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ARTIFICIAL INTELLIGENCE TOOLS INTO HIGHER MATHEMATICS EDUCATION: OPPORTUNITIES, CHALLENGES, AND STUDENT PERCEPTIONS

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Abstract. The article examines the use of artificial intelligence (AI) tools in higher mathematics education, focusing on the opinions and experiences of Bulgarian students. The research aims to explore how they impact on personalized learning, student engagement, skill development, and ethical challenges. An online questionnaire with 20 closed questions and three demographic questions distributed among students from three universities in Bulgaria was used for data collection. The analysis shows that students use AI tools such as ChatGPT and Photomath for learning purposes but perceive them more as a supplement to traditional methods rather than a core component of learning. Although 52.3% of respondents believe that AI tools is effective, 34.1% disagree. The students also note that AI tools cannot fully replace human understanding, and there are ethical concerns surrounding its use.

Keywords: artificial intelligence tools; higher mathematics

1. Introduction

The advent of artificial intelligence (AI) has ushered in a new era of opportunity in many fields, including education. Through machine learning and deep learning algorithms, AI supports the understanding and teaching of complex mathematical concepts by creating adaptive learning materials and providing intelligent support systems for students. AI tools could analyse learning data and predict academic success, thus assisting educators in improved educational processes and reduction of knowledge gaps. These innovations not only facilitate teaching but also motivate students and make learning interesting and accessible. Exemplifications of adaptive learning systems that can be used in HM education are ALEKS[1], MyMathLab[2], and WebAssign[3]. Some studies conducted in recent years indicate that the following artificial intelligence technologies are used by students in their HM learning: Wolfram Alpha[4], Desmos[5], Symbolab[6], Photomath[7], Maple Calculator[8], Mathway[9], and Microsoft Math Solver[10] (Dhivya 2024; Manrique & Palomares 2024).

AI tools used to teach higher mathematics have several fundamental aspects that make them very beneficial during the learning process. They offer adaptive learning materials that respond to individuals' particular needs by analysing their progress and making individualized recommendations. Interactivity is also vital, with tools frequently featuring visualizations and simulations to help students learn complex mathematical topics. They provide fast feedback, allowing students to quickly fix their mistakes and consolidate their information. AI tools may also automatically grade coursework, saving educators time and assuring objectivity. They can analyse enormous amounts of data to identify patterns and trends that would be impossible to spot manually. Students can use the tools to collaborate on assignments and projects in real time. Finally, these tools are frequently available online and on mobile devices, allowing students to learn whenever and wherever they want, with access to a wealth of resources such as video tutorials, articles, and interactive exercises.

The use of AI tools in higher mathematics education presents education with several challenges and problems. First, technical difficulties can interrupt the learning process. There is also the risk of over-reliance on technology, which can reduce students' ability to solve problems independently and develop critical thinking. Another important concern is the protection of personal data, as AI tools collect and analyse large amounts of information about students. Unequal access to modern technology can deepen social and economic inequalities in education. Additionally, AI tools cannot always accurately identify students' individual needs and learning styles, which can lead to inappropriate recommendations and learning difficulties. The integration of AI can reduce the personal contact between teachers and students, which is important for developing critical thinking and motivation.

Training educators to effectively use AI tools also requires additional effort and time. Issues of transparency and understanding of the processes of AI systems create ethical and methodological challenges. Finally, the integration of AI into the curriculum may require significant changes in teaching methodologies, challenging educational institutions and their traditional approaches. All these factors highlight the need for careful planning and management of the implementation of AI tools in higher mathematics education to ensure that they truly contribute to the quality of education without creating new problems.

The importance of researching the application of AI in higher mathematics education stems from the growing need for innovation and efficiency in education. In Bulgaria, such research is especially needed to modernize the educational process and meet world standards in education.

2. Related Works

The literature review on AI tools used in higher mathematics education includes a considerable quantity of research that covers the opportunities and challenges of implementing AI tools in this area. One of the most significant elements influencing students' mathematical achievement is a lack of specialized help tailored to their specific needs. The objectives of this review are to explore the four main aspects of adopting AI tools in higher mathematics education: personalized learning experiences, improved student engagement, improved skills, and ethical considerations.

According to research, AI tools could improve the educational process by offering more *individualized learning experiences* and making content and resources more accessible. One example is the MathE platform, which was created in 2019 and is intended to help students who are having problems learning higher mathematics or who wish to expand their knowledge of various mathematical topics.

The article (Azevedo et al. 2024) presents data stored in the MathE platform from 372 students from 8 countries who provided 9546 responses to 833 questions, which are used to explore active learning tools. The data provides valuable information about how students from different countries engage with and respond to math questions, helping educators and researchers understand learning behaviors, preferences, and challenges. This data covers responses from students in eight countries, providing a global perspective on instructional trends and challenges in mathematics education while allowing for cross-cultural comparative analyses. Observations on the *effectiveness of personalized learning* show how students choose topics, levels of question difficulty, and pace of learning, which contributes to the discussion of educational technology and personalized learning approaches.

Previous research has shown the potential of AI tools to facilitate the development of complex skills such as critical thinking. Likewise, AI applications as intelligent learning systems can provide personalized instruction and feedback to students on their complex tasks. It can stimulate students' critical thinking by challenging them with questions appropriate to their skill level (Cotton et al. 2023). Moreover, as an intelligent conversational agent, they can provide valuable opportunities for students to improve their argumentation skills through practical exercises. Although AI applications can assist in the development of complex learning outcomes, they are less competent in content that requires higher order thinking skills, such as analytical thinking (Rudolph et al. 2023). This is due to their high reliance on the data they are trained on, without a deep understanding of the context and common sense that are essential in this case.

The review of publications (Hwang & Tu 2021) determined that AI tools

has considerable potential to improve learning outcomes and the development of higher cognitive skills in students. Students can use AI tools *to improve their skills and grasp of complicated ideas.* It discovers that most research on AI in mathematics education has been published by researchers in the domains of education and educational technology, emphasizing the need for greater participation by mathematics researchers. The authors classify the studies they reviewed into three main clusters: "AI-based learning systems", "personalized/adaptive learning", and "learning strategies and models". They find that the most studied topics are related to discrete mathematics and algebra, while geometry, topology and applied mathematics are less frequently studied. It is concluded that AI most often plays the role of intelligent learning systems that assess students' problems and provide immediate support to improve their learning outcomes.

An examination of the publications on the topic matter identifies multiple challenges connected with deploying ChatGPT and other AI innovations within academic settings. They can furnish unreliable, antiquated, or false data, causing *misinterpretations and inaccurate judgments by learners* (Limna et al. 2023). *Learners might grow excessively dependent on these AI mechanisms for resolving issues and gaining knowledge*, which hampers their ability to think critically and develop independence. The use of AI technology for assignments and homework might impair the learning process and the acquisition of critical competencies, making it harder to assess student understanding objectively. Frequent use of AI technologies can *reduce lecturer-student engagement* (Limna et al.2023). The introduction of ChatGPT raises concerns about traditional ways of measuring students' knowledge and competences, as AI can make it *impossible to measure their genuine abilities and knowledge.* AI technologies can influence students' motivation and skill development. The potential of AI technologies to facilitate finding answers can lead to *a simplification of the learning process and a reduction in the active participation of students* in the search and analysis of information (Zawacki-Richter et al. 2019). The use of AI technologies also raises ethical questions about the fairness and appropriateness of their use in the educational process (Hua et al. 2023).

A lot of research has focused on the ChatGPT tool for teaching and learning mathematics. Analysing the content of 50 articles, author of (Lo 2023) concluded that ChatGPT can serve as an assistant for teachers to generate learning materials and as a virtual teacher for students, but there are challenges such as *generating false or fake information* and the ability to bypass plagiarism detection systems. Research presented in (Wardat et al. 2023) founds that respondents emphasized ChatGPT's ability to analyze and break down complex math problems into smaller components, generating step-by-

step solutions. However, according to them, ChatGPT still cannot fully replace human understanding and can often encounter *difficulties in solving more complex mathematical problems*. Nevertheless, there is potential to develop. The study finds that ChatGPT is a good instructional tool, but caution should be exercised when using it and should develop rules for safe use. It also emphasizes the need for a new educational philosophy, which may emerge with the integration of chatbots into universities.

The presence of possible contributions makes studies of AI tools, use in higher mathematics education, valuable. The focus of this study is on the opinions and experiences of Bulgarian students regarding the use of AI tools in higher mathematics education. The study examines how they impact personalized learning, student engagement, skill development, and the ethical challenges associated with their use. The results show both the potential benefits and limitations of AI tools in the educational process.

3. Conceptual framework

The purpose of this study was to investigate four aspects of the perceptions of students studying for the educational-qualification degree "bachelor" or "master" in a specialty of professional directions: 4.6. Informatics and Computer Science, and 5.3. Communication and Computing, on the use of AI in mathematics education, namely personalized learning experiences, improved student engagement, improved skills and challenges, and ethical considerations. Students in these majors are generally more likely to use and appreciate innovative technologies, such as AI, because of their academic and professional interests. They have a better understanding of the technical aspects of AI and can more adequately assess the reliability and effectiveness of AI tools used in education.

The first aspect, "Personalized Learning Experiences", examines how students use specific AI tools for preparation and to what extent they expect AI to help them understand complex mathematical concepts. The second aspect, "Improved Student Engagement", looks at the frequency of using AI tools, including ChatGPT, and how this affects students' motivation and confidence in solving complex problems. The third aspect, "Enhanced Skills", focuses on the effectiveness of AI in education, the reliability of AI-provided answers, and its impact on acquiring competencies such as problem-solving and critical thinking. This aspect also investigates how AI compares to traditional methods and human skills in solving mathematical problems. The fourth aspect, "Challenges and Ethical Considerations", explores the extent to which students use AI in their preparation, which learning platforms they prefer, and their opinions on the future of AI in education.

4. Methodology

An online questionnaire was built to collect data, containing 20 closed-ended questions meant to study students' use and opinions of AI technologies in higher mathematics education, as well as three demographic questions. Responses are measured using Likert scales. Cronbach's alpha and Guttman's Lambda 6 (G6(smc)) were employed as coefficients to assess the questionnaire's internal consistency. The overall Cronbach's alpha was 0.7821, indicating that the questionnaire had strong internal consistency. The results are interpreted using the table generated by George and Mallery in 2003 (George &. Mallery 2003). The G6(smc) value is quite high (0.9122), demonstrating the questionnaire's dependability.

The questionnaire was distributed among the students in one non-state and two state universities, where training is conducted in professional fields: 4.6. Informatics and computer science and 5.3. Communication and computer technologies. The survey's complete anonymity allows for voluntary participation and students' freedom to answer questions honestly, as well as the online distribution – completion at respondents' convenience.

The sample includes students pursuing educational qualification degrees "bachelor" and "master" in the above-mentioned professional fields. A total of 88 individuals took part in the survey, with around 72.72% pursuing undergraduate degrees. Data collection took place in April and May of 2024.

5. Results

Most respondents were aged 18 – 24 (77.3%), with the next largest group being 25 – 34 (11.4%). The following gender distribution is reported: men (59.1%) and women (40.9%). Most respondents are bachelors (72.72%).

5.1.Personalized Learning Experiences

The high rate of use of interactive lessons and assignments (47.4%) and mobile math applications (36.8%) demonstrates the trend of students seeking individualized support and resources that match their specific needs and learning pace. Personalized learning is supported by the usage of systems like Photomath (51.2%), Wolfram Alpha (32.6%), Khan Academy (27.9%), and Desmos (25.6%), which offer adaptive learning based on the student's level. A substantial number of respondents (88.6%) reported using ChatGPT for academic purposes, indicating that they find its replies and explanations valuable in their studies.

5.2. Improved Student Engagement

According to the poll results, a substantial percentage of respondents use AI on a regular or occasional basis (20.5% and 65.9%, respectively). They use the learning platforms frequently (22.7%), occasionally (45.5%), and rarely

(20.5%). Those who utilize them may be more interested and motivated because of AI tools' interactive and adaptable characteristics, but students still see them as a supplement to traditional education. 31.8% of respondents believe that traditional methods are more effective in teaching higher mathematics than AI. Regarding the question of whether AI demotivates students to study higher mathematics, 22.7% believe that AI motivates them, while 36.4% are not particularly demotivated. AI tools can be both a motivator and a challenge for students, depending on their attitude and expectations.

5.3. Enhanced Skills

Although 52.3% of respondents believe that using AI in their higher mathematics education is effective, there is still a significant percentage (34.1%) of respondents who find it not very effective. Most students, to some extent (45.5%) or rarely (34.1%), rely on AI in solving mathematical problems and in their preparation because, although they perceive AI applications as a useful tool, they are not inclined to completely replace traditional learning methods with them.

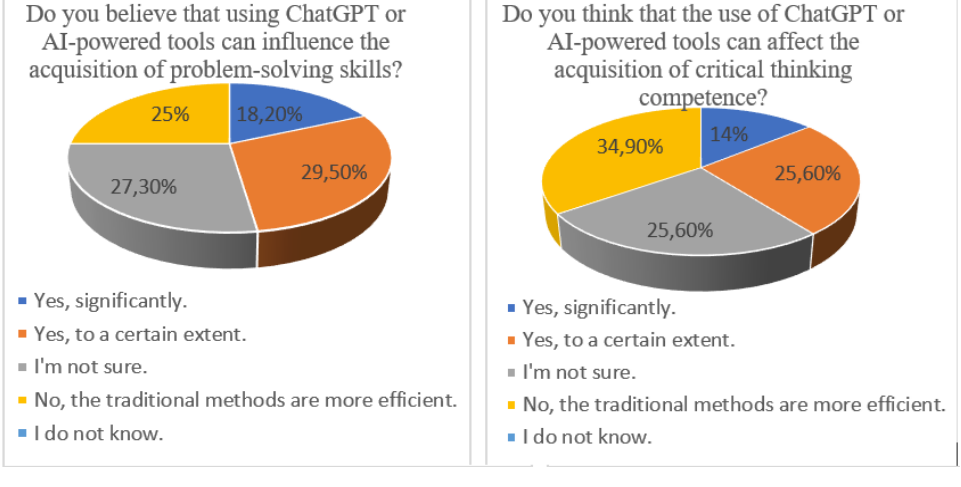

Figure 1. AI applications for developing competencies

To develop problem-solving competence, 25% of respondents would trust traditional methods as more effective, while 18.2% of them would choose AI tools as significantly more effective (fig. 1). 34.9% of respondents believe that traditional methods are more effective in developing critical thinking, while only 14% believe that AI significantly supports this process (fig. 1). A significant percentage of respondents believe that AI tools are not reliable (18.2% for theoretical basis and 29.5% for calculations) (fig. 2).

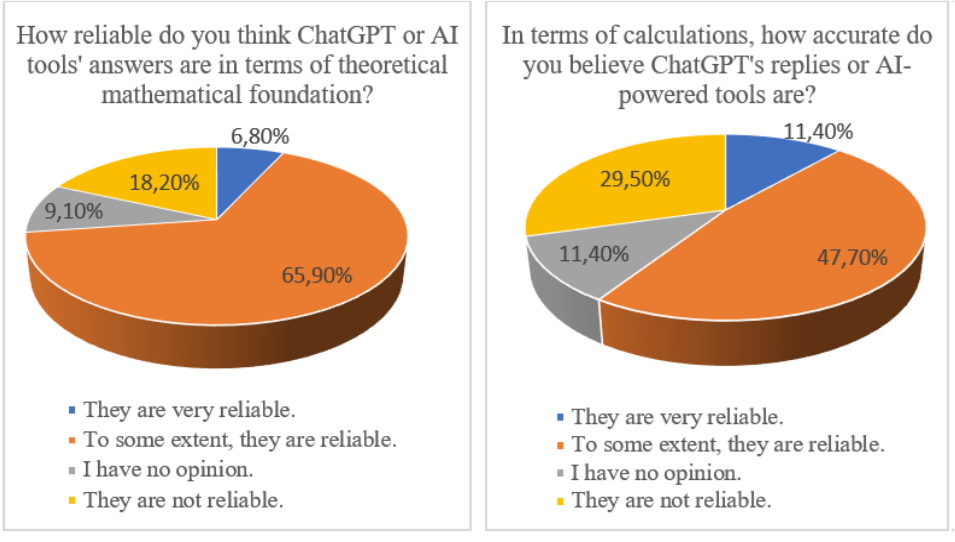

Figure 2. Reliability of AI tools in higher mathematics education

5.4. Challenges and Ethical Considerations

The results show that there are respondents who believe that AI can demotivate students (to a significant extent, 6.8%, to some extent, 13.6%), which is an important ethical consideration in implementing AI technologies in education. For most students, the higher mathematics education process does not rely on AI-powered tools or resources. When asked, "What part of your higher mathematics education process is based on tools and resources using AI" answers included "a small part" (25.6%), "a very small part" (32.6%), and "none" (16.3%). It is interesting to note that young people are skeptical about the potential use of AI in education. 36.4% of respondents believe AI will have a limited role in education, while 13.6% believe it will not have a significant one. The result achieved differs significantly from the result of a comparable question in (Gouia-Zarrad & Gunn 2024), where the question was "Would you be interested in using ChatGPT in future math or engineering courses?" and 85% of respondents said yes.

In (Hadjiski & Kaltenborn 2023) presented a possible framework was presented for managing the learning process in modern personalized learning systems based on the latest advances in artificial intelligence – large linguistic models (LLM), machine learning (ML), reinforcement learning (RL), generative transformer circuits (GTS). The paper presents a scheme of traditional personalized education with elements of artificial intelligence and a modern student-centered personalized learning system. Based on the results of the

survey, it can be concluded that the model of traditional personalized education with elements of artificial intelligence is currently being implemented. This is demonstrated by the fact that AI is used as a supplement to traditional learning methods, rather than as a core component. Although there is significant interest and use of AI tools, traditional methods still play a key role and are preferred by many students. This shows that in practice there is a transition towards greater integration of AI into educational platforms, but the personalized learning described in the student-centered personalized learning system has not yet been fully realized.

In the analysis of the survey results, there are several potential inconsistencies or discrepancies that may affect the understanding of the data: a mismatch between commonly used AI tools and the perception of their effectiveness; disparity between partial use of AI and perception of its importance; divergence in attitudes towards AI and its future importance; skepticism about AI and traditional methods. Although a significant percentage of respondents use AI tools (such as Photomath, Wolfram Alpha, ChatGPT, etc.), 34.1% of them believe that these tools are not very effective in teaching higher mathematics. This disparity shows that although AI is actively used, the opinion about its usefulness is not unequivocally positive. According to the results, a large percentage of respondents use AI tools only partially or rarely (for example, 45.5% sometimes and 34.1% rarely). However, most of them (e.g. 52.3%) believe that AI is effective in higher mathematics education, which is in the context of its use only to a limited extent. The Spearman correlation coefficients for perception of AI effectiveness and development of problem-solving (0.0888) and critical thinking (0.0117) skills are very low. This may mean that students who find AI tools effective do not see significant improvement in their skills of problem-solving and critical thinking. The results show that a significant percentage of respondents find AI tools unreliable (18.2% for the theoretical basis and 29.5% for the calculations). This is also in the context of data on the perception of AI as an adjunct rather than a core element of learning. Although AI is visibly integrated into the educational process, many respondents believe that traditional methods are more effective for developing competencies.

6. Limitations

As a limitation of the sample, it is worth noting that it covers students from two professional fields, which limits the possibilities to generalize the results to other disciplines and professional fields. The overall number of respondents is modest, which may reduce the statistical power of the analysis. Despite the limitations of the research, the study's findings provide significant insight into the opinions of learners about the usage of AI in mathematical education.

7. Discussion and conclusions

The study raises several important discussion points. The first question concerns the need to investigate the primary advantages of AI technologies in education and how these resources can be better integrated into traditional teaching methods.

The second question focuses on the impact of AI tools such as Photomath, Wolfram Alpha, Khan Academy, and Desmos on students' motivation and engagement in higher mathematics education. It is crucial to analyse to what extent these tools facilitate understanding and mastery of complex concepts and whether there is a risk of them replacing traditional learning, along with potential consequences thereof.

The third question, warranting further examination, explores the reasons why some students still prefer traditional teaching methods over AI tools in studying higher mathematics. Here, it is necessary to discuss the main advantages of traditional methods according to students and explore measures to increase trust and effectiveness of AI tools. The fourth question delves into the role of AI in developing competencies, considering how AI tools can be used more effectively to foster skills such as critical thinking and problem-solving. The fifth question relates to ethical considerations in implementing AI technologies in education. It is important to discuss how potential demotivating effects of AI tools can be minimized and what measures should be taken to ensure their reliability in educational settings.

In conclusion, the study shows that AI has significant potential to improve students' learning outcomes and engagement in higher mathematics education, but traditional methods still play an important role. Despite many students using AI tools, a large portion of them remain skeptical about their effectiveness and reliability. Further research and improvements in AI technologies are necessary to increase students' trust and ensure their ethical use in education.

NOTES

1. ALEKS. https://www.aleks.com/
2. MyMathLab. https://mlm.pearson.com/northamerica/mymathlab/
3. WebAssign. https://www.webassign.net/
4. Wolfram Alpha. https://www.wolframalpha.com/
5. Desmos. https://www.desmos.com/
6. Symbolab https://www.symbolab.com/
7. Photomath. https://photomath.com/
8. Maple Calculator. https://www.maplesoft.com/products/Maplecalculator/

9. Mathway. https://www.mathway.com/Algebra
10. Microsoft Math Solver. https://math.microsoft.com/bg

REFERENCES

AZEVEDO, B.F., PACHECO, M.F., FERNANDES, F.P., PEREIRA, A.I., 2024. Dataset of mathematics learning and assessment of higher education students using the MathE platform, *Data in Brief*, vol. 53, 110236. doi: 10.1016/j.dib.2024.110236

COTTON, D.R., COTTON, P.A., SHIPWAY, J.R., 2023. Chatting and cheating: Ensuring academic integrity in the era of ChatGPT, *Innovations in Education and Teaching International*, vol. 61, no. 2, pp. 228 – 239. doi: 10.1080/14703297.2023.2190148

DHIVYA, L., RAMAKRISHNAN, N., 2024. The Extent Of Mobile Application Usage For Learning Mathematics Among Higher Secondary Students, *Educational Administration: Theory and Practice*, vol. 30, no. 5, pp. 6272 – 6278. https://kuey.net/index.php/kuey/article/view/3930

GEORGE, D., MALLERY, P., 2003. *SPSS for Windows step by step: A simple guide and reference.* 11.0 update (4th ed.), Allyn & Bacon, Boston, MA.

HADJISKI, M., KALTENBORN, R., 2023. Personalizirano obuchenie na bazata na izkustven intelekt kato predizvikatestvo za savremenite obrazovatelni sistemi. *Avotomatika i informatika*, no. 4, pp. 23 – 40 (in Bulgarian).

HUA, SH., JIN, SH., JIANG, SH., 2024. The Limitations and Ethical Considerations of ChatGPT. *Data Intelligence Just Accepted MS*, vol. 6, no. 1, pp. 201 – 239. doi: 10.1162/dint_a_00243

HWANG, G.-J., TU, Y.-F., 2021. Roles and Research Trends of Artificial Intelligence in Mathematics Education: A Bibliometric Mapping Analysis and Systematic Review, 2021. *Mathematics*, vol. 9, no. 6, p. 584. doi: 10.3390/math9060584

LIMNA, P., KRAIWANIT, T., JANGJARAT, K., KLAYKLUNG, P., CHOCKSATHAPORN, P., 2023. The use of ChatGPT in the digital era: Perspectives on chatbot implementation. *Journal of Applied Learning & Teaching*, vol. 6, no. 1, pp. 64 – 74. doi: 10.37074/jalt.2023.6.1.32

LO, C.K., What Is the Impact of ChatGPT on Education? A Rapid Review of the Literature, 2023. *Education science,* vol. 13, no. 4, p. 410. doi: 10.3390/educsci13040410

MANRIQUE, P.C.J., PALOMARES, N.R., 2024. Embracing the future: exploring teachers perspective and readiness for integrating Artificial

Intelligence (AI) in mathematics classroom in selected public and private senior high school. *Ignatian International Journal for Multidisciplinary Research*, vol. 2, no. 5, pp. 2654 – 2675.
doi: 10.5281/zenodo.11393926

RUDOLPH, J., TAN, S., TAN, S., 2023. ChatGPT: Bullshit spewer or the end of traditional assessments in higher education? *Journal of Applied Learning & Teaching*, vol. 6, no. 1, pp. 342 – 363.
doi: 10.37074/jalt.2023.6.1.9

WARDAT, Y., TASHTOUSH, M.A., ALALI, R., JARRAH, A.M., 2023. ChatGPT: A revolutionary tool for teaching and learning mathematics. *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 19, no. 7, em2286. doi: 10.29333/ejmste/13272

ZAWACKI-RICHTER, O., MARÍN, V.I, BOND, M., GOUVERNEUR, F., 2019. Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, vol. 16, no. 1, p. 39. doi: 10.1186/s41239-019-0171-0

ZHAI, X., 2022. ChatGPT user experience: Implications for education. *SSRN*. doi: 10.2139/ssrn.4312418

ЛИТЕРАТУРА

ХАДЖИЙСКИ, М., КАЛТЕНБОРН, Р., 2023. Персонализирано обучение на базата на изкуствен интелект като предизвикателство за съвременните образователни системи. *Автоматика и информатика*, № 4, стр. 23 – 40.

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