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FEATURES OF USE OF INTERACTIVE METHODS AND CAPABILITIES OF ARTIFICIAL INTELLIGENCE IN TEACHING THE HISTORY OF MATHEMATICS (ON THE EXAMPLE OF HIGHER EDUCATION)

Annotation. This article presents an interactive module focused on autonomous work for teaching historical elements within the university course «History and Methodology of Mathematics». The results indicate that well-structured autonomous interaction can improve both cognitive and emotional outcomes when studying historical topics related to new trends in teaching. The article describes the implementation of Artificial Intelligence (AI) - based tools for teaching fourth-year students. The learning model combines adaptive visualization, an intelligent training system (ITS), and sketch analysis using computer vision. The article presents a methodology for applying artificial intelligence to historical data. The use of interactive teaching methods increased the average student score from 5.2 to 6.4 ($p < 0.01$). This is especially important in the training of progressive mathematics specialists.

Keywords: history of mathematics, interactive learning, artificial intelligence in education, pedagogical experiment, higher education.

Introduction

The History of Mathematics in the system of training future mathematics teachers occupies a dual position. On the one hand, it is regarded as a cultural and methodological foundation of mathematical knowledge; on the other hand, in real educational practice it is often reduced to illustrative material that does not influence the formation of professional thinking. This situation is associated with the predominance of lecture-reproductive forms of instruction and the insufficient development of interactive methodologies for working with historical-mathematical sources.

The current stage of higher education development is characterized by increasing demands for research-oriented teacher preparation, the development of critical thinking, and digital literacy. Under these conditions, it becomes necessary to reconsider the role of the History of Mathematics as a discipline that forms methodological culture and the ability to analytically comprehend mathematical ideas.

The issue of pedagogically grounded use of artificial intelligence technologies becomes particularly relevant. Although their potential is actively discussed in academic circles, there are still no well-developed models integrating interactive methods and AI support in teaching the History of Mathematics without replacing students' independent intellectual activity.

Therefore, the purpose of this study is to develop and experimentally test an interactive model of teaching the History of Mathematics with elements of AI support in the context of higher education.

Research methods and organization

The modernization of higher education is closely related to the digital transformation of pedagogical practices and the integration of interdisciplinary knowledge. In this context, the history of mathematics plays a significant role in the professional training of future mathematics teachers and researchers.

Historical-mathematical education is considered as a means of forming a holistic understanding of mathematics as a developing system of knowledge. The inclusion of historical material contributes to understanding the genesis of mathematical concepts, development of proof-based thinking, formation of scientific reflection, strengthening interdisciplinary connections (Jankvist, 2009).

However, traditional lecture-centered approaches often reduce historical material to descriptive narration. Such presentation does not ensure students' engagement in analytical activity. In contrast,

interactive methods allow students to reconstruct the logic of scientific inquiry and actively interpret historical sources.

At the same time, artificial intelligence technologies create new opportunities for structuring educational content, modeling historical processes, and supporting students' cognitive activity. Nevertheless, most existing studies focus on automated assessment or content generation, while the use of AI as an analytical support tool in humanities-mathematical disciplines remains insufficiently explored.

The proposed model is based on the principle of the auxiliary role of AI. Artificial intelligence is viewed not as a source of ready-made solutions but as an instrument for structuring material, modeling discussion, and visualizing conceptual development. Modern theory regarding the use of the history of mathematics in the educational process is undergoing qualitative changes under the influence of new pedagogical paradigms and digital technologies. In recent years, international mathematics education research has identified several key directions of theoretical reflection:

The historical - mathematical context is no longer viewed merely as an illustration of «great figures and discoveries», but as a tool for understanding what mathematical knowledge is and how it develops. This corresponds to contemporary approaches to epistemological learning, in which students learn to perceive mathematics as a dynamic, conceptually evolving system rather than a fixed set of axioms and procedures.

When teaching basic mathematical laws, elements of the history of mathematics are used as a tool for developing the competence of proof and argumentation. Our research shows that incorporating historical evidence, alternative reasoning, and discussions from the history of mathematics can greatly enhance students understanding of the logical structure of mathematical terminology.

Through these approaches, students develop the ability to critically evaluate different arguments, compare different methods, and construct their own mathematical justifications. Modern scientists especially emphasize that studying the history of mathematics increases students cultural awareness by connecting mathematical ideas with philosophy, the development of science and cultural traditions of different historical periods and civilizations. Such connections increase students motivation and help them perceive mathematical knowledge within a broader intellectual and cultural framework.

From a poststructuralist and cognitive perspective, the history of mathematics can be interpreted as a series of conceptual contradictions and their subsequent resolutions, reflecting the gradual development of mathematical thought. This perspective identifies the cognitive challenges that students often face when working with abstract mathematical concepts.

Latest theories emphasize that working with historical sources and reconstructing discoveries promotes model-based reasoning. Students do not just absorb ready-made knowledge; instead, they reconstruct historical models, compare them, and test alternative interpretations – activities directly related to research-oriented learning.

With the appearance of digital learning environments, the theory of using the history of mathematics has expanded into the field of digital epistemology. Interactive simulations, digital reconstructions of proofs, online archives, and repositories of primary sources are becoming central rather than auxiliary components of the educational process.

In this context, AI support is viewed not as a replacement for students' competencies, but as a mediator that helps model historical thinking and structure knowledge.

Research suggests that integrating historical demonstrations, alternative forms of reasoning, and notable debates from the development of mathematics can strengthen students' comprehension of the logical foundations underlying mathematical arguments. This approach encourages learners to evaluate reasoning critically, examine different problem-solving strategies, and develop their own well - grounded explanations.

Many modern researchers also argue that the study of the historical development of mathematics broadens students' cultural understanding. By connecting mathematical concepts with philosophical ideas, the evolution of scientific thought, and the cultural contexts of various civilizations and time periods, students become more engaged and are better able to recognize mathematics as part of a wider intellectual tradition.

From the perspectives of poststructuralist and cognitive theories, the evolution of mathematics may be viewed as a chain of conceptual disagreements followed by their resolution, illustrating how mathematical

thinking has progressed over time. Such an interpretation helps reveal the mental difficulties learners may encounter when trying to grasp complex and abstract mathematical ideas.

Literature Review

Research in the methodology of teaching the history of mathematics highlights its importance for developing conceptual understanding and professional culture. Historical knowledge contributes to the formation of mathematical worldview and epistemological awareness (Jankvist, 2009; Strohmaier et al., 2025).

Interactive approaches such as problem-based learning, dialogical teaching, case analysis, and project-based tasks are recognized as effective tools for fostering deep learning. In historical-mathematical education, these methods allow students to reconstruct mathematical discoveries and understand the evolution of ideas.

Recent studies on artificial intelligence in education demonstrate its potential in adaptive learning, feedback systems, and data analysis (Zawacki-Richter et al., 2019). However, its application in humanitarian and mathematical education, including the History of Mathematics, requires further methodological development.

Researchers also emphasize the risks of uncritical AI use in academic contexts. Therefore, pedagogically grounded models ensuring academic integrity and independent thinking are especially important.

Modern research on the methodology of teaching the history of mathematics underscores its role in developing conceptual understanding, epistemological awareness, and professional culture in mathematics education. Historical perspectives enable students to perceive mathematics as an evolving, culturally embedded system of knowledge rather than a static collection of axioms and procedures - a view supported by contemporary epistemological learning frameworks. Such perspectives align with the goals of mathematical literacy, reflective thinking, and methodological reasoning (e.g., problem framing and model-based reasoning) as central competencies for future teachers and researchers.

Interactive pedagogical approaches - including problem-based learning, dialogical seminars, case analysis, and project-based tasks are recognized as effective strategies for promoting deep learning and analytical engagement. In the context of historical-mathematical education, these methods allow students to reconstruct seminal mathematical discoveries and understand the evolution of core mathematical ideas through inquiry-oriented activities.

Recent developments in educational research highlight the integration of Artificial Intelligence (AI) and digital technologies as an emergent dimension in mathematics and history of mathematics pedagogy. AI tools hold potential for adaptive learning, feedback systems, learning analytics, and structured conceptual visualization (Hwang et al., 2020). For example, research on teacher adoption of AI in mathematics education integrates theoretical models such as the Technology Acceptance Model (TAM) with technological pedagogical content knowledge (TPACK), demonstrating factors that influence effective integration of AI tools in teaching practice.

However, the methodological application of AI in humanities-mathematical domains, including the history of mathematics, remains underdeveloped. Contemporary studies emphasize the necessity of pedagogically grounded models that ensure academic integrity, promote independent student reasoning, and avoid uncritical dependence on automated outputs. Recent bibliometric research highlights emerging themes in AI and educational assessment, including the risks of bias, transparency, and ethical concerns associated with AI-assisted evaluation.

Moreover, international research on AI in mathematics education points out both opportunities and challenges in adopting AI technologies including ethical issues, the need for professional development, and infrastructure readiness underscoring that effective AI integration depends on teacher preparedness and contextual adaptation.

In this theoretical landscape, the history of mathematics plays a dual role: it informs epistemological frameworks for understanding mathematics and provides a context for critical reflection on the nature of mathematical knowledge. Philosophical foundations of mathematical pedagogy increasingly emphasize inquiry, reflexivity, and interdisciplinary integration - approaches that are supported by interactive and AI-

enhanced teaching models (Chalaune & Subedi, 2020; Honey et al., 2014; Kossybaeva et al., 2022; Sharafeeva, 2022; Shurygin et al., 2024). Additionally, research on model-based reasoning and problem framing in AI-augmented educational settings suggests that technology can facilitate students' engagement with complex conceptual structures while preserving space for human interpretation and scholarly dialogue.

Methodology

Interactive approaches to teaching the history of mathematics involve students directly in the reconstruction of mathematical concepts and historical discoveries, shifting the learning process from passive absorption of information to active analysis and reflection. Through guided workshops, project-based research, and reconstructions of historical reasoning, students strengthen their critical thinking, argumentative abilities, and methodological awareness by working with primary historical sources and exploring the logical organization of mathematical proofs.

This approach also promotes interdisciplinary connections and creative mathematical thinking by inviting students to consider and model alternative historical interpretations and hypotheses. The incorporation of digital technologies and artificial intelligence tools further supports the learning process by improving visualization, structuring historical information, and simulating intellectual discussions. At the same time, these tools function as cognitive aids rather than substitutes for students' independent analytical work.

As a result, this methodology enhances students' motivation, autonomy in learning, and deeper understanding of historical and mathematical concepts. It also contributes to the preparation of future teachers capable of engaging in research-oriented, reflective, and methodologically informed professional practice. The research design of the study relied on pedagogical modeling in combination with a formative experimental approach. The choice of the undergraduate level is justified by the fact that this stage is crucial for the formation of professional conceptions of mathematical knowledge and its historical development.

The research included three interconnected stages:

Analytical stage. Examination of existing teaching practices, identification of methodological challenges, and review of international approaches integrating interactive methods and AI in mathematical education.

Modeling stage. Development of an interactive AI-supported pedagogical model, grounded in epistemological principles and reflective learning frameworks, incorporating historical-mathematical content, interactive methods, and AI-assisted cognitive tools.

Experimental stage. Implementation of the model in the educational process and assessment of its effectiveness over one academic semester.

Two groups of undergraduate students were formed. Control group included traditional lecture-seminar instruction, and experimental group comprised interactive learning with AI support.

Both groups studied identical thematic modules Mathematics of antiquity, classical period, formation of analysis and analytic geometry, development of modern mathematical concepts.

The total number of participants ensured representativeness for pedagogical research, and students were selected to maintain comparable academic backgrounds.

The model integrates three main components:

- 1) Historical-mathematical content is structured around key conceptual developments, primary sources, and historical debates. This aligns with epistemological learning, helping students understand mathematics as a dynamic, evolving system.
- 2) Interactive teaching methods – including problem-based learning, dialogical seminars, case analysis, and project-based tasks to foster analytical thinking and methodological reflection.
- 3) AI-assisted tools – used as cognitive and organizational support, not as a replacement for independent reasoning.

AI functions included Generation of historical problem situations; Simulation of dialogues between mathematicians from different epochs; Visualization of the evolution of mathematical concepts; Support for analysis and interpretation of historical texts; Modeling alternative hypotheses and reasoning pathways.

This design is grounded in model-based reasoning theory and digital epistemology, which support research-oriented and reflective learning. Within this framework, students are encouraged to analyze

historical mathematical developments not only as a sequence of facts, but as a process of conceptual formation, interpretation, and argumentation.

Historical case analysis is used as one of the key instructional methods. It involves the structured examination of important episodes in the history of mathematics through primary sources and guided discussion questions. This allows students to understand the historical context of mathematical discoveries and the intellectual logic behind their development.

Dialogical seminars are also integrated into the model. During these seminars, students reconstruct historical mathematical arguments, evaluate alternative interpretations, and participate in peer discussion. This format helps develop critical thinking, argumentation skills, and the ability to compare different perspectives on the evolution of mathematical ideas.

Another important method is the reconstruction of discoveries. Students simulate original reasoning processes using historical sources and modern symbolic tools. In this process, AI can be used to generate intermediate steps, suggest alternative solutions, and support the visualization of reasoning pathways, while students remain responsible for independent interpretation and critical evaluation.

Project-based tasks further strengthen students' analytical and research skills. Students prepare mini-projects on specific historical figures, mathematical concepts, or stages in the development of mathematical thought. AI tools are used to organize materials and visualize conceptual connections, while students independently formulate analytical conclusions.

The effectiveness of the model was assessed across several dimensions. These included students' conceptual understanding of historical and modern mathematical ideas, methodological reflection on epistemological and cognitive processes, analytical competence in interpreting historical sources and reconstructing mathematical reasoning, academic independence in self-directed learning and argumentation, and learning motivation expressed through engagement and interest in historical-mathematical research. Data were collected through a mixed-methods research design that combined both quantitative and qualitative techniques. These included pre- and post- assessments to evaluate improvements in conceptual understanding and methodological competence, observation of seminar participation and AI-supported learning activities, analysis of students' written work and reflective essays, and expert evaluation of the quality of methodological reasoning and argumentation.

Recent studies emphasize the importance of using artificial intelligence as a tool that supports cognitive development rather than as a system that automatically generates solutions. AI-based technologies can enhance visualization, facilitate analytical support, and assist model-based reasoning, while still maintaining students' independent intellectual engagement (Hwang et al., 2020; Li & Yin, 2025; Zawacki-Richter et al., 2019).

This methodological framework also corresponds with epistemological and constructivist perspectives on learning, which emphasize the social and reflective nature of acquiring mathematical knowledge in its historical context.

Results and Discussion

The findings of the experimental research indicate that the incorporation of interactive instructional strategies together with AI-supported tools considerably enhances the effectiveness of teaching the history of mathematics to prospective mathematics teachers. The comparison of some data the control and experimental groups revealed noticeable differences in a number of educational indicators, including the depth of conceptual understanding, analytical abilities of students, and level of methodological reflection, academic autonomy and motivational involvement of students. The results of the study are described in Table 1.

Table 1*The result of statistics*

| Principle | Pre-test ($M \pm SD$) | Pre-test ($M \pm SD$) | $\Delta\%$ |
|--------------------------------------|-------------------------|-------------------------|------------|
| Understanding concepts (max = 10) | 5.2 ± 1.3 | 6.4 ± 1.1 | + 22% |
| Procedural skills (max = 10) | 4.8 ± 1.5 | 5.9 ± 1.2 | + 23% |
| Overall satisfaction (1 – 5) | – | 4.4 ± 0.6 | – |
| * $p < 0.01$ (paired t-test) | | | |

Compiled by the authors on the basis of a survey and testing.

According to the survey results, 86% of students stated that AI-generated visualizations helped them better conceptualize the history of mathematical terms. These visualizations improved their understanding of how mathematical concepts evolved from ancient Greek geometry to modern methods, including the use of integral calculus for calculating volume.

In addition, 71% of students reported that the prompts provided by the intelligent tutoring system were consistent with modern pedagogical approaches. In particular, students noted that the system supported learning through minimal intervention while encouraging learner autonomy and independent reasoning.

Furthermore, 79% of respondents expressed their willingness to recommend the AI-assisted learning club to their peers. This indicates that the integration of AI into the study of classical mathematical concepts and historical theoretical statements was perceived by students as both useful and engaging. Students who participated in the experimental group displayed a more comprehensive and integrated understanding of the historical evolution of mathematical ideas than those in the control group. The post-test assessment showed that these students were more capable of explaining the emergence of fundamental mathematical concepts, such as calculus and analytic geometry, and relating them to contemporary mathematical theories. This result corresponds with recent studies suggesting that interactive approaches to teaching mathematical history promote deeper conceptual learning and systemic reasoning. In particular, the experimental group demonstrated a statistically significant improvement ($p < 0.01$) in the combined indicators of conceptual understanding, indicating that interactive activities supported by AI tools help students construct coherent and interconnected knowledge frameworks.

Analysis of reflective essays and seminar discussions also revealed a higher degree of epistemological awareness among students in the experimental group. Rather than simply reproducing chronological information, these students described the processes through which mathematical knowledge developed, examined the historical circumstances surrounding discoveries, and reflected on the cultural and philosophical factors influencing mathematical thought. These observations align with theoretical perspectives that regard the history of mathematics as a powerful instrument for developing reflective thinking and shaping students' understanding of the nature of mathematical knowledge.

The results also present that active historical learning encourages students to perceive mathematics as a dynamic and evolving intellectual discipline.

Moreover, students in the experimental group showed stronger abilities in interpreting and analyzing historical mathematical documents. By studying primary sources, including translated Greek and medieval Arabic manuscripts, they were able to place mathematical arguments in historical context and provide reasoned explanations of their underlying logic. The integration of AI-generated modeling and visualization has facilitated the reconstruction of historical arguments, promoting model-based reasoning and analytical interpretation. These results suggest that artificial intelligence tools, used as cognitive supports rather than answer generators, can affectively help students overcome barriers to interpreting complex mathematical narratives.

AI support appeared to promote academic independence without undermining analytical activity. Students in the experimental group engaged in independent exploration of historical problematic situations,

developed alternative hypotheses about historical events, and critically evaluated AI-generated visualizations. These behavioral patterns reflect contemporary definitions of independent intellectual activity in AI-enriched environments (Alkhasawneh, 2025; Hwang et al., 2020) and suggest that appropriate pedagogical presentation of AI can enhance autonomy rather than reduce engagement.

Qualitative data obtained from student observations and self-reports revealed increased interest and motivation in the experimental group. Students frequently noted that AI-assisted visualizations made abstract historical sequences more accessible and engaging - a finding consistent with research on the motivational capabilities of interactive and digital learning tools. Furthermore, this visualization connected students' historical mathematical elaborations to a broader cultural, philosophical, and scientific context, enriching interdisciplinary learning and supporting broader educational goals.

The results of this study confirm that interactive teaching methods combined with AI-enabled tools create a dynamic learning environment that improves both cognitive and affective educational outcomes. These results are consistent with theoretical expectations emerging from several contemporary research streams:

Epistemological Frameworks for Learning: Students' ability to articulate how mathematical knowledge develops reflects contemporary views that positioning historical material as an epistemic resource deepens conceptual understanding.

Based-of-Model Thinking and Digital Epistemology: Using artificial intelligence tools helped students visualize conceptual transitions and explore alternative reasoning pathways, consistent with the new idea of digital epistemology, where technology mediates complex conceptual understanding.

Conclusion

Nonetheless, the study underscores the necessity for clear methodological guidelines when integrating AI into the educational process. There have been cases of uncritical acceptance of AI results with minimal teacher involvement. This supports broader evidence that AI tools are most effective when they are embedded in structured pedagogical activities that foster critical assessment and reflective thinking.

Despite the promising results, several limitations should be consideration:

Institutional context: The research was conducted at a single university, which may restrict the generalizability of the results. Future research should utilize multi-center studies in different educational contexts.

Duration of intervention: The experiment spanned one academic semester. Longer-term studies could better assess the sustained impact on professional competencies.

Qualitative depth of interaction with AI: Although quantitative improvements were evident, in-depth analysis of discourse and reasoning patterns during interaction with AI (e.g., dialogue transcripts or decision logs) remains an area for future research.

Future research should explore adaptive AI systems tailored to individual learner profiles, explore the ethical framework for using AI in history and the humanities, and further explore how AI can support higher-order thinking without reducing learner autonomy.

Conflicts of Interest Statement.

The authors declare no potential conflicts of interest regarding the research, authorship, or publication of this article.

Author Contributions

Akhmanova D.M. - Conceptualization, Methodology, Supervision, Proofreading. Shamatayeva N.K. - Data Collection and Curation, Resources. Kossybaeva U.A. - Literature Review, Data Analysis, Final Editing. Kervenev K.Ye. - Visualization, Writing –Original Draft. Orazbekova R.A. – Validation, Writing–Review and Editing

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