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ARTIFICIAL INTELLIGENCE PEDAGOGICAL APPROACH FOR FOSTERING CONCEPTUAL UNDERSTANDING IN COLLEGE MATHEMATICS

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Abstract

In this paper, we studied the implications of Artificial Intelligence (AI) in mathematics courses at the college level, with a concentration on its impact on students' conceptual understanding. AI offers a wide range of innovative tools and adaptive platforms that enable instructors to explain math concepts in inventive and engaging ways. Our study examines how these tools can improve students' understanding, as these platforms facilitate individualized learning experiences, represent concepts in various ways, and offer immediate feedback. Our goal is to evaluate the success of AI-driven techniques in supporting different learning methodologies and improving student engagement in the mathematical classroom. The findings shall assist us in recognizing the power of AI in transferring teaching approaches in college education to enhance conceptual learning.

Keywords:

Artificial Intelligence, Mathematical Education, College Level, Pedagogical Approach

1. Introduction

With the rapid growth of artificial intelligence, AI has had a significant impact on education in general and particularly on higher education (Abar et al., 2024; Borah & Borah, 2024). While students often struggle to understand mathematical concepts and solve complex problems, AI provides innovative pedagogical approaches that assist learners in building conceptual understanding (Canonigo, 2024; Fathi et al., 2025; Li & Lyu, 2025). Conceptual understanding is a crucial aspect of mathematical learning because it helps students develop reasoning, connect ideas, and make sense of core concepts (Panaoura, 2025).

Traditional pedagogies—lectures, reading textbooks, and completing end-of-chapter assessments—have been effective for decades; however, they may not be optimal for Generation Z learners, especially with the emergence of AI-enhanced learning tools (Abiola et al., 2024; Li et al., 2024; Tang, 2025). Moreover, large class sizes, restrictive curricula, and limited instructional time may negatively affect learning outcomes (Abar et al., 2024).

In contrast, traditional strategies are increasingly being supplemented by intelligent techniques that enhance conceptual learning by providing real-time feedback, individualized guidance, and increased opportunities for students to engage with mathematical concepts (Canonigo, 2024; Torres-Peña et al., 2024; Trindade et al., 2025).

2. Literature Review

The implementation of AI in college mathematics instruction has demonstrated positive impacts on conceptual understanding when integrated effectively with traditional teaching (Canonigo, 2024; Li et al., 2024). AI platforms such as ChatGPT, GeoGebra, and MathGPT have played significant roles in supporting mathematical thinking.

AI tutoring systems and adaptive learning platforms personalize learning experiences by adjusting difficulty levels, providing targeted exercises, and offering immediate feedback (Abar et al., 2024; Borah & Borah, 2024; Fathi et al., 2025). Interactive simulations and dynamic visualizations further support students in understanding abstract concepts (Choustoulakis, 2024; Tang, 2025).

Intelligent tutoring systems employ inquiry-based learning, constructivist approaches, and problem-posing strategies to help students explore mathematical ideas deeply (Shao & Tang, 2025; Xing et al., 2025). Numerous studies report that AI-augmented instruction improves motivation, engagement, and conceptual comprehension compared with traditional methods (Canonigo, 2024; Torres-Peña et al., 2024; Li & Li, 2025).

AI also reduces misconceptions by analyzing patterns in student errors and providing tailored remediation (Fathi et al., 2025; Shao & Tang, 2025). Nonetheless, AI must complement—not replace—instructors. Ethical use, responsible integration, and continuous research are necessary to ensure quality outcomes (Panaoura, 2025; Trindade et al., 2025).

Table 1.1 *Evidence Table Summarizing AI's Impact on Conceptual Understanding*

Claim	Evidence Strength	Justification	Papers
Integrating AI into college mathematics education enhances conceptual understanding	Strong (9/10)	Research shows more advantages of using AI than traditional ways of teaching.	Abar et al. (2024); Abiola et al. (2024); Canonigo (2024); Choustoulakis (2024); Li & Lyu (2025); Li et al. (2024)
Implementing AI in teaching helps to reduce misconceptions and improve deep learning	Strong (8/10)	AI offers real-time feedback and adaptive platforms that help students understand pure mathematics.	Canonigo (2024); Choustoulakis (2024); Li et al. (2024)
Pedagogical structure and human involvement are still essential	Moderate (7/10)	Research shows the need for instructors to thoughtfully integrate AI into teaching.	Abar et al. (2024); Choustoulakis (2024); El-Shara (2025); Shao & Tang (2025); Torres-Peña et al. (2024)

3. Theoretical Background of Conceptual Understanding

In this section, we begin by defining conceptual understanding as the ability of learners to recognize the broader context of a problem and connect the relationships between facts and methods. It focuses more on the reasons underlying mathematical operations and how to apply that knowledge to new applications, rather than memorizing formulas and performing algorithms and calculations. Advanced mathematical thinking enables students to be creative in problem-solving by developing logical conceptual models and applying mathematical principles to various applications across multiple fields, as well as successfully explaining and defending their arguments. Indeed, conceptual understanding is the most essential aspect of teaching mathematics to college students since it supports long-term memory. Various characteristics differentiate between students who only memorize processes and those who fully understand the mathematical concepts they are learning. The initial aspect is thinking outside the box and being able to approach problems from different perspectives. Furthermore, showing expertise in delivering concepts via symbolic, visual, numerical, and oral forms. Other indicators include recognizing the relationship between concepts; for example, students can relate integration to calculating surface area. Finally, students can extend their knowledge of mathematical concepts and apply them to their majors.

Despite the importance of conceptual comprehension in college mathematics, there are some common factors that cause its weakness. One factor is the priority of proper answers rather than logic, as students are more concerned with getting the right response, especially in exams. The other factor is a limited amount of lecture time, which might be a result of many students or a heavy syllabus. Moreover, pure mathematical courses such as real analysis, complex analysis, and topology can be challenging to absorb and apply. Finally, instructors may be unable to provide prompt assistance and feedback to each student, allowing them to clear their misconceptions. These challenges emphasize the importance of innovative strategies, such as AI-powered environments that enable students to engage deeply with mathematical concepts.

Several educational learning theories emphasize the significance of conceptual understanding and serve as a foundation for improving AI to be a tool that aligns with conceptual understanding. Based on a constructive learning approach, students learn by engaging in the educational process and constructing new knowledge from preexisting knowledge. While the dual process framework states that conceptual and procedural are considered as a looping process where each improves the other. Cognitive load theory is another crucial theory that employs visualization and scaffolding to minimize unneeded information ~~in order to~~to enhance conceptual knowledge.

4. AI's Impact in Mathematics Education: Foundation, Capabilities, and Integration

In the field of education, AI refers to the application of computational systems that can mimic human intelligence to assist in the learning and teaching process. These interactive systems encourage practice and participation, as students typically begin by investigating a concept independently after taking a diagnostic test that serves as their current knowledge. After they have absorbed the concept, they move to the next phase, which involves assessing their knowledge, tracking their progress, and receiving feedback. The use of these platforms in mathematics education has increased exponentially to assist the learning process and minimize misunderstanding.

AI tools that boost mathematical education outcome could be divided into four categories including Generative AI such as ChatGPT, Gemini, Wolfram Alpha and others which help explain concepts, solve problems and simulate mathematics; Natural language processing (NLP) is the process by which machines can learn, understand and generate human language; Machine learning (ML) is a field of AI in which systems use algorithms to analyze data, to make predictions and decisions and the intelligent tutoring systems (ITS) which defined as AI powered platforms which can act as an individual tutor based on a learner's needs knowledge and learning styles providing immediate feedback.

The ability of AI platforms to satisfy the goals of conceptual understanding helps to reshape the pedagogy of math education in general and particularly in higher education. One important factor that affects the learning process is real-time feedback that helps students notice their mistakes and rethink to get correct answers. AI also supports visualization, which minimizes the effort of understanding abstract concepts. Moreover, AI promotes scaffolding in math education as most platforms start by adjusting students' level and providing one-to-one support, starting from easy concepts to hard ones. Throughout machine learning, AI can identify the area of misconception by analyzing students' performance in timely matters. Moreover, NLP allows students to interact with AI agents, which helps students improve their metacognitive skills.

Different approaches have been used to integrate AI into math education for college students. It has been started by implementing AI for assignments and Online examinations. Outside of classrooms, many powered AI platforms support the learning process by allowing students to explore topics, practice problems, and provide self-assessments. Furthermore, the role of AI has been expanded to provide one-to-one AI available for twenty-four hours at no cost. Within the lecture time, AI power platforms could be utilized to activate students and support their engagement. This can be done throughout our visualization of concepts, short quizzes, riddles, and classwork in general. AI also plays an important role for instructors as it offers automatic grading with statistical analysis of the grades along with a dashboard in a timely manner. Research shows that AI is considered a sophisticated tool that reshaped math education to enhance both the learning process and outcome.

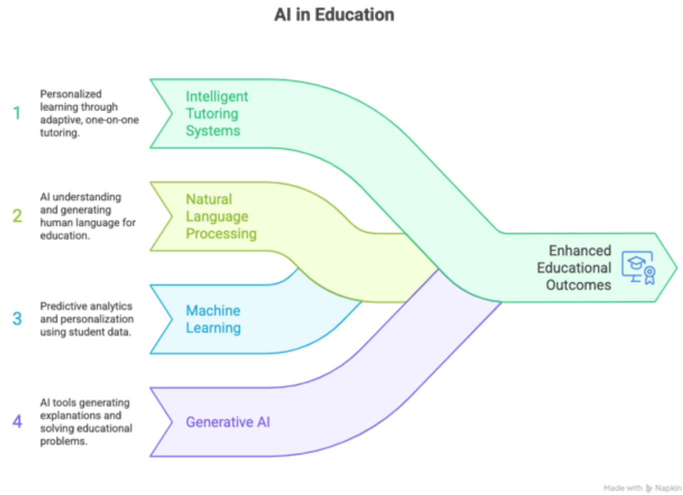


Figure 1: *The Four Categories of AI Technologies Utilized in Mathematics Education*

5. Empirical Analysis of AI Tools with Illustrative Case Studies

Learning mathematics has been reshaped by AI applications that go beyond automating procedures. There are several AI applications that might assist college students in improving their understanding of math concepts. These tools are used to visualize and illustrate mathematical definitions and concepts to boost the learning process, as well as to provide feedback and additional exercises with guidance throughout the lesson, thereby serving as private tutors for students. In this section, we'll present and analyze some case studies in which we implemented an AI approach to help explain and understand mathematical concepts in various topics, to highlight the capability of AI applications to enhance learning mathematics.

5.1 Limits in Calculus

One of the most challenging concepts for first-year students in calculus is the idea of limits and continuity. In standard calculus textbooks, the limit is often introduced by the tangent line problem, in which one aims to find an equation of the graph $y = (x)$ at a specific point $P(x_0\ f(x_0))$. Since the slope of the tangent line cannot be calculated directly using one point, a distinct point $(x_1 , f(x_1))$. on the curve is selected to define a line $\overrightarrow{PQ}$ which is known as a secant line. The main idea is to approximate the slope of the tangent line by moving Q along the curve toward P until the secant line approaches the position of the tangent line, and hence the slope of the tangent line or the limit is captured as the distance between P and Q approaches 0. In traditional lectures, instructors often use methods similar to the following standard mathematical procedures to obtain the main definition of the limit:

- Step 1: Find the slope of the scant line $\overrightarrow{PQ}$ By the following formula:

$$m_{secant} = \frac{(x_1)-f(x_0)}{x_1-x_0} \quad (1)$$

- Step 2: Move the point $Q(x_1, f(x_1))$ closer to $P(x_0, f(x_0))$ such as:

$x_1 = x_0 + h$, where h is the distance between x_0 and x_1, as h approaches 0 (h → 0), $m_{secant.}$ approaches $m_{tangent}$ and hence:

$$m_{tangent} = \lim_{h\to 0} m_{secant} = \lim_{x_1 \to x_0} \frac{(x_1)-f(x_0)}{x_1-x_0} \quad (2)$$

The concept of limit can be presented in different ways using the AI techniques, including the tangent line problem and the infographic graph shown in Figure 2. Then, illustrate the main idea using a Gemini-generated story, as outlined in the table below. Although the standard approach seems to be straightforward, the AI approach enhances students' understanding through graphs and visualizations. Furthermore, introducing the concept through storytelling might effectively connect the idea of limits to real-world problems.

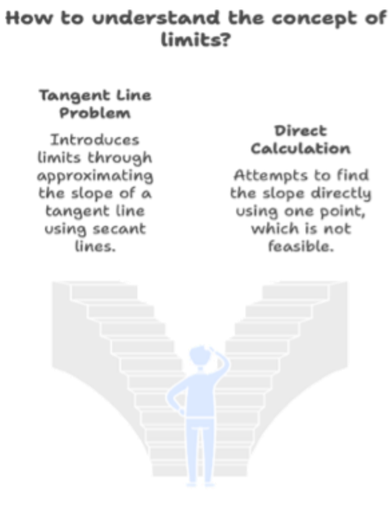
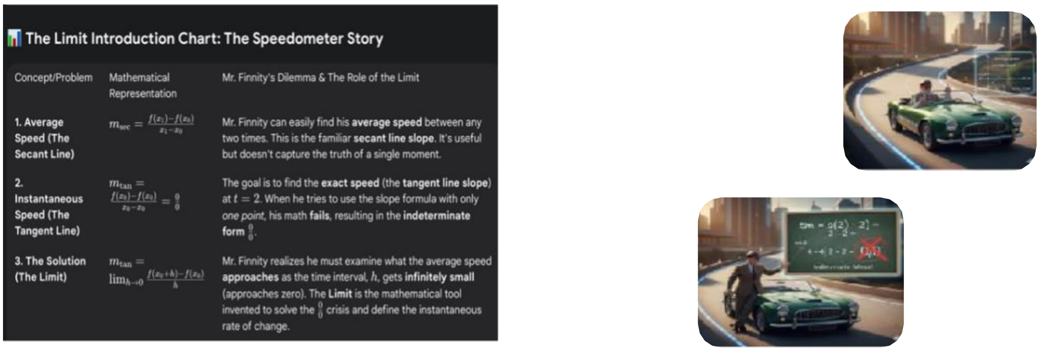


Figure 2: *AI-Visual Representation of the Concept of Limits in Calculus*



📊 The Limit Introduction Chart: The Speedometer Story

Concept/Problem	Mathematical Representation	Mr. Finnity's Dilemma & The Role of the Limit
1. Average Speed (The Secant Line)	$m_{\sec} = \frac{f(x_1)-f(x_0)}{x_1-x_0}$	Mr. Finnity can easily find his **average speed** between any two times. This is the familiar **secant line slope**. It's useful but doesn't capture the truth of a single moment.
2. Instantaneous Speed (The Tangent Line)	$m_{\tan} = \frac{f(x_0)-f(x_0)}{x_0-x_0} = \frac{0}{0}$	The goal is to find the **exact speed** (the **tangent line slope**) at $t = 2$. When he tries to use the slope formula with only *one point*, his math **fails**, resulting in the **indeterminate form** $\frac{0}{0}$.
3. The Solution (The Limit)	$m_{\tan} = \lim_{h\to0} \frac{f(x_0+h)-f(x_0)}{h}$	Mr. Finnity realizes he must examine what the average speed **approaches** as the time interval, h, gets **infinitely small** (approaches zero). The **Limit** is the mathematical tool invented to solve the $\frac{0}{0}$ crisis and define the instantaneous rate of change.

Figure 3: *AI-Generated Infographic Illustrating the Concept of Limit through a Narrative Approach*

To investigate the limit's concept more deeply, AI-powered platforms such as GeoGebra, Demos, and Wolfram Alpha enable students to explore how functions behave near a point by manipulating parameters and observing real-time changes via interactive graphs, as well as providing step-by-step examples for a better understanding of the formal definition.

We use the Wolfram Alpha platform to assist with solving the problem:

$$\lim_{x\to0}\frac{1}{x} \qquad (3)$$

The detailed answer is provided along with a graph that illustrates the behavior of the function near 0 in Figure 4.

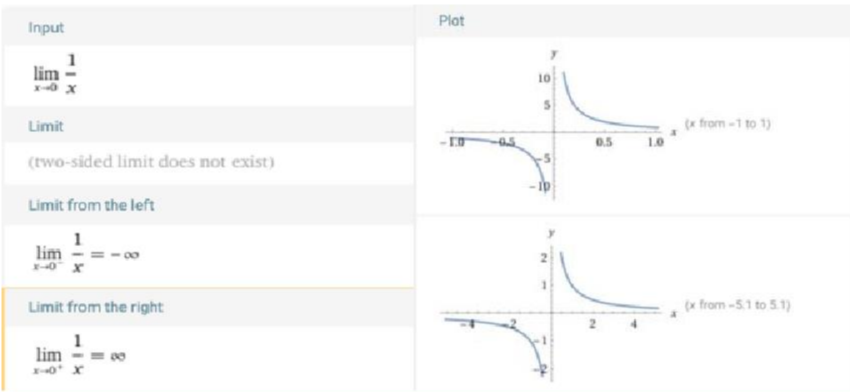


Figure 4: *Wolfram Alpha Visualization of a Function's Behavior Near Zero, Providing a Detailed Solution and Interactive Graph to Reinforce the Concept of Limits in Calculus*

In addition to explaining concepts and supporting students' understanding, the capacity of AI to provide hints and boost critical thinking before providing the final answer enhances instructional methods, alongside offering extra examples to reinforce the same ideas for more practice.

For instance, a platform called Mathzai has been used to solve the following problem:

$$\lim_{x \to 2} \frac{x^2+x-6}{x-2} \qquad (4)$$

The result is illustrated below in four stages: beginning with hints, followed by a detailed explanation of concepts in detail, presenting the final answer, and concluding with a comprehensive solution alongside similar problems and related videos to ensure full understanding of the concept.

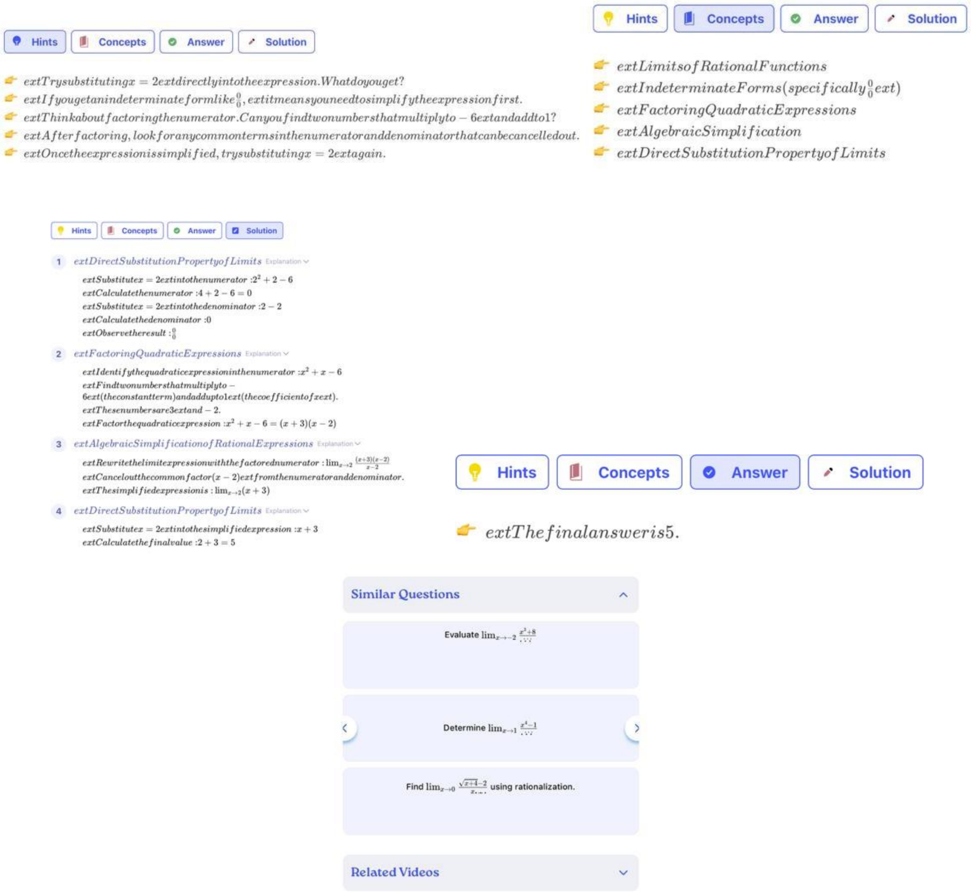


Figure 5: *AI-powered solution workflow Using Mathzai, illustrating a four-stage approach: hints, detailed concept explanation, final answer, and supplementary resources for a comprehensive understanding of limits in calculus*

5.2 Ordinary Differential Equations Simulation

The ordinary differential equations course is widely used in simulating real-world problems, and it is considered one of the most difficult courses to introduce to college students. Students must be familiar with ODEs terminologies and typical problems as well as the types of ODEs, ODEs solving techniques, simulation, and solution interpretation.

Consider introducing the separable differential equations. A separable equation is defined formally as follows:

A differential equation in the form

$$y' = (x)g(y) \qquad (5)$$

Where the right-hand side is a product of a function of x and a function of y.
The procedure to solve the separable equation starts by rewriting the equation as

$$\frac{dy}{dx} = (x)g(y) \qquad (6)$$

Divide both sides by (y)

$$\frac{1}{g(y)}\frac{y}{dx} = f(x) \qquad (7)$$

Integrate both sides with respect to x, to get

$$\int \frac{1}{g(y)}\frac{dy}{dx}dx = \int f(x)dx \qquad (8)$$

$$\int \frac{1}{g(y)}dy = \int (x)dx \qquad (9)$$

Since $y = (x)$, then $\int \frac{1}{g(y)}\frac{dy}{dx}dx = \int \frac{1}{g(y)}dy$, and hence

$$\int \frac{1}{g(y)}dy = \int (x)dx + c \qquad (10)$$

Where c is an arbitrary constant.

Calculating the integrals yields to obtain the integral curve $\Phi(x, y) = c$, which represents a parameter family of solutions. This constant can be determined if initial or boundary conditions are provided.

To better understand this concept, AI platforms such as MATLAB Simulink and Wolfram Mathematica enable students to observe the behavior of solutions over time as initial conditions and parameters change. We use a platform called ASKSIA AI, which generates a visual map to explain the method of separating variables, as illustrated in the graph below.

```
Start with: dy/dx = g(x) * h(y)
                 |
     Can you write the equation f(x)*g(y)?
                 |
          Yes ----------------- No
           |                     |
Separate variables          other methods
    1/h(y) dy = g(x) dx
           |
     Integrate both sides
           |
     Find implicit or explicit
        solution y(x)
```

Figure 6: *AI-Generated Visual Map Illustrating the Procedure for Separable Differential Equations Using the Method of Separating Variables, Enhancing Comprehension through Step-by-Step Visualization*

We then implemented ASKSIA AI to solve the problem:

$$y' - (1 + x^2) = 0 \qquad (11)$$

The step-by-step solution is presented in the figure below, along with the graph representing the family of solutions.

This is a first-order linear differential equation. Let's solve it step-by-step.

Rewrite it as:

$$y' = (1 + x^2)y$$

This is a separable differential equation. We can write:

$$\frac{dy}{dx} = (1 + x^2)y$$

Separate variables:

$$\frac{dy}{y} = (1 + x2)dx$$

Now, integrate both sides:

$$\int \frac{1}{y} dy = \int (1 + x^2) dx$$

Now, integrate both sides:

$$\int \frac{1}{y} dy = \int (1 + x^2) dx$$

This gives:

$$\ln |y| = x + \frac{x^3}{3} + C$$

Exponentiate both sides:

$$|y| = e^{x + \frac{x^3}{3} + C} = e^C \cdot e^x \cdot e^{\frac{x^3}{3}}$$

Let $C_1 = e^C$ (a new constant):
y = C_1 e^{x + \frac{x^3}{3$$

So the general solution is:

$$\boxed{y = Ce^{x + \frac{x^3}{3}}}$$

- Here is the graph showing the **family of solutions** for the differential equation

$$y = e^{x + \frac{x^3}{3}}$$

with multiple curves different values of the constant C ranging from −2 to (2).

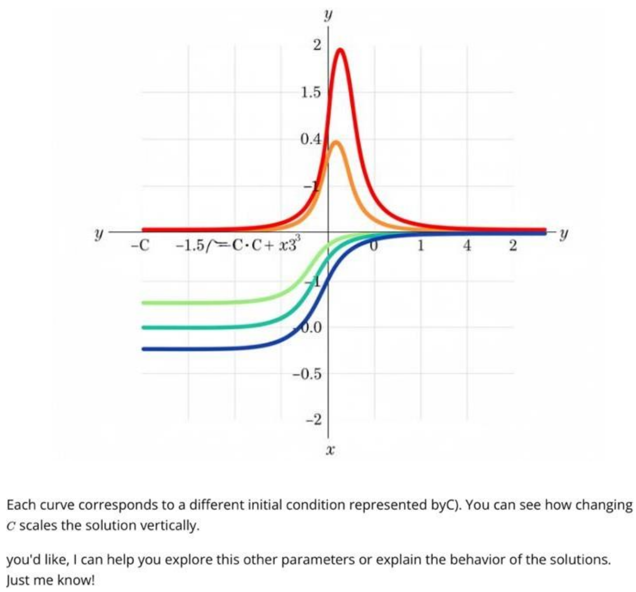


Figure 7: *AI-Powered Step-by-Step Solution of a Separable Differential Equation Using ASKSIA AI, Accompanied by a Graph Illustrating the Family of Solutions Based on Varying Initial Conditions*

6. Pedagogical Impacts of AI on Teaching College Mathematics

The implication of Artificial Intelligence in college mathematics education has a significant effect on modifying math pedagogy. To employ AI effectively to support conceptual understanding, it is necessary to carefully modify teaching strategies, redefine the instructor's role, and address fairness, accessibility, and ethics.

As AI enables the shift from traditional lectures to interactive classrooms, changes in teaching practice must include AI platforms that allow students to explore and investigate math concepts individually or in groups. These platforms can assess students with immediate feedback and provide instructors with analysis to help them monitor students' learning and then provide students with the required instructions. Certainly, the shift in teaching methods should embrace blended learning models that combine physical lecturing with a digital approach to enhance students' engagement. If these key changes are considered, the shift in teaching methodologies will effectively foster the learning process as it emphasizes reasoning, visualization, and reflection rather than just memorizing its benefits in college education.

7. Conclusion

This research examined the substantial transformation of mathematical education for college students resulting from the implication of AI approaches. Research indicates that AI can address most challenges in teaching mathematics by improving students' understanding of mathematical concepts through diverse platforms that simplify the understanding of abstract mathematics, enable visualization of concepts in various formats, offer tailored exercises for practice, and

provide prompt feedback. Nevertheless, to achieve good results with the implication of AI in education, it is crucial to adopt AI while considering instructional design, considering ethics, institutional policy, and support. The education process must depend mainly on instructors, not AI, and use AI as a secondary tool to support the learning process without affecting the conceptual understanding negatively. Indeed, with the innovation of AI in all various fields, particularly in education, it will undoubtedly be considered as an essential factor in mathematics education, which leads to creativity and diversity, and excellence. The adoption of AI in mathematical teaching offers an opportunity for instructors to deliver courses in a high-standard strategy by enabling students to apply logic, analyze problems, and relate concepts across different contexts. In conclusion, the integration of artificial intelligence with mathematical education at the college level has the potential to significantly improve conceptual understanding. It is primarily beneficial to both educators and learners since it redesigns the way they learn and teach in order to assist the learning process and align with the new generation.

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References

Abar, C. A. A. P., Dos Santos Dos Santos, J. M., & de Almeida, M. V. (2024). Contributions of the integration between computational thinking and artificial intelligence for mathematics education. In Springer International Publishing (pp. 290–299). https://doi.org/10.1007/978-3-031-54256-5_27

Abiola, O., Ajuwon, A., Shukurat, E., & Chiekezie, N. (2024). Innovative teaching strategies in mathematics and economics education: Engaging students through technology, AI, and effective mentoring. Open Access Research Journal of Science and Technology, 11(2). https://doi.org/10.53022/oarjst.2024.11.2.0103

Borah, P., & Borah, A. (2024). A review of the use of artificial intelligence in teaching and learning of mathematics. International Journal on Science and Technology, 15(4). https://doi.org/10.71097/ijsat.v15.i4.1190

Canonigo, A. (2024). Leveraging AI to enhance students' conceptual understanding and confidence in mathematics. Journal of Computer Assisted Learning, 40, 3215–3229. https://doi.org/10.1111/jcal.13065

Choustoulakis, E. (2024). Integrating artificial intelligence (AI) tools into teaching mathematical economics in tertiary education. European Journal of Open Education and E-learning Studies, 9(1). https://doi.org/10.46827/ejoe.v9i1.5683

El-Shara, I. (2025). The effect of using MatGPT on mathematical proficiency among undergraduate students. International Journal of Information and Education Technology, 15(4). https://doi.org/10.18178/ijiet.2025.15.4.2284

Fathi, T., Saad, A., Larhzil, H., Lamri, D., & Ibrahmi, E. (2025). Integrating generative AI into STEM education: Enhancing conceptual understanding, addressing misconceptions, and assessing student acceptance. Disciplinary and Interdisciplinary Science Education Research. https://doi.org/10.1186/s43031-025-00125-z

Li, C., Lyu, B. (2025). Investigating the motivational and knowledge affordances of conversational AI using induction, concretization, and exemplification in math learning. British Journal of Educational Technology. https://doi.org/10.1111/bjet.13612

Li, C., Zhu, W., Xing, W., & Guo, R. (2024). Analyzing student attention and acceptance of conversational AI for math learning: Insights from a randomized controlled trial. In Proceedings of the 14th Learning Analytics and Knowledge Conference. https://doi.org/10.1145/3636555.3636895

Li, Z., & Li, M. (2025). Research on talent cultivation in advanced mathematics education through artificial intelligence. Journal of Contemporary Educational Research, 9(4). https://doi.org/10.26689/jcer.v9i4.9890

Panaoura, R. (2025). Teaching mathematics in the artificial intelligence era: Challenges and concerns in higher education. Social Education Research. https://doi.org/10.37256/ser.6220256730

Shao, H., & Tang, G. (2025). Empowering mathematical problem-posing pedagogy with generative AI: A theoretical framework and case study. In Proceedings of the 14th International Conference on Educational and Information Technology (ICEIT) (pp. 111–115). https://doi.org/10.1109/iceit64364.2025.10975950

Tang, W. (2025). Artificial intelligence in mathematics education: Trends, challenges, and opportunities. International Journal of Research in Mathematics Education, 3(1). https://doi.org/10.24090/ijrme.v3i1.13496

Torres-Peña, R., Peña-González, D., Chacuto-López, E., Ariza, E., & Vergara, D. (2024). Updating calculus teaching with AI: A classroom experience. Education Sciences. https://doi.org/10.3390/educsci14091019

Trindade, M., Edirisinghe, G., & Luo, L. (2025). Teaching mathematical concepts in management with generative artificial intelligence: The power of human oversight in AI-driven learning. The International Journal of Management Education. https://doi.org/10.1016/j.ijme.2024.101104

Xing, W., Song, Y., Li, C., Liu, Z., Zhu, W., & Oh, H. (2025). Development of a generative AI-powered teachable agent for middle school mathematics learning: A design-based research study. British Journal of Educational Technology. https://doi.org/10.1111/bjet.13586

Xu, X. (2025). Game-based adaptive learning in probability education. International Journal of Information and Education Technology, 15(1). https://doi.org/10.18178/ijiet.2025.15.1.2212