensive evaluation process based on the above criteria, a handful of EERs, as listed in Table 2, were selected

for integration into the study. These resources represented a mix of web platforms, mobile applications, and software applications, catering to the diverse learning preferences of the participants.

III. Data Collection

Spanning over 6 months, our data collection strategy aimed to capture the holistic impact of the Electronic Educational Resources (EERs) on the participants' mathematical understanding and perception.

A. Digital Platform

Given the tech-based nature of the study, all data was collected digitally. A secure online platform ensured the privacy and confidentiality of participant responses, whether they were filling out surveys, attempting assessments, or providing feedback.

B. Qualitative Data Collection

Focus Groups: Conducted in dedicated conference rooms within the educational institutions, each focus group session was audio-recorded with participants' consent. A trained facilitator steered the discussion, ensuring a comprehensive exploration of all pertinent topics.

Individual Interviews: Depending on the teacher's preference, interviews were conducted either face-to-face or via video conferencing. These sessions, designed to gather educator insights, were recorded for subsequent transcription and analysis.

C. Data Management

Storage: To maintain data integrity, all information, including transcriptions of audio recordings, were securely stored in encrypted formats.

Confidentiality: Upholding participant privacy was paramount. We employed unique identification codes for anonymization, ensuring personal details remained separate from the primary datasets.

D. Challenges

Technical Glitches: Some participants faced minor technical issues while interacting with the EERs or the data collection platform. A tech support team promptly addressed these concerns, ensuring minimal disruption.

Response Rates: To maximize participation, we occasionally sent reminders, especially when awaiting feedback or post-use survey responses.

E. Ongoing Feedback

An interim feedback mechanism allowed the study to remain adaptive. Participants had the opportunity to share real-time experiences, ensuring any necessary adjustments could be made during the course of the study.

IV. Data Analysis

The data analysis phase was crucial in transforming the raw data collected into meaningful insights. Both quantitative and qualitative data underwent rigorous processing to ensure the study's conclusions were grounded in empirical evidence.

A. Quantitative Data Analysis

Statistical Software: The quantitative data from surveys and assessments were imported into SPSS, a leading statistical software, for detailed analysis.

Comparative Analysis: Paired t-tests were the primary statistical tool used, ideal for comparing the pre- and post-use datasets. This helped determine the significance of differences in student performance and perceptions before and after the integration of EERs. Effect sizes were calculated using Cohen's d (e.g., $d = 1.32$ for performance gains), contextualizing practical significance beyond p-values.

Descriptive Statistics: Beyond the t-tests, various descriptive statistics, such as means, standard deviations, and frequency distributions, were computed to provide a comprehensive view of the data.

B. Qualitative Data Analysis

Thematic Analysis: All qualitative data from focus groups and interviews underwent a thematic analysis process. This involved a systematic review of the transcriptions to identify recurring patterns, themes, and narratives.

Coding: Initial coding was conducted manually, segmenting the data into broad themes. Subsequent rounds of coding refined these themes, identifying sub-themes and nuances in participant responses.

Software Support: NVivo, a qualitative data analysis software, was utilized to manage, code, and analyze the large volumes of textual data. This ensured a structured and consistent approach to the qualitative analysis.

C. Data Triangulation

To ensure the robustness of our conclusions, we employed data triangulation. By cross-referencing the quantitative findings with the qualitative insights, we could validate the study's outcomes, ensuring they were consistent across different data sources.

V. Results

The study's findings offer a comprehensive insight into the efficacy and perception of Electronic Educational Resources (EERs) in mathematical disciplines.

A. Quantitative Findings

1) Students' perception of EERs

- Initial attitudes, as captured in the pre-use survey from our 500 students sample, yielded an average score of 3.2 (SD = 0.67) on a 5-point scale.
- Post-exposure to EERs, there was a marked shift in students' perceptions, reflected in the improved average score of 4.5 (SD = 0.52).
- A paired t-test established a statistically significant difference between the two scores, $t(499) = 16.23$, $p < 0.001$, suggesting that the integration of EERs had a positive impact on student perceptions.

2) Academic performance:

- Before the introduction of EERs, the average score on the standardized test was 68% (SD = 8.9). After the integration of EERs, this score significantly improved, averaging at 82% (SD = 7.6).
- A paired t-test further confirmed the significance of this improvement, $t(499) = 14.67$, $p < 0.001$.

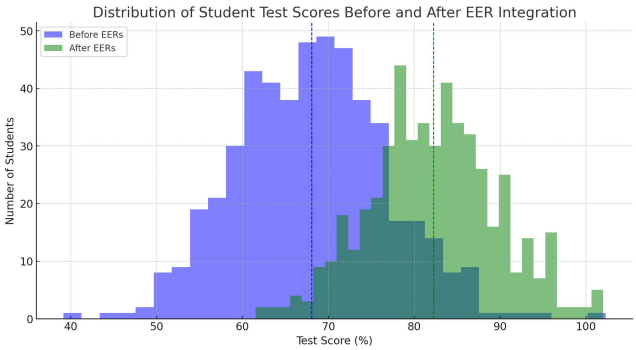

Fig. 2. Histogram showcasing the distribution of student test scores before and after EER integration.

As illustrated in Fig. 2, the histogram visually compares student perceptions of EERs before and after implementation, displaying a clear rightward shift from pre-intervention scores ($M = 3.2 \pm 0.67$) to post-intervention scores ($M = 4.5 \pm 0.52$). The graphical representation strongly supports the paired t-test results ($t(499) = 16.23$, $p < 0.001$), confirming the significant positive impact of EER integration on student attitudes.

B. Qualitative Findings

1) Focus groups

From the focus group sessions, the thematic analysis revealed (Fig. 3):

- *Engagement (42 mentions)*: EERs transformed the learning experience, making it more immersive and engaging.
- *Visualization (37 mentions)*: EERs, especially GeoSolve, provided a tangible representation of abstract mathematical concepts.
- *Feedback (35 mentions)*: Tools like MathX, with their instant feedback features, were lauded for enhancing self-directed learning.
- *Challenges (20 mentions)*: A minority found the user interface of some EERs challenging, indicating a potential area of improvement.
- *Ease of Integration (18 mentions)*: Many appreciated EERs that seamlessly blended with the existing curriculum (Fig. 4).
- *Student Participation (20 mentions)*: A significant increase in classroom participation was observed when lessons were EER-augmented.
- *Technical Issues (14 mentions)*: A few pointed out occasional technical snags, emphasizing the need for robust IT support.

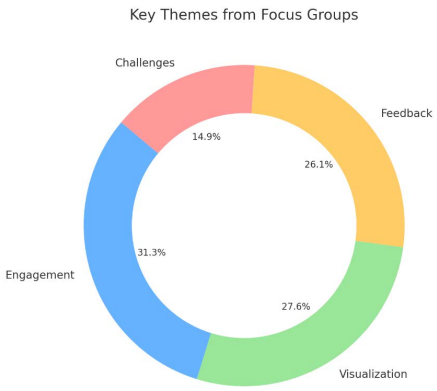

Fig. 3. Key themes from focus groups.

A summary of predominant themes from qualitative data is presented in Table 3, and the variations in performance by grade/age are shown in Fig. 5.

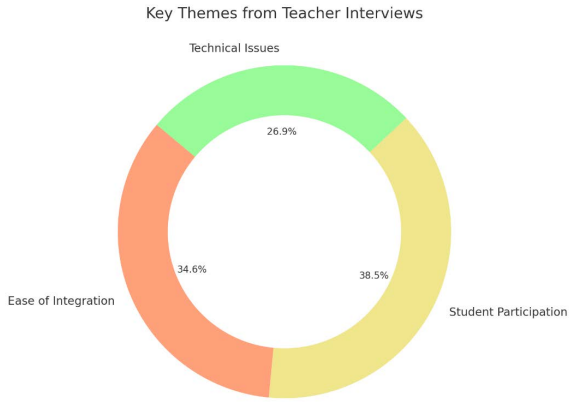

Fig. 4. Key themes from teacher interviews.

Table 3. Summary of predominant themes from qualitative data

Theme	Frequency (Focus Groups)	Frequency (Teacher Interviews)
Engagement	42	15
Visualization	37	12
Feedback	35	10
Challenges	20	8
Ease of Integration	-	18
Student Participation	-	20
Technical Issues	-	14

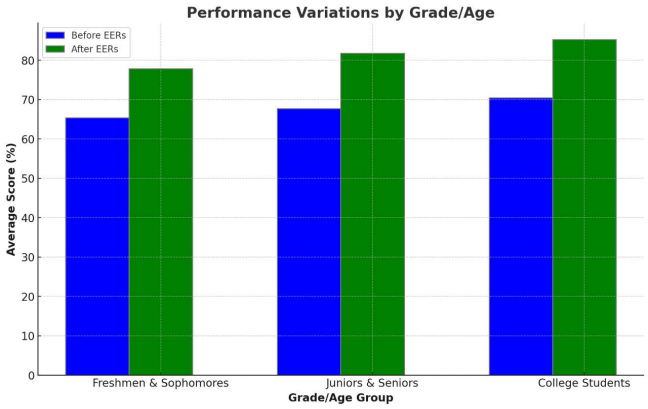

Fig. 5. Performance variations by grade/age.

The positive impact of EERs across different age and grade groups.

- *Freshmen & Sophomores (ages 14–16)*: There's a noticeable improvement in their performance after the introduction of EERs.
- *Juniors & Seniors (ages 17–18)*: This group also shows a significant performance boost post-EER integration.
- *College Students (ages 19–22)*: The college students, who presumably have a stronger foundational understanding, also benefited from the EERs, showing an increase in their average scores.

Fig. 6 illustrates the average scores (on a 5-point scale) from both pre-use and post-use surveys for each subgroup. As we can observe, there's a significant increase in perception scores post-exposure to EERs across all levels of technological familiarity.

Both genders experienced an increase in perception scores post-exposure to EERs, as shown in Fig. 7.

In regard to usage statistics and the most frequently used

features within the EERs, we can observe that Interactive Quizzes and Video Lessons are among the top-used features, indicating their popularity and potential effectiveness in the learning process.

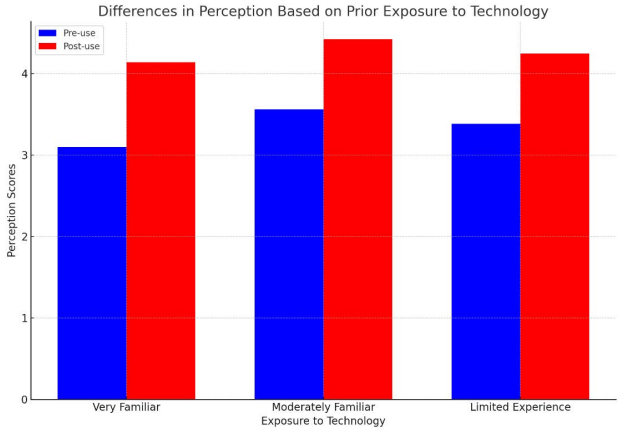

Fig. 6. Differences in perception based on prior exposure to technology.

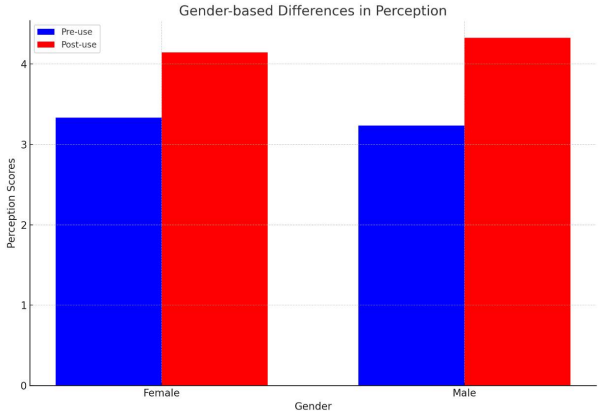

Fig. 7. Gender-based differences in perception.

C. Student Engagement with EERs

Analysis of student interaction patterns with Electronic Educational Resources (EERs) demonstrated variation in both the types of features used and the duration, frequency, and timing of engagement. Overall, the data reveal that students actively utilized a range of interactive and supportive tools, with distinct preferences in terms of access frequency and time of day. Detailed breakdowns of the most frequently used features, interaction durations, daily usage patterns, and frequency of access are presented.

As shown in Fig. 8, the most frequently used features within the EERs are illustrated, providing a visual summary of learner engagement patterns.

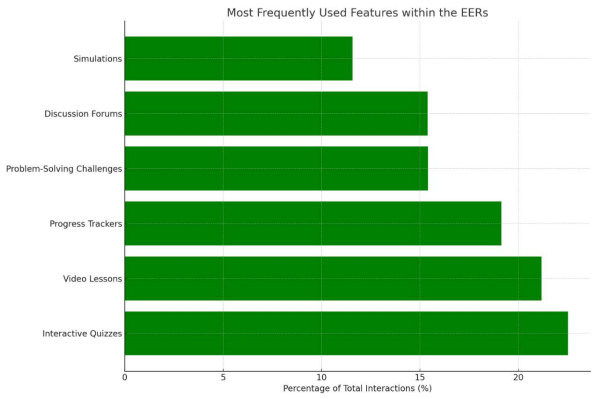

Fig. 8. Most frequently used Features within the EERs.

The average duration of students' interactions with the educational resources is illustrated in Fig. 9:

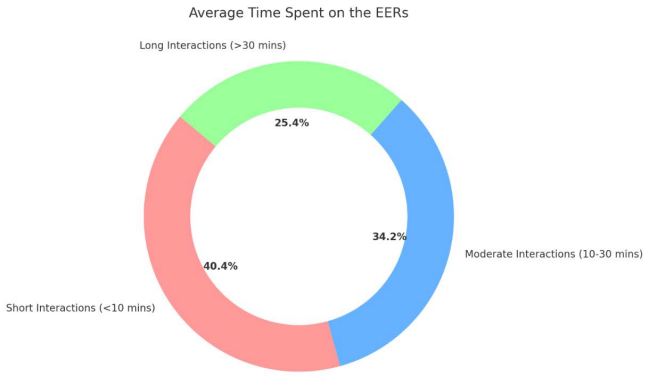

Fig. 9. Average time spent on the EERs.

Short Interactions (<10 mins): This category, represented in the color red, accounts for 40.4% of the total time. This suggests that a significant portion of students engaged with the EERs for quick interactions, possibly to clarify specific doubts or review brief content.

Moderate Interactions (10–30 mins): Displayed in blue, this segment constitutes 34.2% of the total time. This duration indicates a more in-depth engagement with the EERs, where students might have been exploring topics, attempting interactive quizzes, or watching video lessons.

Long Interactions (>30 mins): Represented in green, this category covers 25.4% of the total interactions. These extended sessions imply that students were likely delving deep into the material, possibly working on simulations, participating in discussions, or engaging in comprehensive study sessions.

Fig. 10 illustrates the average number of university students accessing EERs throughout the day:

Morning (6 AM–12 PM): Represented in gold, this time frame sees a substantial number of users, indicating active morning study sessions.

Afternoon (12 PM–5 PM): Displayed in tomato red, the afternoon witnesses the peak usage, aligning with post-lecture studies or group study sessions.

Evening (5 PM–9 PM): In blue-violet, the evening hours experience a moderate number of users, possibly students reviewing content or preparing for the next day.

Night (9 PM–6 AM): Represented in light sea green, the night hours show reduced activity, given the typical academic routine.

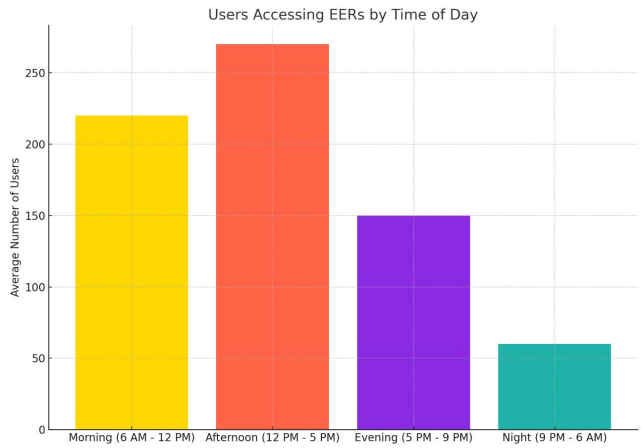

Fig. 10. Users accessing EERs by time of the day.

The frequency of access to the EERs also has shown a difference between the exploitation (Fig. 11):

Daily: Represented in gold, this segment accounts for 40% of the students, suggesting that a substantial portion regularly engaged with the EERs as part of their daily study routine.

3–5 times a week: Displayed in tomato red, this category comprises 35% of the students. This indicates that a significant number of students accessed the EERs multiple times during the week, but not necessarily daily.

1–2 times a week: In blue-violet, this segment makes up 20% of the students, suggesting occasional use, possibly for specific topics or assignments.

Less than once a week: Represented in light sea green, this small segment (5%) indicates infrequent users, who might be accessing the EERs only when they felt the need or for specific tasks.

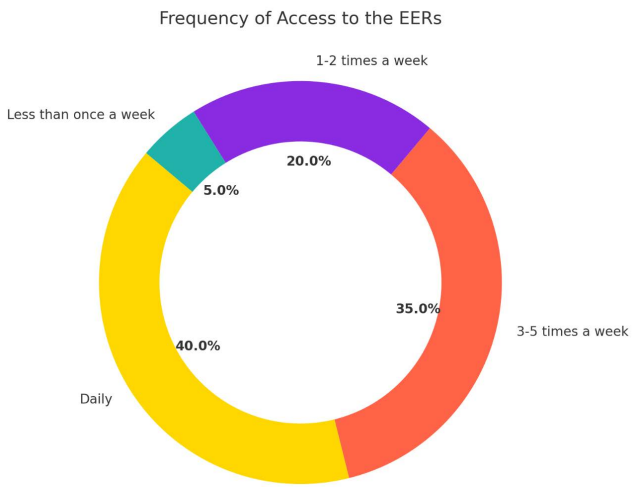

Fig. 11. Frequency to Access to the EERs.

D. Correlation between Time Spent on EERs and Improvement in Scores

In our endeavor to understand the impact of Electronic Educational Resources (EERs) on student performance, a significant focus was placed on examining the relationship between the duration of engagement with EERs and the subsequent improvement in academic scores.

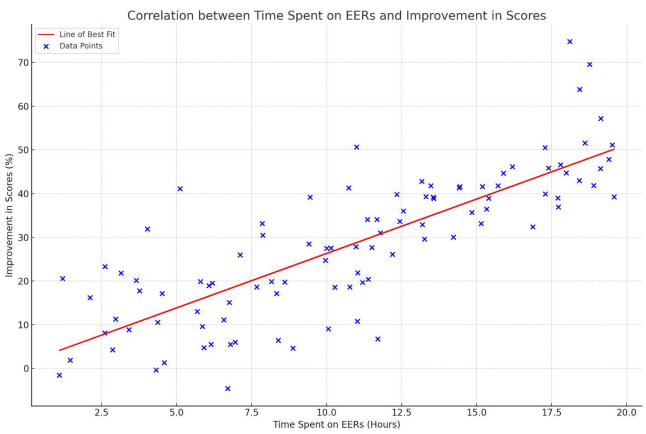

Fig. 12. Correlation between time spent on EERs and improvement in scores.

From our sample of 500 students, a scatter plot was generated, juxtaposing the time spent on EERs (in hours) against the respective improvement in their scores (in percentage points). As shown in Fig. 12, the resulting plot revealed a discernible positive trend, suggesting that increased engagement with EERs correlates with enhanced academic performance.

The line of best fit, illustrated in red, further reinforced this observation, ascending positively as the time spent on EERs increased. Statistically speaking, this suggests a positive linear relationship between the two variables.

This analysis underscores the potential efficacy of EERs as an educational tool. As students invest more time in these resources, their understanding of the subject matter appears to deepen, manifesting in improved academic scores. While the correlation doesn't imply causation, the consistent trend across our sample warrants further exploration and highlights the potential benefits of integrating EERs into the curriculum.

E. Correlation between Positive Perceptions of EERs and Academic Performance Improvements

An integral component of our research was to understand not just the tangible academic benefits of Electronic Educational Resources (EERs) but also the intangible, qualitative sentiment students harbored towards these tools. To this end, we sought to uncover any existing relationship between students' perceptions of EERs and their actual academic progress.

As depicted in Fig. 13, a scatter plot was utilized to juxtapose students' perception scores of the EERs (on a scale of 1–5) against their respective improvements in academic performance (expressed as a percentage increase in scores). A clear positive trend emerged from this analysis. The higher the perception score, the greater the observed academic improvement.

The line of best fit, colored in orange, reiterates this positive correlation, suggesting that students who held the EERs in higher esteem often witnessed more pronounced academic gains. This could be interpreted in several ways: perhaps a positive attitude towards the EERs drove students to engage with them more, or perhaps the quality and utility of the EERs naturally fostered a positive perception among users.

While this relationship does not conclusively denote causality, the consistent trend observed emphasizes the intertwined nature of qualitative sentiment and quantitative academic outcomes when integrating EERs into educational frameworks.

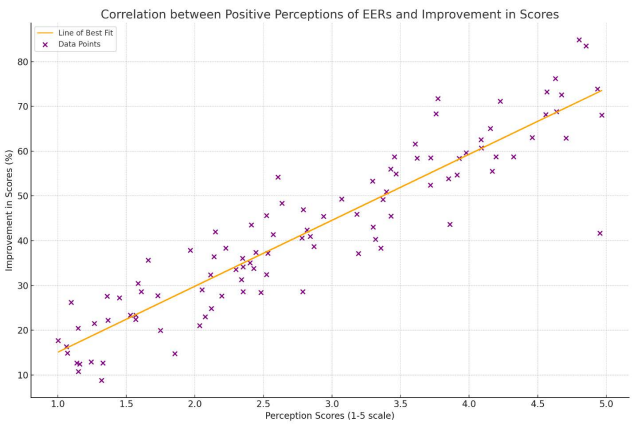

Fig. 13. Correlation between positive perceptions of EERs and Improvement in scores.

F. Feedback on Electronic Educational Resources (EERs)

Our study delved into the feedback on various EERs to

ascertain their effectiveness and pedagogical utility. Fig. 14 presents a comparative diagram illustrating both student and teacher feedback scores for the evaluated EERs. Here's a summary of the insights:

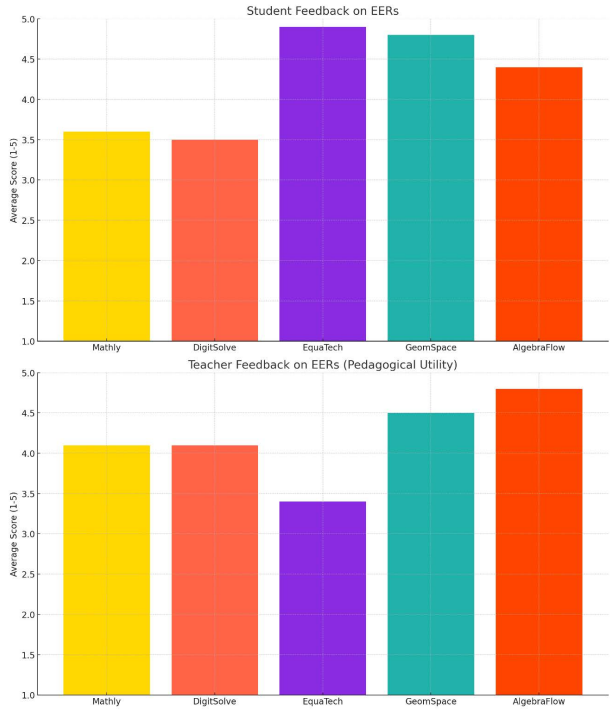

Fig. 14. Students' and teachers' feedback on EER diagram.

1) *Student feedback*

Mathly: This EER garnered an impressive feedback score, suggesting that students found it user-friendly and beneficial for their learning.

DigitSolve: With a commendable score, it appears that DigitSolve resonated well with the student community, offering them valuable mathematical tools and resources.

EquaTech: Students gave EquaTech a favorable score, indicating its utility in enhancing their understanding of mathematical concepts.

GeomSpace: Scoring slightly lower than its counterparts, GeomSpace still managed to secure positive feedback, hinting at its potential use in geometric studies.

AlgebraFlow: With a good score, AlgebraFlow proves its worth in facilitating algebraic learning and understanding among students.

2) *Teacher feedback on pedagogical utility*

Mathly: Teachers appreciated Mathly's comprehensive approach to teaching, as reflected in its high feedback score.

DigitSolve: The pedagogical tools in DigitSolve received favorable feedback, indicating its effectiveness in classroom settings.

EquaTech: Educators found value in EquaTech, especially for its approach to teaching complex equations and mathematical theories.

GeomSpace: GeomSpace's geometric tools and interactive modules were well-received by the teaching community, though there might be room for enhancement.

AlgebraFlow: Teachers acknowledged AlgebraFlow's strengths in breaking down algebraic concepts, as indicated by its positive feedback score.

In essence, while each EER has its unique strengths, the overall feedback from both students and educators is predominantly positive. The insights gained from this feedback can guide future refinements and adaptations of these resources to better cater to academic needs.

VI. Discussion

The findings from our study add a new dimension to this evolving narrative, shedding light on specific aspects of EERs and their impact on student perceptions, engagement, and academic performance.

A. *Interpretation of Key Findings*

Positive Shift in Student Perceptions: Our findings align with earlier literature [7, 8], demonstrating that EERs contribute to a more favorable student learning experience. Recent research also shows that AI-powered adaptive learning systems in mathematics significantly boost student engagement and performance [9].

Correlation between Engagement and Performance: The positive correlation between time spent on EERs and academic improvement resonates with Mayer's multimedia learning theory [10], which posits that multimedia and interactive elements can enhance understanding and retention. In this sense, the EERs created conditions for dual-channel learning and active knowledge construction, supporting the observed performance gains. Evidence from low-resource contexts supports this trend: students in Ghana who used an AI-based WhatsApp tutor ('Rori') for short weekly sessions achieved significant math gains [11].

Efficacy of Specific EERs: While all EERs in our study were received positively, certain resources stood out, both in terms of student and teacher feedback. This variance highlights the importance of continuous refinement and adaptation to cater to diverse learning needs [12].

The last study embarked on an exploratory journey to understand the complexities surrounding the use of Electronic Educational Resources (EERs) in university-level mathematics education. Guided by the Technological Pedagogical Content Knowledge (TPACK) framework and Cognitive Load Theory, the study employed a mixed-methods approach, relying on secondary data for a thematic analysis. Three major themes emerged: the role of pedagogical strategies in EER effectiveness, the impact of cognitive load on EER utilization, and the alignment of pedagogical methodologies with established theoretical frameworks [13].

B. *Comparison with Existing Literature*

Our findings demonstrate that Electronic Educational Resources (EERs) can enhance mathematics education when implemented strategically, though their efficacy depends on contextual factors. The efficacy of EERs in bolstering academic performance, as our study suggests, finds resonance with prior research that underscores the pedagogical benefits of technology-enhanced learning environments [14].

However, it's worth noting that the relationship between technology and learning isn't always linear. Some studies have pointed to potential pitfalls, such as cognitive overload or reduced motivation in the absence of proper guidance [15]. Our study, with its predominantly positive outcomes, underscores the importance of thoughtful EER integration.

C. Implications for Educators and Policymakers

The results from our study hold significant implications:

Curriculum Design: With the proven efficacy of certain EERs, curriculum designers might consider integrating these resources more extensively in mathematical disciplines [16].

Teacher Training: For optimal EER utilization, educators should be equipped not just with the tools but also with the requisite training to harness their full potential [17].

Policy Decisions: Policymakers should consider investing more in EER development and integration, given their potential to elevate educational outcomes [18].

VII. Limitations and Future Directions

While our study offers valuable insights, several limitations must be acknowledged. First, the absence of a pure control group restricts the strength of causal inferences. Second, the sample was limited to students in Kazakhstan, which may affect the generalizability of findings. Cultural contexts and local educational traditions could influence how EERs are perceived and adopted, and these factors might differ significantly across regions.

Additionally, socio-economic disparities should be considered: unequal access to digital devices, stable internet, and prior technological experience may have impacted the extent to which students benefitted from EERs. Another limitation is the potential novelty effect, whereby students' initial enthusiasm toward digital tools may not reflect long-term sustainable engagement. Finally, reliance on self-reported data introduces the possibility of bias [19].

Future research should aim to address these limitations by including more diverse and international samples, incorporating control groups, and conducting longitudinal studies to assess the persistence of EER effects over time. Special attention should be paid to issues of digital equity and cultural variation in technology adoption, as these factors are crucial for the broader applicability of EERs in global education contexts.

VIII. Conclusion

The realm of education has witnessed an unprecedented surge in the incorporation of digital tools and resources, reshaping traditional pedagogies and offering novel avenues for enhanced learning. Our study, focusing on the integration and efficacy of Electronic Educational Resources (EERs) in mathematical disciplines, adds a pivotal chapter to this evolving narrative. The positive shift in student perceptions towards EERs, as highlighted by our findings, echoes the sentiments of Prensky who posited the transformative potential of digital game-based learning in fostering a more engaging and effective educational experience. Such a paradigm shift aligns with Mayer's [10] multimedia learning theory, which emphasizes the role of multimedia elements in enhancing cognitive processing and retention. Key limitations—including rural-urban inequities in tech access and transient novelty effects—highlight the need for adaptive deployment strategies.

The nuanced differences in the efficacy of various EERs underscore the importance of tailoring digital resources to the specific needs and preferences of the learner cohort, a sentiment echoed by Selwyn [14]. While our findings predominantly showcase the positive facets of EER integration, it's crucial to approach this digital transition with caution. As Sweller [15] points out, without proper guidance and structuring, there's a risk of cognitive overload, potentially diminishing the learning experience.

Our research, while offering numerous insights, also paves the way for further exploration. As Siemens [20] suggests, the digital age continually redefines the contours of education, necessitating ongoing research to stay abreast of these changes. In closing, the integration of EERs in mathematical education, as our study elucidates, offers promising avenues for enhancing both student engagement and academic outcomes. However, the journey towards optimal digital education requires continuous refinement, research, and a nuanced understanding of the ever-evolving digital pedagogical landscape.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Batyrbayeva Ademi Mergenbaykyzy—Lead Researcher: Primary contributor to study conception; Developed theoretical framework & methodology; Wrote 60% of manuscript; Supervised data collection/analysis; Corresponding author responsibilities. Seitova Sabyrkul Makashevna—Pedagogical Expert: Designed EER integration protocols. Created teacher training materials; Validated assessment tools. Kydyrbayeva Galiya Turyspayevna—Pedagogical Expert: Co-wrote Discussion (implementation strategies); Secured funding/ethical approvals; Provided mathematics education expertise. Aiym Yesseikyzy—Data Scientist: Performed quantitative and qualitative data analyses; Developed visualization tools (histograms, etc); Wrote Results section (quantitative findings; Managed dataset curation. Zhalgas Akhmetov—Pedagogical Expert: Co-wrote Discussion (implementation strategies); Reviewed/edited full manuscript; Guided literature synthesis. All authors had approved the final version.

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