

Using ChatGPT for the Development of Critical Thinking in Youth: Example of Inequality Proof

M. Drushlyak *, T. Lukashova*, Yuliia Sabadosh**, Ivan Melnikov * and O. Semenikhina *

* Sumy State Pedagogical University named after A. S. Makarenko, Sumy, Ukraine

** Vinnytsia National Technical University

marydru@fizmatsspu.sumy.ua, tanya.lukashova2015@gmail.com, avataric87@gmail.com,

i.melnikov@fizmatsspu.sumy.ua, e.semenikhina@fizmatsspu.sumy.ua

Abstract – The article explores the problem of using artificial intelligence in education. Practices of using ChatGPT in professional training are analyzed, highlighting both the positive aspects and risks of AI implementation in the educational process. The possibility of using AI to develop pre-service teachers' critical thinking is justified. ChatGPT is used as a generator of possible pupils' responses. The application of artificial intelligence, specifically ChatGPT, in proving inequalities is demonstrated. The generated responses are analyzed. Results of a pedagogical experiment on using ChatGPT for the development of pre-service mathematics teachers' critical thinking are described. The evaluation criteria for individual tasks are based on key characteristics of critical thinking: 1) the ability to analyze information critically; 2) the ability to identify logical inconsistencies in statements; 3) the ability to eliminate logical inconsistencies; 4) a tendency to seek the most rational solution to a problem. The sign test is employed for statistical analysis of the results. The hypothesis regarding the positive impact of analyzing proofs of inequalities proposed by ChatGPT on the development of students' critical thinking is confirmed. Problems in using ChatGPT in the Ukrainian language are identified.

Keywords – critical thinking; artificial intelligence; proof of inequalities; mathematics education; pre-service mathematics teachers; professional training.

I. INTRODUCTION

In the modern paradigm of the interaction between the labor market and higher education, employers shape their perceptions of the qualities a graduate should possess, as well as the breadth of knowledge and skills required for effective professional realization. Therefore, university education should focus not only on hard skills (knowledge, abilities, skills in a specific subject area) but also on skills unrelated to the subject area, yet essential for successful problem-solving, awareness of responsibility for decisions made, the ability to lifelong learning, etc. [1]. Such skills include critical thinking a crucial ability for any professional. Critical thinking, as a complex reflective thinking process, involves the ability to make associations, comparisons, analyses, syntheses, evaluations, and predictions of consequences. It enables individuals to go beyond the given data, identify new characteristics, and substantiate their thoughts and proposals. The development of critical thinking is often not an ultimate goal of education, but it significantly influences an individual's social realization. Therefore, educators find it important to employ tools that contribute to such development.

Since 2022, research has emerged in the scholarly discourse linking issues of critical thinking development and the use of artificial intelligence (AI) in education. Within society, there are prevalent theses such as "AI is the killer of professions," "AI influences people's thoughts by generating posts for social media and comments," "AI as a generator of academic texts undermines scientific results," "AI will contribute to the leakage of confidential and personal information," and so on. Due to such concerns, some schools prohibit the use of AI, including ChatGPT [2; 3]. Scholars perceive the potentially negative impact of AI on assessment methods [4], scientific integrity [5; 6], and the development of higher-order thinking skills [7].

The contemporary discourse surrounding artificial intelligence and its impact on education typically focuses on the challenges it poses for educators [8] or the opportunities it provides for both teachers and students [9]. One of the key challenges in the use of AI in education, according to researchers, is the ethics of AI usage, which is considered a component of AI literacy [10]. The findings that have been conducted on this topic have focused on topics such as privacy, responsible use of AI in education, bias, and the potential for AI to contribute to the digital gap [11]. Scholars also emphasize the importance of developing students' critical thinking skills and the ability of educators to distinguish between authored texts, credible information, and deception or misinformation generated by AI [12]. The mentioned research suggests that AI is gradually becoming a digital tool for successful learning among students. However, we propose a somewhat different approach. We propose to consider AI as a means of developing the critical thinking of young people, a digital educational tool for educators.

The article's goal is to justify the potential use of artificial intelligence in developing the pre-service mathematics teachers' critical thinking in proving inequalities, using the example of ChatGPT.

The research objective led to the fulfillment of the following tasks:

- to analyze the practices of using ChatGPT;
- to demonstrate the utilization of artificial intelligence with ChatGPT in proving inequalities and analyzing of the generated responses;
- to present the results of a pedagogical experiment using ChatGPT for the development of pre-service mathematics teachers' critical thinking.

II. PRACTICES OF CHATGPT USAGE

GPT (Generative Pre-trained Transformer) is a type of artificial intelligence that utilizes machine learning algorithms to generate text in natural language. ChatGPT possesses a wide range of capabilities, including text completion, essay and story writing, poetry and script generation (dialogue creation), social media post drafting, summarization, classification, paraphrasing, translation, answering questions (providing medical advice, expressing opinions on subjective topics), email composition, code generation in various programming languages, and analyzing communication tone [13]. However, ChatGPT lacks an understanding of the meaning of the words it processes and utilizes [14]. It recognizes patterns and generates plausible responses, as noted in [15]: ChatGPT provides the most probable answer and is unafraid to be "wrong"; it fears being "ignorant," so if it doesn't know the answer, it will "make it up". ChatGPT lacks the human ability to assess the credibility of the data on which it was trained [16]. ChatGPT does not have access to the internet, and its free version, ChatGPT3.5, has limited knowledge about events in the world after 2021 [17], which may lead to the provision of outdated and inaccurate answers.

W. M. Lim, et al. [18] argue that on one hand, AI leads to the disruption of the education system, while on the other hand, it ushers in a new era of accessible information and automation to enhance the quality of education. These two perspectives highlight the paradoxical nature of AI and its role in education – it can dismantle some educational practices while simultaneously supporting them. Tlili et al. [19] analyzed of social media, tweets, content analysis of interviews, and user experiences regarding the use of ChatGPT in education. Based on their analysis, they recommend reconsidering the forms and criteria for assessing assignments. Specifically, they suggest that essays or descriptive tasks need to be replaced with more creative assignments or those requiring critical analysis and creative efforts from students.

M. Farrokhnia et al. [20] used a SWOT analysis methodology to identify the strengths and weaknesses of ChatGPT. The article also presents opportunities and threats associated with the use of ChatGPT in education. Strengths of ChatGPT include the ability to generate realistic responses, self-improvement or self-learning capabilities, provide personalized responses, offer real-time answers, enhance information accessibility, facilitate individual learning, aid in comprehensive learning, and reduce the workload on teachers (for example, ChatGPT can create tests). According to the authors, the weaknesses of ChatGPT include a lack of deep understanding of words and generated text, difficulties in assessing the quality of responses, the democratization of plagiarism in education/science, and the potential negative impact on the development of student's cognitive skills (creativity, critical thinking, problem-solving, etc.).

Educational practices using ChatGPT in education are described in a series of findings: pair programming education, in particular, ChatGPT acted as the student's partner in pair programming [21]; using ChatGPT in language learning, including foreign [22]; using ChatGPT as a facilitator of self-directed learning among adult

learners [23]; the problems of using AI in geographical education were investigated [24]; summarized the experience of using ChatGPT in medical education in general and for personalization of training, and development of critical and problem thinking of medical workers [25].

The generalization of the mentioned practices, aside from the noted considerations (academic integrity, authenticity of response texts, reliability and relevance of answers, correctness of provided sources, etc.), suggests that the use of ChatGPT requires precision and accuracy in formulating prompts. When engaging ChatGPT in task-solving, clarifications and hints are acceptable, with chain prompts being particularly relevant for complex tasks, involving refinement through several intermediate stages.

III. USING CHATGPT FOR PROVING INEQUALITIES AND ANALYZING GENERATED RESPONSES

In the preparation of pre-service mathematics teachers, significant emphasis is placed on teaching students to prove mathematical statements. The problem of teaching students to prove mathematical statements includes several aspects: learning ready-made proofs by students and the ability to reproduce them; independent construction of proofs by analogy with the given examples; searching for and presenting proofs following the teacher's instructions; independent search and execution of proofs for mathematical statements; analyzing various proof methods, comparing them, and determining the advantages of each method; selecting the most rational approach among several proof methods. A pre-service mathematics teacher should not only know how to prove the theorems or mathematical statements of the school mathematics curriculum but also they should be able to anticipate errors that students may make in their proofs, both typical ones and situational errors influenced by various factors such as preparation, fatigue, inattention, etc. This requires a high level of development of pre-service teachers' critical thinking, including the ability to critically analyze information, identify logical inconsistencies in statements, rectify them, and pinpoint the reasons for errors. Furthermore, the teacher should be capable of articulating their thoughts, maintaining a reasonable degree of doubt, and seeking a rational approach to problem-solving. Experience in detecting such errors is also crucial.

Let's illustrate ChatGPT's work with tasks on proving inequalities.

Task 1. Ask ChatGPT to prove the inequality $1 + 2^3 + 3^3 + \dots + n^3 \geq \frac{n^4}{4}$ for all $n \in N$ (Figure 1).

Note that among the methods chosen by ChatGPT, it initially selects the method of mathematical induction. Probably, this is because the problem statement includes the requirement "to prove for all natural numbers n ". Since one of the natural and effective ways to prove such statements is the method of mathematical induction, the chatbot likely opts for this standard reasoning approach.

Task 2. Identify mistakes made by ChatGPT.

It should be noted that ChatGPT carefully outlines all the steps involved in the method of mathematical induction and, at first sight, provides a correct proof. However, in the final step (Figure 1, highlighted in red), it makes several errors in identical transformations. Therefore, analyzing the response is a useful exercise in finding mistakes in a seemingly correct proof and examining ways to correct them. In this case, correcting the mistakes is a simple task:

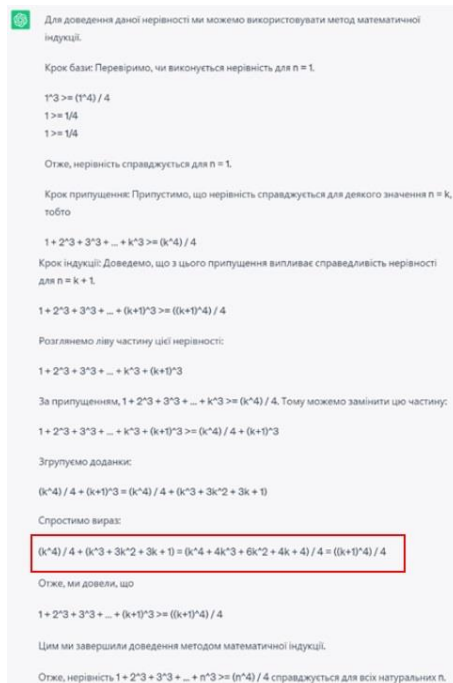
$$\frac{k^4}{4} + (k+1)^3 = \frac{k^4}{4} + (k^3 + 3k^2 + 3k + 1) = \frac{k^4 + 4k^3 + 6k^2 + 4k + 4}{4} + \frac{6k^2 + 8k + 3}{4} = \frac{(k+1)^4}{4} + \frac{6k^2 + 8k + 3}{4} \geq \frac{(k+1)^4}{4}.$$


Figure 1. The solution of Task 1 (source: made by authors)

Task 3. Point out ChatGPT mistakes. Analyze whether a corrected answer is provided or if the feedback is taken into account.

A new prompt to ChatGPT regarding the proof of the same inequality using the method of mathematical induction provides the following response, assuming $k \geq 1$ (Figure 2). In this proof, ChatGPT makes more errors in transformations and makes unwarranted conclusions.

Upon pointing out the error in identical transformations, ChatGPT attempts to correct them but fails (Figure 3). After presenting the correct way to fix the mistake (providing accurate transformations), ChatGPT responds correctly (Figure 4). However, when asked which specific transformations are correct, it reiterates its previous reasoning. In other words, it fails to rectify the mistake even with external assistance, reverting to its prior algorithm (Figure 5).

Therefore, ChatGPT may make mistakes in proving inequalities, and its use can be a training digital tool not only for a math teacher's work but also for the development of pre-service teachers' critical thinking.

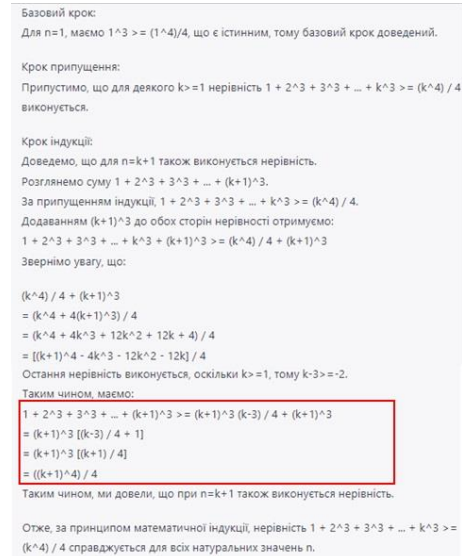


Figure 2. Task 3 Execution Result (source: made by authors)

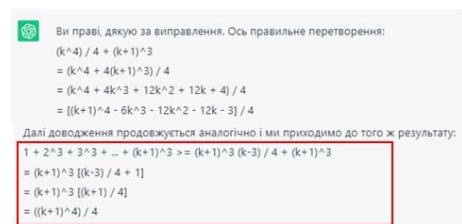


Figure 3. Response (1) of ChatGPT to the indication of its mistakes (source: made by authors)

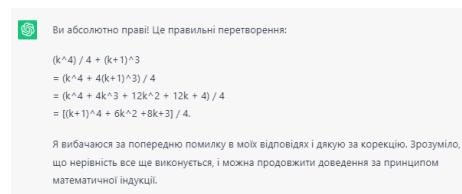


Figure 4. Response (2) of ChatGPT to the indication of its mistakes (source: made by authors)

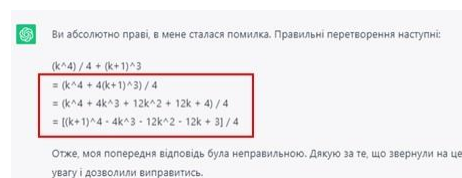


Figure 5. Response (3) of ChatGPT to the indication of its mistakes (source: made by authors)

IV. EXPERIMENT

Experimental confirmation of the expediency of using ChatGPT for the development of pre-service mathematics teachers' critical thinking was implemented through the conduct of a pedagogical experiment. We proceeded from the assumption that the use and subsequent analysis of ChatGPT-generated answers are an important element of the professional training of pre-service mathematics teachers, fostering their critical thinking.

Individual tasks were given to students as part of the "Teaching Methods of Mathematics" course.

Task 1. Ask ChatGPT to prove the inequality $1 + 2^3 + 3^3 + \dots + n^3 \geq \frac{n^4}{4}$ for all $n \in \mathbb{N}$. What proof method does ChatGPT prioritize? Record the results for the report.

Task 2. Identify mistakes made by ChatGPT (if any). Record the results for the report.

Task 3. Point out ChatGPT's mistakes. Analyze whether ChatGPT corrected the solution or considered your previous comments. Record the results for the report.

Task 4. Propose alternative methods for ChatGPT to prove the given inequality. How many methods does it suggest? Are there mistakes in them? Which method do you think is the most rational? Which method do you think is the simplest? Record the results for the report.

Task 5. Ask ChatGPT to perform tasks 1-4 after a month. Identify any errors made by ChatGPT (if any). Analyze whether ChatGPT took into account your previous comments. Record the results for the report.

The evaluation criteria for individual tasks are based on key characteristics of critical thinking: 1) the ability to critically analyze information; 2) the ability to identify logical inconsistencies in statements; 3) the ability to address logical inconsistencies; 4) a tendency to seek the most rational solution to a problem. To these characteristics, evaluation criteria for critical thinking were developed (Figure 6).

The student could be awarded up to 2 points for each criterion (Table 1). The individual task included Task 5, which allowed assessing critical thinking a month later (based on the same tasks but possibly different responses from ChatGPT).

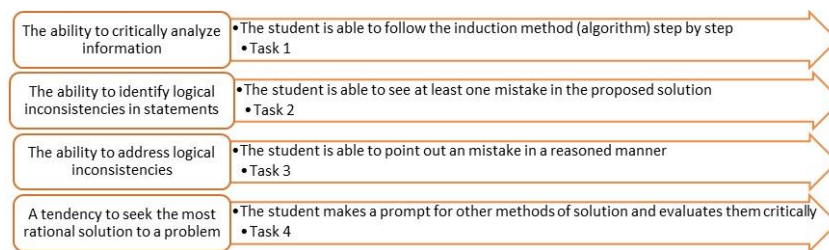


Figure 6. The criteria for assessing tasks (source: made by authors)

TABLE 1. EVALUATION CRITERIA FOR STUDENT'S CRITICAL THINKING BASED ON THEIR TASK PERFORMANCE (SOURCE: MADE BY AUTHORS)

No	Criteria	Assessment features		
		0 score	1 score	2 score
1	The ability to critically analyze information	The student does not distinguish the steps of the induction method		The student distinguishes the steps of the induction method
2	The ability to identify logical inconsistencies in statements	The student does not see mistakes	The student sees only one mistake	The student sees more than one mistake
3	The ability to address logical inconsistencies	The student does not formulate arguments for the correction of mistakes	The student incorrectly formulates arguments regarding the correction of mistakes	The student formulates arguments for the correction of mistakes and gets a correct result
4	A tendency to seek the most rational solution to a problem	The search was performed without analysis of the provided result	The search for the most rational way has been carried out, but one's position has not been argued	The search for the most rational way has been carried out, and one's position has been argued

In the pedagogical experiment conducted in May-June 2023, 17 pre-service mathematics teachers participated. The students were aware of their participation in the experiment and did not object to it. To process individual tasks, students encrypted their works.

Limitations of research. The small sample size is explained by the fact that access to ChatGPT in Ukraine has been available since March 2023, limiting the number of participants in the experiment. The limited number of respondents constrains the use of traditional statistical methods of assessment (Student's t-test, Wilcoxon-Mann-Whitney test, etc.).

The effectiveness of ChatGPT as a means for developing critical thinking was tested in a group of students – pre-service mathematics teachers. We cannot generalize these results to teachers of other subjects. However, we anticipate a similar positive outcome in the training of natural sciences and computer science teachers,

as their professional preparation is based on mathematical knowledge and skills.

To track the development of critical thinking, we limited the research only four criteria, which is determined by the number of tasks in individual student work. A greater number of tasks may provide more criteria for evaluating responses, allowing for a more accurate assessment of the development of students' critical thinking.

All the mentioned limitations do not impact the overall result and conclusions of the study.

The results of evaluating the works according to the developed criteria are presented in Table 2. To analyze the results, which were independent within the student group but dependent pairwise, the sign test was used. The null hypothesis " H_0 : the analysis of solutions proposed by ChatGPT does not affect the development of critical thinking" and the alternative hypothesis " H_a : the analysis of

solutions proposed by ChatGPT positively impacts the development of critical thinking" were formulated. The significance level was 0.05.

The analysis of task results revealed that there were 10 positive changes in marks. The total number of changes

was 12. The hypotheses were constructed to investigate a one-sided critical region, with a critical value of 9. Since $10 > 9$, the alternative hypothesis about the positive impact of the analysis of solutions proposed by AI on the development of students' critical thinking is accepted.

TABLE II. RESULTS OF EVALUATION (SOURCE: MADE BY AUTHORS)

No participant	Mark for tasks 1-4	Mark for task 5	Sign of differences	No participant	Mark for tasks 1-4	Mark for task 5	Sign of differences
1	2	2	0	10	2	2	0
2	6	7	+	11	4	4	0
3	4	5	+	12	5	7	+
4	4	5	+	13	6	8	+
5	5	5	0	14	4	3	-
6	3	3	0	15	3	2	-
7	3	4	+	16	3	4	+
8	2	4	+	17	4	7	+
9	2	4	+				

V. DISCUSSION

Proof-oriented tasks (proofs of inequalities, theorems, etc.) are quite challenging to algorithmize and carry a significant heuristic load. Solving such tasks requires abstract and/or analytical thinking, promotes critical thinking, develops analytical skills, the ability to logically justify and draw correct conclusions, and provides an opportunity to comprehensively reinforce a wide range of theoretical issues studied in the school mathematics curriculum. This includes the basics of inequality theory, questions of the equivalence of transformations, properties of functions, the application of derivatives and integrals, the use of geometric reasoning, estimates of areas and volumes, and so on. The ability to solve proof-oriented problems is gradually formed not only in students but also in pre-service teachers. Today, the simulation of the learning process is simplified thanks to the use of ChatGPT.

For the development of pre-service teachers' critical thinking, it is important to apply professional knowledge and skills in realistic situations. Ukrainian practices today are quite limited, and therefore, the use of AI as a learning environment can be effective. The authors, based on their experience of communicating with ChatGPT, have found that the generated responses to mathematical tasks typically contained mistakes and required verification or clarification. Since the development of critical thinking occurs through the analysis of ideas, statements, and solutions [26], the analysis of generated responses serves as a method for developing pre-service teachers' critical thinking. Without an adequate level of preparation, students face the risk of unsuccessful first experiences in professional activities and a sharp decline in motivation to work as teachers. Therefore, we consider the simulation of professional situations such as "working with students" through the simulation by artificial intelligence to be important for the preparation of pre-service teachers.

Our research correlates with the Concept of Artificial Intelligence Development in Ukraine. Among the priority areas in which the tasks of the state policy for the development of the artificial intelligence field are implemented, education is highlighted. In higher education, among other things, the creation of specialized educational

programs in artificial intelligence within the "Information Technologies" field is foreseen. This includes incorporating artificial intelligence topics into other educational programs across various specialties, establishing interdisciplinary, including joint, master's and doctoral programs, and integrating leading online courses on artificial intelligence into educational programs [27]. Additionally, this aligns with the Great Transformation Program "Education 4.0: Ukrainian Sunrise" from the Ministry of Education [28].

Until February 18, 2023, ChatGPT was blocked in Ukraine. Access to it determined the active use of AI by students and teachers. In the context of the conducted research and article writing, several problems were identified in using ChatGPT for proving inequalities, including: 1) different results depending on the language of prompt writing – tasks written in Ukrainian lead to significantly more mistakes compared to tasks written in English; 2) when performing tasks at different time intervals and from different computers, different solutions are generated. On the one hand, this prevents cheating, but on the other hand, it complicates the task evaluation process, which was not automated. The identified issues suggest recommending the use of the Ukrainian language specifically for the development of critical thinking in youth. Additionally, we see cross-checking of students' work as a promising approach.

It should be noted that during the research, no ethical principles of AI usage in education were violated, and the Recommendations on the use of generative AI in education and research by UNESCO [29] were adhered to.

VI. CONCLUSION

One of the new trends in the digitalization of society is the spread of AI in all spheres of its activity. Education, as an established social institution, is experiencing the impact of AI. Recent studies show that scientists see the benefits of introducing AI into the educational process (the possibility of personalizing learning, assistance in creating didactic materials, etc.) and the risks of such implementation (for academic integrity, adequate assessment, access to personal data, etc.). Given the rapid

development of AI, research into positive practices of implementing AI in professional training, and thus in teacher training, is becoming increasingly important.

The best training results are obtained in situations close to real life. Our study describes the positive practice of implementing ChatGPT in the professional training of mathematics teachers. We have substantiated the possibility of using AI to develop the critical thinking of future mathematics teachers: ChatGPT has become a digital environment that generates possible answers from students to the task of "to prove inequality," which simulates real educational cases. Checking the generated answers, on the one hand, forms the teacher's professional skills of "finding an error" and "arguing an error," and on the other hand, develops the critical thinking of future mathematics teachers (the ability to analyze information critically; the ability to identify logical inconsistencies in statements; the ability to address logical inconsistencies; a tendency to seek the most rational solution to a problem).

We see the prospect of further research in implementing similar practices of using ChatGPT in training teachers of other subject specialties.

REFERENCES

- [1] 10 Top Soft Skills for 2020: What They Are and How To Train Them, 2016. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/owowwm>.
- [2] M. Dibble, "Schools ban ChatGPT amid fears of artificial intelligence-assisted cheating", *VOA News*, 2023. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/moyhy>.
- [3] A. Lukpat, "ChatGPT banned in New York City public schools over concerns about cheating, learning development", *The Wall Street Journal*, 2023. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/moyic>.
- [4] J. Rudolph, S. Tan, and S. Tan, "ChatGPT: Bullshit spewer or the end of traditional assessments in higher education?" *Journal of Applied Learning & Teaching*, 2023, vol. 6(1), pp. 1-22. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.37074/jalt.2023.6.1.9>.
- [5] D. R. Cotton, P. A. Cotton, and J. R. Shipway, "Chatting and cheating: Ensuring academic integrity in the era of ChatGPT", *Innovations in Education and Teaching International*, 2023, pp. 1-12. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1080/14703297.2023.2190148>.
- [6] A. Shiri, "ChatGPT and academic integrity", *Information Matters*, 2023, vol. 3(2), pp. 1-5. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.2139/SSRN.4360052>.
- [7] T. Susnjak, "ChatGPT: The end of online exam integrity?" *arXiv*, 2022. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.48550/arXiv.2212.09292>.
- [8] C. Stokel-Walker, "AI bot ChatGPT writes smart essays – should professors worry?" *Nature*, 2022. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1038/d41586-022-04397-7>.
- [9] X. Zhai, "ChatGPT user experience: Implications for education", *Journal of Applied Learning and Teaching*, 2023, vol. 6(1), pp. 1-22. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.37074/jalt.2023.6.1.9>.
- [10] D. Ng, J. Leung, S. Chu and M. Qiao, "Conceptualizing AI literacy: An exploratory review", *Computers and Education: Artificial Intelligence*, 2021, vol. 2, pp. 100041. <https://doi.org/10.1016/j.caeai.2021.100041>.
- [11] W. Holmes, K. Porayska-Pomsta, K. Holstein, E. Sutherland, T. Baker, S. B. Shum and K. R. Koedinger, "Ethics of AI in education: Towards a community-wide framework", *International Journal of Artificial Intelligence in Education*, 2021, pp. 1-23.
- [12] M. Rusandi, Ahman, I. Saripah, D. Khairun, and Mutmainnah, "No worries with ChatGPT: building bridges between artificial intelligence and education with critical thinking soft skills", *Journal of Public Health*, 2023, pp. fdad049. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1093/pubmed/fdad049>.
- [13] V. Nanovska, "What you need to know about ChatGPT so that it becomes an effective assistant and not a trap", *Mediamaker*, 2023. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/owoxd>.
- [14] J. Gao, H. Zhao, C. Yu, and R. Xu, "Exploring the feasibility of ChatGPT for event extraction", *arXiv*, 2023. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.48550/arXiv.2303.03836>.
- [15] I. Bogost, "ChatGPT is dumber than you think", 2022. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/moyhu>.
- [16] A. Lecler, L. Duron, and P. Soyer, "Revolutionizing radiology with GPT-based models: Current applications, future possibilities, and limitations of ChatGPT", *Diagnostic and Interventional Imaging*, 2023, vol. 104 (6), pp. 269-274. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1016/j.diii.2023.02.003>.
- [17] C. Stokel-Walker, and R. van Noorden, "What ChatGPT and generative AI mean for science", 2023. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/moyig>.
- [18] W. M. Lim, A. Gunasekara, J. L. Pallan, J. I. Pallant, and E. Pechenkina, "Generative AI and the future of education: Ragnar'ok or reformation? A paradoxical perspective from management educators", *The International Journal of Management Education*, 2023, vol. 21, pp. 100790. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1016/j.ijme.2023.100790>.
- [19] A. Tlili, B. Shehata, M. Adarkwah, A. Bozkurt, D. Hickey, R. Huang, and B. Agyemang, "What if the devil is my guardian angel: ChatGPT as a case study of using chatbots in education", *Smart Learning Environments*, 2023, 10:15. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1186/s40561-023-00237-x>.
- [20] M. Farrokhnia, S. K. Banihashem, O. Noroozi, and A. Wals, "A SWOT analysis of ChatGPT: Implications for educational practice and research", *Innovations in Education and Teaching International*, 2023, pp. 1-15. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1080/14703297.2023.2195846>.
- [21] B. Banić, M. Konecki, and M. Konecki, "Pair Programming Education Aided by ChatGPT", *MIPRO 2023. 46th ICT and Electronics Convention*. May 22-26, 2023. Opatija, Croatia. pp.981-085. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.23919/MIPRO57284.2023.10159727>.
- [22] L. Kohnke, B. L. Moorhouse, and D. Zou, "ChatGPT for Language Teaching and Learning", *RELC Journal*, 2023, vol. 54(2), pp. 537-550. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1177/00336882231162868>.
- [23] X. Lin, "Exploring the Role of ChatGPT as a Facilitator for Motivating Self-Directed Learning Among Adult Learners", *Adult Learning*, 2023. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1177/10451595231184928>.
- [24] R. L. Wilby, and J. Esson, "AI literacy in geographic education and research: Capabilities, caveats, and criticality", *The Geographical Journal*, 2023, pp. 1-8. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.1111/geoj.12548>.
- [25] M. Sallam, "ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns", *Healthcare*, 2023, vol. 11, pp.887. Accessed: 12.26.2023 [Online]. Available: <https://doi.org/10.3390/healthcare11060887>.
- [26] N. P. Kozachenko, "Critical thinking: marginal approaches and optimal ways", *Actual problems of spirituality*, 2017, vol. 18, pp. 165-178.
- [27] *The concept of artificial intelligence development in Ukraine*, 2021. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/owoyd>.
- [28] Ministry of Education and Science of Ukraine. *Education 4.0 Ukrainian Sunrise*, 2022. Accessed: 12.26.2023 [Online]. Available: <http://surl.li/owox>.
- [29] UNESCO. Guidance for generative AI in education and research, 2023. Accessed: 01.05.2024 [Online]. Available: <https://unesdoc.unesco.org/ark:/48223/pf0000386693/>