

ARTIFICIAL INTELLIGENCE IN EDUCATION: CHATGPT-BASED SIMULATIONS IN TEACHERS' PREPARATION

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Abstract. Today, the problem of using artificial intelligence (AI) in education is essential. Recent studies have detected several challenges in using AI for correct assessment, academic integrity, etc. So, the problem of finding positive practices for using AI in education needs to be studied more closely. We perceive ChatGPT as a digital tool for teacher training, which makes it possible to simulate students' problem-solving processes and analyze them critically. It is shown that ChatGPT makes mistakes in solutions, so the generated false answers become an essential training tool in teacher training. It became the base for experimental teaching. The research aims to substantiate the effectiveness of using ChatGPT as a simulation environment to develop pre-service teachers' critical thinking. The statistical analysis of the experiment results proved that ChatGPT is an effective digital tool for developing mathematics and computer science teachers' critical thinking.

Keywords: artificial intelligence, ChatGPT, critical thinking, education

SZTUCZNA INTELIGENCJA W EDUKACJI: SYMULACJE OPARTE NA ChatGPT W PRZYGOTOWANIU NAUCZYCIELI

Streszczenie. Obecnie problem wykorzystania sztucznej inteligencji (AI) w edukacji jest niezwykle istotny. Ostatnie badania wykryły kilka wyzwań związanych z wykorzystaniem sztucznej inteligencji do prawidłowej oceny, uczciwości akademickiej itp. Tak więc problem znalezienia pozytywnych praktyk w zakresie wykorzystania sztucznej inteligencji w edukacji wymaga dokładniejszego zbadania. Postrzegamy ChatGPT jako cyfrowe narzędzie do szkolenia nauczycieli, które umożliwia symulację procesu rozwiązywania problemów przez uczniów i jego krytyczną analizę. Wykazano, że ChatGPT popełnia błędy w rozwiązaniach, więc wygenerowane fałszywe odpowiedzi stają się niezbędnym narzędziem szkoleniowym w szkoleniu nauczycieli. Stało się to podstawą nauczania eksperymentalnego. Badanie ma na celu potwierdzenie skuteczności wykorzystania ChatGPT jako środowiska symulacyjnego do rozwijania krytycznego myślenia nauczycieli. Analiza statystyczna wyników eksperymentu dowiodła, że korzystanie z ChatGPT jest skutecznym narzędziem cyfrowym do rozwijania krytycznego myślenia nauczycieli matematyki i informatyki

Słowa kluczowe: sztuczna inteligencja, ChatGPT, krytyczne myślenie, edukacja

Introduction

Today's education sector actively utilizes information technologies, the implementation of which is discussed on various digital platforms and more deeply analyzed by the academic community. Recently, researchers have noted the popularity of Artificial Intelligence (AI) in education, which is rapidly evolving but needs to be studied more at the level of educational practices. It has already produced a variety of challenges [38, 46] and issues, including how to distinguish credible information from deception and misinformation [32]; how to ethically evaluate work not done by a student but generated by AI [26]; what potential consequences assessment of works created based on AI might have [31]; how AI will impact scientific integrity [9, 33] and the development of students' thinking skills [39]. At the same time, the widespread and further active use of AI is seen as inevitable. Therefore, finding positive practices in using AI in education requires more careful study.

1. Literature review

At the beginning of 2023, GPT (Generative Pre-training Transformer) gained popularity. It is a type of Artificial Intelligence (AI) that utilizes machine learning algorithms to generate text in natural language. Starting from February 18, 2023, this service became available in Ukraine, and it began to be used in the educational process not only worldwide [1, 2, 13, 28] but also in Ukraine [3, 17, 24, 29, 34–36, 45].

Developers of ChatGPT envisioned various capabilities, including text completion, essay and story, social media post writing, summarization, classification, paraphrasing, translation, question answering (providing medical advice, expressing opinions on subjective topics), composing emails, generating code in different programming languages, and analyzing communication tone [27]. However, as highlighted in the finding [16], ChatGPT does not understand the meanings of the words it processes. While AI recognizes patterns and generates plausible responses, it does not comprehend the concepts it operates

with [5]. ChatGPT provides responses likely based on learned patterns and sources of potential errors or inaccuracies. It's important to note that ChatGPT is "dependent" on the correctness of the prompt formulation, available hints, or clarifications. The mentioned aspects and our experience in "communicating" with ChatGPT have inspired us to use it as a digital tool to prepare mathematics and informatics teachers.

Critical thinking, as a specific type of thinking, is characterized by the ability to identify flaws in reasoning or conclusions. An analysis of definitions of critical thinking indicates that it is an active, thoughtful, and purposeful process that occurs during the interpretation and evaluation of information and experience to clarify or enhance understanding of something [6, 25]. Such a process is impossible without the skills to analyze facts, evaluate arguments, justify positions, make comparisons, and predict consequences [7]; the ability to interpret arguments, draw conclusions to support one's judgments [14]; and the ability to reject opinions that lack sufficient justification [40].

According to [18], critical thinking is also impossible without an intellectual foundation, which implies a sufficient level of general and specific knowledge, mastery of basic methods of cognitive activity and logical argumentation, proficiency in effective problem-solving techniques, teaching methods, self-learning, self-control, and self-correction. The generalization of these considerations, projected onto the professional training of a mathematics and information teacher, suggests that the development of critical thinking in the process of mathematical education typically occurs during the solving of mathematical (computational, logical, graphical, etc.) problems or through self-assessment and verification of solutions by others. If AI can now generate such solutions, they can be positioned as a means of simulating student responses and considered a digital tool for their professional development.

Simulation-based learning replicates certain aspects of reality to shape and develop specific professional skills [10], for example, in solving typical tasks in a particular field. Simulation in the educational process is considered a teaching method that facilitates the acquisition of target complex skills [8].

The effectiveness of simulation is associated with the ability to create diverse situations that allow the acquisition of quasi-professional experience [42]. Compared to traditional teaching, simulation has more significant potential for developing practical skills, generating ideas, and demonstrating abilities [30, 42].

Using simulations improves the understanding of acquired knowledge and skills, identifies gaps in the system of professional skills, and allows addressing them during the professional training stage [20]. In particular, the research conducted by B. Banić, M. Konecki, and M. Konecki [4] demonstrated that ChatGPT can be a simulation tool to train future programmers. The generalization of these results suggests the possibility and potential usefulness of using AI in teacher training. ChatGPT can act as a virtual environment that enables the simulation of problem-solving processes and the critical analysis of solutions, forming the basis for developing students' critical thinking.

The research goal is to substantiate the effectiveness of using ChatGPT to develop critical thinking in pre-service mathematics and informatics teachers.

2. Method

2.1. Research methodology

To achieve the goal, the use of empirical and statistical methods was involved:

- 1) the pedagogical experiment aimed to assess the effectiveness of using ChatGPT as a response generator for developing the pre-service mathematics and informatics teachers' critical thinking (through the generation of solutions to elementary mathematics problems);
- 2) statistical methods (Student's t-test) to justify the reliability of the conclusions drawn.

The pedagogical experiment was conducted within the framework of the courses "Teaching Mathematics with Computer Support" (4th year of undergraduate studies)

and "School Mathematics Course with Computer Support" (1st year of master's studies). The overall scheme of the experiment is presented in Figure 1. Students were assigned five methodological problems (task conditions are provided below in the "Experiment Results" section). Completing these tasks was based on responses generated by ChatGPT, and we considered ChatGPT responses as a generator of students' solutions (simulation environment). Following a break (about a month), we asked students to solve the same methodological problems; it required a reanalysis of the newly generated ChatGPT responses. This experimental setup allowed us to assess the development of students' critical thinking.

2.2. Population and sample

The research was conducted at the Faculty of Physics and Mathematics of Sumy State Pedagogical University named after A. S. Makarenko. Thirty-two pre-service mathematics teachers were involved in the experiment.

2.3. Tools

The following abilities were identified as critical thinking development indicators in students (Figure 2). We assessed the tasks according to Table 1.

The results of the assessments were systematized and processed using the Student's t-test for means (the results were independent for respondents, although pairwise dependent). The null hypothesis H_0 : "Means for both assessments are the same" (or identical: ChatGPT-based simulation does not impact the development of students' critical thinking). The alternative hypothesis H_a : "Means for both assessments are different" (or identical: ChatGPT-based simulation positively impacts the development of students' critical thinking). The chosen level of significance was 0.05.



Fig. 1. Experiment design (source: made by authors)

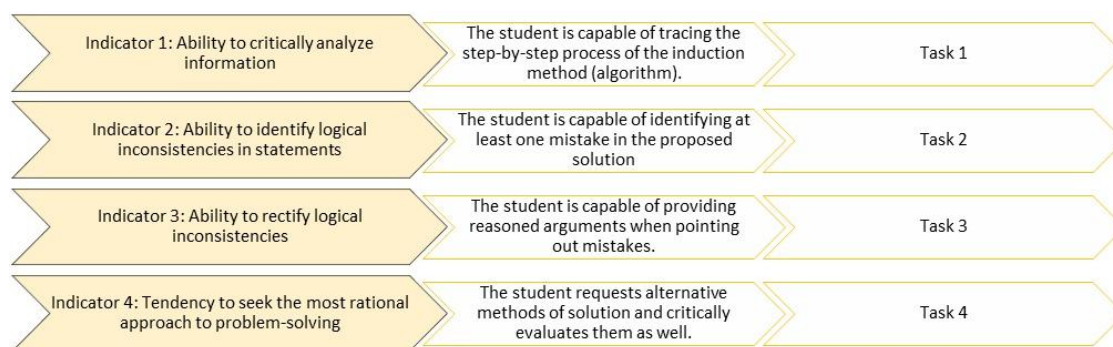


Fig. 2. Indicators of the Development of Students' Critical Thinking (source: made by authors)

Table 1. Features of Assessment (Source: made by authors)

Score	Indicator 1	Indicator 2	Indicator 3	Indicator 4
0	The student does not differentiate the steps of the induction method.	The student does not identify mistakes.	The student does not formulate arguments regarding mistakes rectification.	The search was conducted without analyzing the provided results.
1	-	The student identifies only one mistake.	The student incorrectly formulates arguments for mistakes.	The search for the most rational approach was conducted but not supported by a reasoned position.
2	The student distinguishes the steps of the induction method.	The student identifies more than one mistake.	The student formulates arguments for mistake rectification and achieves a correct result.	The search for the most rational approach was conducted, and the own position was argued.

3. Findings

3.1. ChatGPT as a generator of inequalities proofs and corresponding methodological comments for the generated responses

To understand the features of working with ChatGPT as a generator of student responses, let's describe our experience of interacting with the AI while proving an inequality. We will solve the task "Prove the inequality $2^n - n^3 > 23$ for all natural $n \geq 10$ " in the ChatGPT environment. ChatGPT generates a response, which we present in English and duplicate with a screenshot in Ukrainian (Figure 3).

Proof.

1. Check the base case: for $n = 10$: $2^{10} - 10^3 = 1024 - 1000 = 24 > 23$. So, the base case holds.

2. Assume that for some $k \geq 10$ $2^k - k^3 > 23$.

3. Prove that the inequality also holds for $k + 1$:

$$2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$$

We have $2^k - k^3 > 23$, so let's look at $-(k+1)^3$.

$$(k+1)^3 = k^3 + 3k^2 + 3k + 1.$$

Substitute this into the expression:

$$2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k^3 + 3k^2 + 3k + 1)$$

$$2^{k+1} - (k+1)^3 = 2^k - k^3 + 2^k - 3k^2 - 3k - 1$$

Since we assume that $2^k - k^3 > 23$, we can change

$$2^{k+1} - (k+1)^3 > 2^k - k^3 + 2^k - 3k^2 - 3k - 1$$

$$> 23 - 3k^2 - 3k - 1$$

It's remained to show that $23 - 3k^2 - 3k - 1 > 23$.

After simplification, we obtain $-3k^2 - 3k - 1 > 0$.

This always holds for any $k \geq 10$, since the coefficients near $3k^2$ and $3k$ are negative, and the constant is also negative.

Remark. The experiment was conducted in Ukrainian, and the figures are presented in the original language, as the results from ChatGPT depend on the language of the prompt.

The ChatGPT chooses the method of mathematical induction, presumably due to the requirement in the problem statement "to prove for all natural numbers n ". This method is one of the most common ways to prove such types of inequalities, so the chatbot selected a standard reasoning approach. It is worth noting that ChatGPT outlines all the steps of the mathematical induction method and provides what appears to be a correct proof, but in the highlighted line after using the induction assumption, it omits the term 2^k which plays a crucial role in further evaluations of the expression.

You
Довести нерівність $2^n - n^3 > 23$ для довільного $n \geq 10$

ChatGPT
Ну давай подивимося. Спробуємо довести цю нерівність методом математичної індукції. Спочнемо з базового випадку, де $n = 10$.

1. Перевіримо базовий випадок:
Для $n = 10$: $2^{10} - 10^3 = 1024 - 1000 = 24 > 23$.

Отже, базовий випадок виконується.

1. Передположимо, що для деякого k нерівність виконується, тобто:
 $2^k - k^3 > 23$.

2. Доведемо, що і для $k + 1$ нерівність також виконується:
 $2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$.

Ми вже маємо, що $2^k - k^3 > 23$, тому поглянемо на решту виразу:
 $-(k+1)^3$.

$(k+1)^3 = k^3 + 3k^2 + 3k + 1$.

Підставимо це у вираз:
 $2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k^3 + 3k^2 + 3k + 1)$.

$2^{k+1} - (k+1)^3 = 2^k - k^3 + 2^k - 3k^2 - 3k - 1$.

Оскільки ми вже припускаємо, що $2^k - k^3 > 23$, можемо замінити це значення:
 $2^{k+1} - (k+1)^3 > 2^k - k^3 + 2^k - 3k^2 - 3k - 1 > 23 - 3k^2 - 3k - 1$.

Нам залишається показати, що $23 - 3k^2 - 3k - 1 > 23$.

Після спрощення отримаємо:
 $-3k^2 - 3k - 1 > 0$.

Це завжди виконується для будь-якого $k \geq 10$, оскільки коефіцієнти перед k^2 та k негативні, а константа від'ємна.

Отже, за допомогою методу математичної індукції ми показали, що нерівність $2^n - n^3 > 23$ виконується для будь-якого $n \geq 10$.

Fig. 3. The result of completing the task (source: made by authors)

Furthermore, in the provided proof, it is claimed that $-3k^2 - 3k - 1 > 0$ for all $k \geq 10$, which is not true. Therefore, analyzing the generated proof is crucial for identifying mistakes and exploring ways to rectify them.

ChatGPT attempts to respond to the specified mistake with a new prompt and correct it, but it fails to do so. It essentially proposes the same proof (Figure 4).

Proof. Let us review the induction step.

We assume that for k $2^k - k^3 > 23$.

Now let's prove $k + 1$:

$$2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$$

Let's consider $2^k - k^3 + 2^k - 3k^2 - 3k - 1$.

It is important to see that $2 \cdot 2^k = 2^k + 2^k$:

$$2^k - k^3 + 2^k - 3k^2 - 3k - 1 = 2^k - k^3 + 2^k - 3k^2 - 3k - 1$$

Now, we can use the assumption and express the first term:
 $> 23 - 3k^2 - 3k - 1$.

So, we get $23 - 3k^2 - 3k - 1 > 23 - 3k^2 - 3k - 1$.

Sorry for the confusion.

After being pointed out more specifically its mistake, ChatGPT suggests the same proof with an incorrect subtraction of 1 for compensation, losing the term 2^k again. In other words,

ChatGPT cannot correct the mistake even with external assistance; it reverts to the previous proof (Figure 5).

Proof. Yes, you are absolutely right, and I apologize for the confusion earlier. Let's correct this mistake.

We assume that for k $2^k - k^3 > 23$.

Let's prove for $k + 1$:

$$2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$$

We consider $2^k - k^3 + 2^k - 3k^2 - 3k - 1$.

Instead of expanding $2 \cdot 2^k$ as $2^k + 2^k$, let's expand as $2^k + 2^k - 1$ (-1 for compensation).

$$2^k - k^3 + 2^k - 3k^2 - 3k - 1 =$$

$$= 2^k - k^3 + 2^k - 3k^2 - 3k - 1 - 1$$

We get:

$$2^k - k^3 + 2^k - 3k^2 - 3k - 2 > 23 - 3k^2 - 3k - 2.$$

Let's use the assumption and expand the first term:
 $> 23 - 3k^2 - 3k - 2$.

We get $23 - 3k^2 - 3k - 2 > 23 - 3k^2 - 3k - 2$.

It's correct for any $k \geq 10$. Thank you for your patience and understanding.

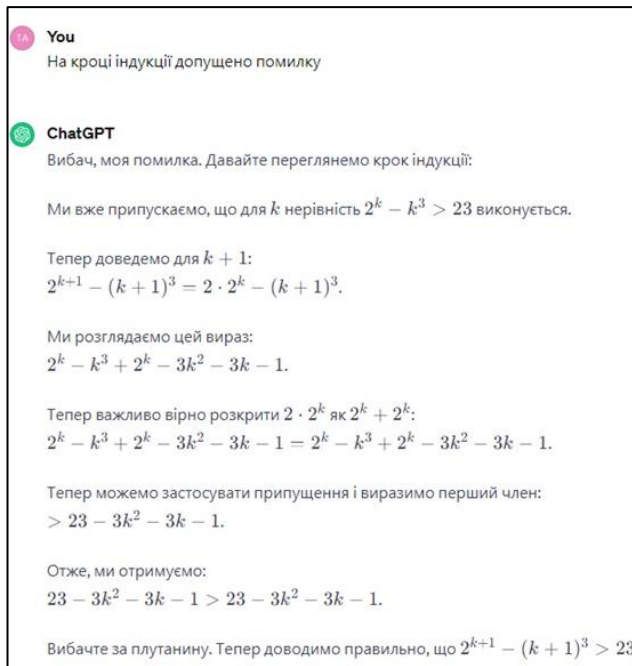


Fig. 4. The reaction (1) of ChatGPT to pointing out its mistakes (source: made by authors)

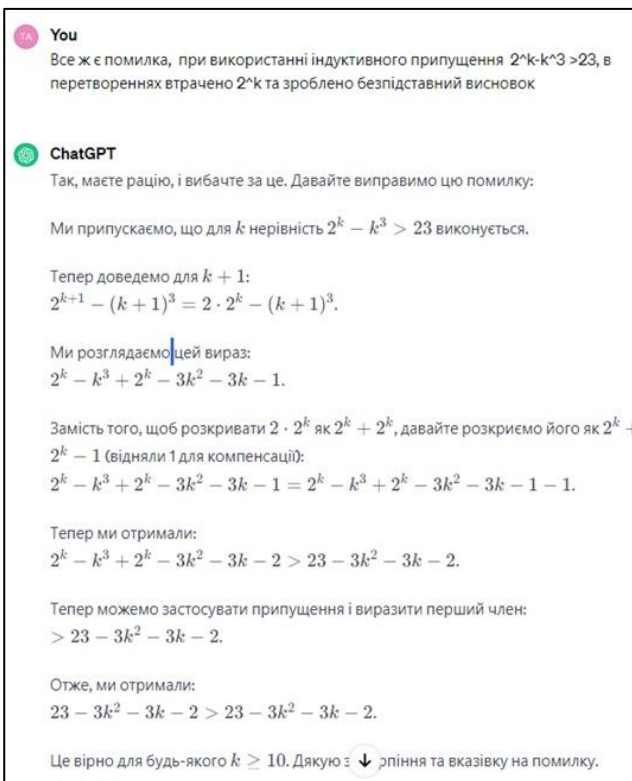


Fig. 5. The reaction (2) of ChatGPT to pointing out its mistakes (source: made by authors)

Specify the mistake in the prompt and get proof that are not complete but does not contain logical and factual mistakes (Figure 6).

Proof. Yes, you are absolutely right, and I apologize for the incorrect calculation. Let's correct this.

We have the assumption $2^k - k^3 > 23$.

Let's expand the expression for $k+1$:

$$2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$$

Let's expand $2 \cdot 2^k$ as $2^k + 2^k$: $2^k - k^3 + 2^k - 3k^2 - 3k - 1$.

Let's group the terms:

$$2^k - k^3 + 2^k - 3k^2 - 3k - 1 = (2^k - k^3) + (2^k - 3k^2 - 3k - 1)$$

Since $2^k - k^3 > 23$, $(2^k - k^3) + (2^k - 3k^2 - 3k - 1) > 23 + (2^k - 3k^2 - 3k - 1)$.

Let's show that $23 + (2^k - 3k^2 - 3k - 1) > 23$.

After simplification, we obtain $-3k^2 - 3k - 1 > 0$.

This actually holds for any k because the coefficients near $3k^2$ and $3k$ are negative, and the constant is also negative.

To complete the proof, it remains to show that for $k \geq 10$, $2^k - 3k^2 - 3k - 1 > 0$.

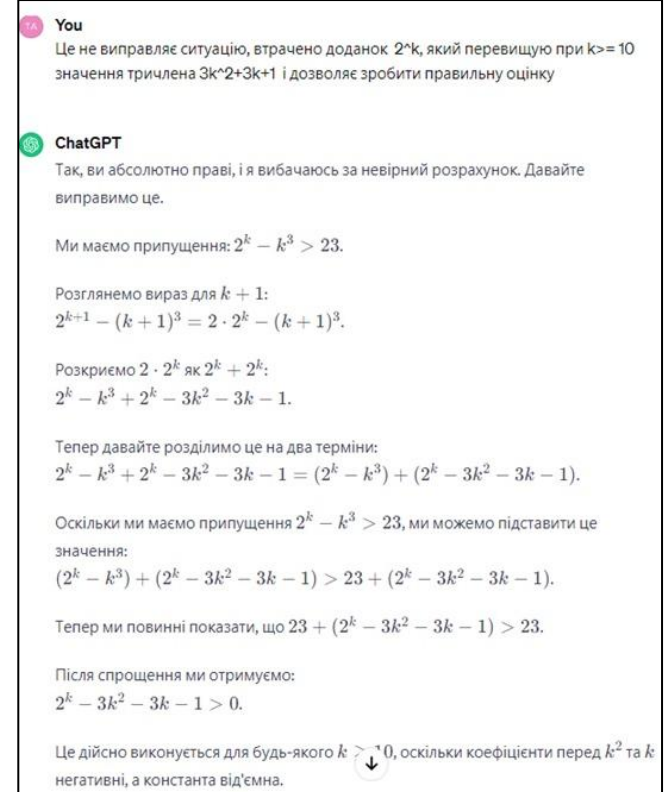


Fig. 6. The reaction (3) ChatGPT to mistake correction (source: made by authors)

Note that the result of the proof of the same inequality proposed by ChatGPT after a month also contains mistakes (Figure 7). Despite the more detailed proof, ChatGPT makes the same mistakes in transformations.

Proof. Let's try to prove the inequality using mathematical induction.

1. The base step.

Let's substitute $n=10$ in the inequality $2^{10} - 10^3 = 1024 - 1000 = 24 > 23$. So, the base case holds.

2. The induction assumption.

Assume that the inequality holds for some $k \geq 10$, $2^k - k^3 > 23$.

3. The induction step.

Let's prove that the inequality also holds for $k+1$.

Let's consider: $2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$.

Consider 2^k separately $2 \cdot 2^k > 2 \cdot k^3$ (for $k \geq 10$, since we have already checked the basic step).

Also, by the assumption $2^k - k^3 > 23$.

Combining these two results, we get

$$2 \cdot 2^k - (k+1)^3 > 2 \cdot k^3 - (k+1)^3 + 23$$

Let's consider $2 \cdot k^3 - (k+1)^3$:

$$2 \cdot k^3 - (k+1)^3 = 2 \cdot k^3 - (k^3 + 3k^2 + 3k + 1) = k^3 - 3k^2 - 3k - 1$$

Let's note that for $k \geq 10$ $k^3 - 3k^2 > 0$.

Thus, we get $2 \cdot k^3 - (k+1)^3 > 23$.

So, the inequality holds for $k+1$ by the induction.

Therefore, for all natural $n \geq 10$ the inequality $2^n - n^3 > 23$ holds.

You
Довести нерівність $2^n - n^3 > 23$ для всіх натуральних $n \geq 10$
< 2/2 >

ChatGPT
Давайте спробуємо довести дану нерівність за допомогою математичної індукції.

- Базовий крок ($n = 10$):**
Підставимо $n = 10$ у нерівність: $2^{10} - 10^3 = 1024 - 1000 = 24 > 23$.
Отже, базовий крок виконано.
- Припущення індукції:**
Припустимо, що нерівність виконується для деякого k , тобто $2^k - k^3 > 23$.
- Крок індукції:**
Доведемо, що нерівність також виконується для $k + 1$.
Розглянемо вираз $2^{k+1} - (k+1)^3$:
 $2^{k+1} - (k+1)^3 = 2 \cdot 2^k - (k+1)^3$
Розглянемо 2^k окремо: $2 \cdot 2^k > 2 \cdot k^3$ (для $k \geq 10$, адже ми вже перевірили базовий крок).
Також, за припущенням індукції, $2^k - k^3 > 23$.
Об'єднавши ці два результати, ми отримуємо:
 $2 \cdot 2^k - (k+1)^3 > 2 \cdot k^3 - (k+1)^3 + 23$
Тепер розглянемо різницю $2 \cdot k^3 - (k+1)^3$:
 $2 \cdot k^3 - (k+1)^3 = 2k^3 - (k^3 + 3k^2 + 3k + 1) = k^3 - 3k^2 - 3k - 1$
Зауважимо, що для $k \geq 10$ ми можемо \downarrow ити цей вираз як $k^3 - 3k^2 > 0$.
Таким чином, отримуємо:
 $2 \cdot k^3 - (k+1)^3 > 23$
Отже, за індукцією нерівність виконується для $k + 1$.

Отже, ми довели, що для всіх натуральних $n \geq 10$ нерівність $2^n - n^3 > 23$ виконується.

Fig. 7. The result of the task solution after a month (source: made by authors)

ChatGPT can generate other methods of proving the given inequality – "the method of using functions", "the method of using function analysis", "the differentiation method", "the method of reduced factors" (keeping the names of the methods as suggested by ChatGPT).

However, "proofs" contain either obvious mistakes in transformations or "hide" them in a correct reasoning shell. None of the proofs generated by ChatGPT were correct. For example, the "proof" (method of using functions, Figure 8) contains many mistakes, starting from the estimation at $n = 10$, with an arithmetic mistake in finding 2^{10} , to the false statement that $f(n+1) - f(n)$ should be less than or equal to zero.

Використання функцій:
Розглянемо функцію $f(n) = 2^n - n^3 - 23$. Ми хочемо показати, що для $n \geq 10$ функція завжди дорівнює або більше нуля.

- Перевіримо базовий випадок: $f(10) = 2^{10} - 10^3 - 23 = 24 - 1000 - 23 = -999 < 0$.
- Для індукції, спростимо $f(n+1) - f(n)$ і покажемо, що він завжди менше або дорівнює нулю для $n \geq 10$.
Розглянемо:
 $f(n+1) - f(n) = 2^{n+1} - (n+1)^3 - (2^n - n^3 - 23)$.
Спростимо це і покажемо, що воно менше або дорівнює нулю.

Fig. 8. The method of using a function (source: made by authors)

Proof (Using Functions). Let's consider the function $f(n) = 2^n - n^3 - 23$. We want to show that for $n \geq 10$, the function is always positive or greater than zero.

1. Let's verify the base case: $f(10) = 2^{10} - 10^3 - 23 = 24 - 1000 - 23 = -999 < 0$.

2. For induction, let's show that $f(n+1) - f(n)$ is always positive or greater than zero for $n \geq 10$.

$$f(n+1) - f(n) = 2^{n+1} - (n+1)^3 - (2^n - n^3 - 23).$$

Simplifying this, we show that it is always positive or greater than zero.

Another method suggested by ChatGPT (Method of using function analysis, Figure 9) also has several drawbacks – it provides general recommendations for proving inequalities using the monotonicity of functions without specifying how to implement it in this particular case.

Proof (Using Function Analysis).

We consider the function $g(n) = 2^n - n^3$. We want to prove that the function is always greater than 23 for $n \geq 10$.

1. Analyze the behavior of the function as $n \rightarrow \infty$.

2. Show that $g(n)$ grows faster than $h(n) = 23$ for all $n \geq 10$.

Використання аналізу функцій:

Розглянемо функцію $g(n) = 2^n - n^3$. Докажемо, що для $n \geq 10$ функція завжди більше за 23.

1. Вивчіть поведінку функції при $n \rightarrow \infty$.

2. Покажіть, що $g(n)$ зростає швидше, ніж $h(n) = 23$, для всіх $n \geq 10$.

Fig. 9. Method of Using Function Analysis (source: made by authors)

When using the method of differentiation (Figure 10), ChatGPT applies the assumption of induction, incorrectly finds the derivative, and uses the differentiation of inequality, which is generally incorrect.

Proof (Method of Differentiation).

1. Base Case. Check for $n = 10$:

$$2^{10} - 10^3 = 1024 - 1000 = 24 > 23.$$

2. Induction Step. Let's assume the inequality holds for some k : $2^k - k^3 > 23$.

Now let's differentiate both parts of the inequality:

$$2^{k+1} - 3k^2 > 0$$

Here, we use the assumption that $2^k - k^3 > 23$ to calculate the derivative $2^{k+1} - (k+1)^3$.

Let's prove that the obtained inequality holds for $k + 1$.

Метод диференціювання:

1. Базовий випадок: Перевіримо для $n = 10$:

$$2^{10} - 10^3 = 1024 - 1000 = 24 > 23.$$

2. Індукційний крок: Припустимо, що нерівність виконується для певного k : $2^k - k^3 > 23$.

Тепер диференціюємо обидві сторони нерівності за n :

$$2^{k+1} - 3k^2 > 0.$$

Тут ми використали припущення, що $2^k - k^3 > 23$ для обчислення похідної $2^{k+1} - (k+1)^3$.

Докажемо, що отримана нерівність \downarrow конується для $k + 1$.

Fig. 10. Differentiation Method (source: made by authors)

When using the method of shortening factors (Figure 11), an attempt is made to use factorization formulas, but this attempt is not implemented. Then, ChatGPT limits itself to general recommendations for proving the inequality by the same functional method using the derivative (mistakenly assuming that at $n = 10$ there will be a minimum (actually, the minimum value of the function) without a specific implementation).

Proof (Method of Factoring).

1. let's consider the inequality: $2^n - n^3 > 23$.

2. Let's expand the difference of squares:

$$\left(\frac{n}{2}\right)^2 - n^3 + 23 > 0$$

3. Let's consider the function $f(n) = \left(\frac{n}{2}\right)^2 - n^3 + 23$.

4. Let's show that $f(n)$ has minimum for $n \geq 10$.

– Let's consider $f'(n)$ and find a point where $f'(n) = 0$.

– Let's use the second derivative test to confirm that this is a minimum.

– Let's check the value at the minimum point.

Метод скорочених множників:

1. Розглянемо нерівність: $2^n - n^3 > 23$.
2. Розкриємо різницю квадратів: $2^n - n^3 - 23 > 0$.
 $(2^{n/2})^2 - n^3 + 23 > 0$.
3. Розглянемо функцію: $f(n) = (2^{n/2})^2 - n^3 + 23$.
4. Покажемо, що $f(n)$ має мінімум для $n \geq 10$.
 - Розглянемо $f'(n)$ і знайдемо точку, де $f'(n) = 0$.
 - Проведемо тестування за допомогою другої похідної для підтвердження, що це мінімум.
 - Перевіримо значення $f(n)$ в точці мінімуму.

Fig. 11. Method of reduced factors (source: made by authors)

Therefore, ChatGPT makes mistakes in proving inequalities, providing an opportunity to use it for generating student-like responses. Generated solutions containing mistakes become important training tools in teacher preparation in general and for developing students' critical thinking in particular. It is worth noting that the response of ChatGPT depends on the formulation of the task itself, and the wording of clarifications or comments on the proposed solutions. Additionally, ChatGPT responses are influenced by the language of the prompt (specifically, the generation of solutions is more accurate in English).

So, all the results were presented in the Ukrainian language, the language in which the experiment was conducted. Note, that when the prompt is formulated in English, ChatGPT provides correct proof without mistakes, although without detailed explanations in the final steps (Figure 12).

<p>You Prove the inequality $2^n - n^3 > 23$ for an arbitrary natural $n \geq 10$</p> <p>ChatGPT Certainly, let's prove the inequality $2^n - n^3 > 23$ for any natural $n \geq 10$.</p> <p>Proof by Mathematical Induction:</p> <p>Base Case: For $n = 10$, let's verify the inequality: $2^{10} - 10^3 = 1024 - 1000 = 24 > 23$.</p> <p>The base case holds true.</p> <p>Inductive Step: Assume that for some $k \geq 10$, the inequality $2^k - k^3 > 23$ is true</p>	<p>Now, let's prove for $k + 1$: $2^{k+1} - (k + 1)^3 = 2 \cdot 2^k - (k + 1)^3$.</p> <p>Consider the expression: $2^k - k^3 + 2^k - 3k^2 - 3k - 1$.</p> <p>Now, split it into two terms: $2^k - k^3 + (2^k - 3k^2 - 3k - 1)$.</p> <p>By the inductive assumption, the first term is greater than 23: $> 23 + (2^k - 3k^2 - 3k - 1)$.</p> <p>Now, we need to show that $(2^k - 3k^2 - 3k - 1) > 0$. This is true for $k \geq 10$ because the exponential term 2^k grows faster than the quadratic and linear terms.</p> <p>Therefore, the inequality holds for $k + 1$.</p> <p>By mathematical induction, the given inequality $2^n - n^3 > 23$ is proven for all $n \geq 10$.</p>
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Fig. 12. The prompt is formulated in English (source: made by authors)

3.2. Experiment results

The tasks aimed at developing students' abilities to find, critically evaluate, and correct (if possible) mistakes in the proofs of inequalities using ChatGPT as a "student" were formulated in individual work (Figure 13).

The results of the double assessment of students are presented in Table 2, processed in the Excel spreadsheet (t-Test: Paired Two Sample for Means) (Table 3), and visualized by a diagram (Figure 14).

The statistical analysis of the results provided grounds to reject the null hypothesis in favor of the alternative one. The means for the two assessments changed significantly: $3.7 < 4.4$. Such changes are not random, as $|t_{\text{stat}}| = 3.97 > 2.04 = t_{\text{critical}}$ ($p = 0.0004$). Therefore, we conclude that the ChatGPT-based simulation positively impacts the development of students' critical thinking.

- Task 1.** Propose to ChatGPT to prove the inequality. What proof method does ChatGPT prioritize? What methods does it suggest for proving? How many of them? Record the results for the report.
- Task 2.** Identify any mistakes made by ChatGPT (if any). Formulate them for the report.
- Task 3.** Point out ChatGPT's mistakes. Analyze whether ChatGPT corrected the solution. Did it take into account your previous comments? Record the results for the report.
- Task 4.** Propose to ChatGPT to prove the given inequality using different methods (at least two other methods). Are there any errors in these methods? Record the results for the report.
- BREAK
- Task 5.** Propose the same tasks to ChatGPT after a month. Identify the mistakes made by ChatGPT (if any). Analyze whether ChatGPT took into account your previous comments. Record the results for the report.

Fig. 13. Tasks for individual work (source: made by authors)

Table 2. Double assessment of student works (Source: made by authors)

No	Mark for tasks 1-4	Mark for task 5	No	Mark for tasks 1-4	Mark for task 5	No	Mark for tasks 1-4	Mark for task 5
1	2	2	12	6	8	23	3	4
2	6	7	13	4	3	24	4	7
3	4	5	14	3	2	25	2	2
4	4	5	15	2	4	26	6	7
5	5	5	16	2	4	27	4	5
6	3	3	17	2	2	28	4	5
7	3	4	18	4	4	29	5	5
8	2	4	19	5	7	30	3	3
9	2	2	20	6	8	31	3	4
10	4	4	21	4	3	32	2	4
11	5	7	22	3	2			

Table 3. Results of statistical analysis (Source: made by authors)

	First assessment	Second assessment
Mean	3.65625	4.40625
Variance	1.78125	3.410282
Observations	32	32
Pearson Correlation	0.817605	
Hypothesized Mean Difference	0	
df	31	
t stat	-3.937	
P(T<=t) one-tail	0.000218	
t critical one-tail	1.695519	
P(T<=t) two-tail	0.000435	
t critical two-tail	2.039513	

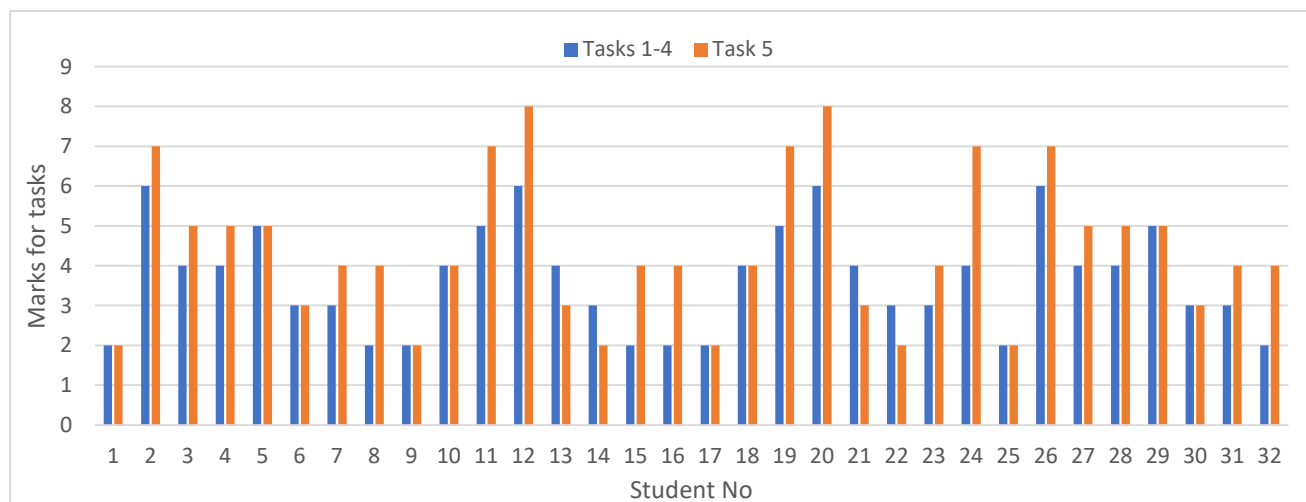


Fig. 14. Diagram of results (source: made by authors)

4. Discussion

In the process of education, students should develop the ability to teach students to prove mathematical statements, which includes not only the ability to prove theorems/equations/inequalities from the school math course but also the ability to anticipate common mistakes made by students, justify mistakes in students' work, and correctly and logically correct the mistakes made by students. Such skills, on the one hand, are professional for a teacher, but on the other hand, they characterize the level of development of their critical thinking, which needs to be enhanced, especially in situations close to real ones. Similar situations, as our research has shown, can be generated using AI, in particular ChatGPT.

The accuracy of responses generated by AI systems can significantly depend on the language used to frame prompts. Our analysis revealed notable inconsistencies, particularly when solving mathematical problems such as proving of inequalities using the induction method. When prompts are posed in English, AI responses tend to be more precise, structured, and logically consistent. However, when prompts are written in other languages, such as Ukrainian, the quality of solutions often decreases, displaying mistakes or omissions in reasoning. This discrepancy may arise due to the dominance of English-language data in AI training models, where a vast proportion of available educational and mathematical content is in English. As a result, AI systems process English prompts with greater familiarity, leading to improved response generation. In contrast, prompts in languages with less representation in training datasets may not yield responses of comparable accuracy, particularly for specialized topics like advanced mathematics. However, it was these differences that became the basis for our research.

The use of ChatGPT in education calls for reconsidering assessment methods [12]. For instance, descriptive tasks like essays should replace more creative ones requiring students' critical thinking and focused creative efforts. In our research,

we modified typical tasks, shifting from "prove the inequality" and "identify possible mistakes in students' work" to "analyze the given response" and "detect/justify/correct mistakes." These tasks are not algorithmic and carry significant heuristic value. Our assignments generally involve abstract thinking and foster the development of skills in analysis, logical reasoning, and concluding. They also provide an opportunity to comprehensively reinforce a wide range of theoretical concepts studied in the school mathematics curriculum, including the basics of inequality theory, the equivalence of transformations, properties of functions, applications of derivatives and integrals, geometric reasoning, estimation of areas and volumes, etc.

Modern education is concerned not only with acquiring knowledge and skills in a specific field of knowledge or future profession (hard skills). With the development of information technologies, qualities that ensure an individual's competitiveness in the modern job market have become essential. These qualities are referred to as soft skills and include analytical thinking and innovation, active learning and learning strategies, complex problem solving, critical thinking and analysis, creativity, originality and initiative, leadership and social influence, resilience, stress tolerance and flexibility, reasoning, problem-solving, and ideation (World Economic Forum, 2020), collectively known as the "Four Cs" – Collaboration, Communication, Creativity, and Critical thinking. In recent years, researchers have emphasized the importance of these 21st-century skills [43]. These skills are crucial for teachers, who must be creative in their professional activities and capable of facilitating communication and promoting student teamwork. Given the nature of their profession (teaching mathematics), possessing and developing critical thinking are particularly essential for mathematics teachers. Our research indicates the potential for developing pre-service teachers' critical thinking as part of their professional training, contributing to cultivating the in-demand skills of the 21st century.

In society and within the academic community, concerns have arisen regarding the use of AI ("job killer", "influences people's thoughts through generating posts and comments for social media", "generates academic texts that are not substantiated", etc.). Due to such concerns, some schools have even prohibited the use of ChatGPT [11, 22]. For instance, S. Marche [23] suggests that it may take "ten years for scholarly circles to confront this new reality: two years for students to understand the technology, another three years for professors to acknowledge that students are using this technology, and then five years for university administrators to decide what to do with it if anything." W. M. Lim, A. Gunasekara, J. L. Pallan, J. I. Pallant, and E. Pechenkina [21] argue that, on the one hand, AI leads to the disruption of the education system. On the other hand, it opens up a new era of accessible information and automation to enhance the quality of education.

M. Farrokhnia, S. K. Banihashem, O. Noroozi, and A. Wals [15], based on the results of the SWOT analysis, identified the strengths of ChatGPT (creating plausible responses, self-improvement or self-learning ability, providing personalized responses, real-time response capabilities, especially for education, increasing information accessibility, facilitating individual learning, supporting comprehensive learning, reducing teachers' workload, e.g., ChatGPT can create tests for you) and weaknesses (lack of deep understanding, difficulties in assessing the quality of responses, democratization of plagiarism in education/science, reduction of high-level cognitive skills such as creativity, critical thinking, reasoning, and problem-solving). Our research demonstrated the positive aspects of using AI in the educational process. ChatGPT has become a digital tool for developing critical thinking in youth by generating plausible but, from a mathematical perspective, incorrect statements, formulations, and conclusions.

The conducted research aligns with the key ideas of the Concept for the Development of Artificial Intelligence in Ukraine [41]. Specifically, for the higher education sector, the concept authors emphasize the importance of incorporating artificial intelligence topics into educational programs across various specialties. We see the implementation of this idea in integrating artificial intelligence as a teaching tool in the professional training of teachers – creating simulation cases with answer generation not only introduces the possibilities of using artificial intelligence and the peculiarities of answer generation but also facilitates additional quasi-professional practice.

Today, there is also a discussion about the ability of AI to assess data accurately: ChatGPT lacks the human ability to evaluate the reliability of the data it has been trained [19]. ChatGPT does not have access to the internet and currently has limited knowledge of events in the world after 2021 [37], leading to the possibility of providing outdated and inaccurate answers. ChatGPT is not afraid to be "wrong"; it is afraid to be "uninformed". It will "make it up" and still respond if it doesn't know the answer. Our research confirms that this can be used as material for critical analysis and developing students' critical thinking.

5. Conclusions

The new educational trend involves the implementation of artificial intelligence in the educational process. A high level of critical thinking is necessary for working with artificial intelligence. On the other hand, artificial intelligence itself can be considered a tool for developing pre-service mathematics teachers' critical thinking. In today's conditions, a pre-service mathematics teacher must possess a high level of critical thinking as an integral component of soft skills for a competitively capable professional. The process of proving mathematical statements is relevant material for developing critical thinking. A pre-service mathematics teacher should not only know how to prove

the theorems of the school mathematics course but also be able to predict typical mistakes that students may make in their proofs. An effective way to implement artificial intelligence in the professional training of pre-service mathematics teachers is using ChatGPT to simulate interactions with students and critically evaluate their solutions during classes.

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