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Unveiling AI's Transformative Power in Mathematical Induction Proofs: Overcoming Challenges to Revolutionize Education

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Abstract

The integration of artificial intelligence in education demonstrates considerable potential, particularly in facilitating students' comprehension of complex mathematical concepts. This study examines the role of AI in supporting students with mathematical induction, a fundamental technique in mathematical proofs. Although AI tools have become increasingly sophisticated, they nevertheless encounter limitations in generating precise logical structures, particularly for tasks demanding abstract reasoning, such as proofs by mathematical induction. This research investigates the interactions between undergraduate students and AI-generated inductive proofs, analyzing how participants engage with, reorder, and rectify AI-produced steps to achieve logical rigor. The study adopts a descriptive qualitative methodology, involving two students enrolled in a Real Analysis course. Data were gathered via observations, interviews, and assessments of task performance. The findings underscore the critical importance of students' analytical engagement with AI tools, illustrating that while AI provides substantive guidance, it cannot supplant the profound cognitive faculties essential for mathematical reasoning. The study concludes that students' active participation and adherence to mathematical rigor are indispensable when employing AI in educational settings, and it proposes enhancements to AI tools to augment their efficacy as pedagogical instruments.

Keywords: Artificial Intelligence, Mathematics Education, Mathematical Induction, proof.

INTRODUCTION

In today's fast-paced world, Artificial Intelligence (AI) is transforming many fields, including education. AI has been recognized for its potential to assist students with problem-solving, concept clarification, and providing immediate feedback (Gabriel et al., 2025). In mathematics, where reasoning and abstract thinking are paramount, AI systems are increasingly being used to support students' understanding of complex topics like mathematical induction (Walkington, 2025). These tools have the potential to guide students through the logic of proofs, making abstract concepts more accessible and less intimidating.

Mathematical induction is a key concept in mathematical proofs, used in various branches like number theory and combinatorics (Yoon et al., 2024). The process of induction involves proving a base case and then assuming the statement holds for some arbitrary n = k before proving it for n = k+1. The logical structure of induction requires careful attention to detail, and the failure to properly organize these steps can lead to flawed reasoning (Arnesen & Skartsæterhagen, 2025; Stylianides & Stylianides, 2009). Inaccurate ordering of steps in an inductive proof often leads to confusion, making the role of AI assistance critical for providing structure in such processes.

As AI tools become more sophisticated, they can suggest logical steps for completing proofs, helping students navigate complex problems (Zhao et al., 2025) These AI systems can assist students by highlighting the necessary components of a proof and providing suggestions based on patterns identified in mathematical logic. However, a common issue is that AI-generated steps may not always follow the precise logical flow needed in mathematical reasoning (Stylianides & Stylianides, 2009). This lack of context awareness in AI systems can lead to errors, requiring students to use their understanding of mathematics to correct the steps provided.

AI's potential to enhance education through problem-solving guidance is clear, but this potential often clashes with the limitations of current AI capabilities. While AI can generate solutions and assist students with the mechanics of proofs, it does not possess the intuitive understanding that human cognition brings to the reasoning process (Braun & Clarke, 2006a; Zhao et al., 2025). Inductive reasoning requires understanding the logical sequence of steps, something AI cannot always achieve autonomously (Walkington, 2025). This limitation emphasizes the need for critical student engagement when interacting with AI-assisted tools.

Finally, the study aims to provide a comprehensive view of AI's potential in transforming mathematics education while acknowledging its current limitations. By focusing on inductive proofs, the research will contribute to the growing body of knowledge regarding AI in education and its role in fostering students' mathematical reasoning and problem-solving skills. This study not only contributes to understanding AI’s current role but also provides valuable suggestions for how it can be improved to become a more effective educational tool (Van Vaerenbergh & Pérez-Suay, 2022).

METHODS

This study uses a descriptive qualitative approach to examine how undergraduate students in a Real Analysis course interact with AI-generated inductive proofs and how they reorder these steps to complete mathematical proofs accurately. The main objective is to gain insights into how students engage with AI in constructing mathematical proofs, especially in the context of mathematical induction.

The participants in this study were two undergraduate students who were selected based on two primary criteria: their strong communication skills and their ability to achieve the research objectives through the completion of proof tasks. Both students were enrolled in the Real Analysis course and demonstrated a solid understanding of mathematical concepts. Their ability to clearly articulate their thought processes during problem-solving tasks made them ideal subjects for this study. The selection of these two students ensured that the research would produce rich, meaningful data regarding their approach to mathematical induction and the reorganization of proof steps.

The research design followed a descriptive qualitatitve approach, where each student was tasked with completing a mathematical proof using AI assistance. The task involved proving the inequality 2^n ≥ n^2 for n ≥ 4, a standard problem that requires inductive reasoning. Initially, the AI generated the proof steps, but these steps were not ordered correctly. The students were asked to identify and correct the errors in the AI-generated proof and reorder the steps to reflect the correct logical structure of an inductive proof.

Data were collected through a combination of observations, interviews, and task performance measurements. The students' interactions with the AI were observed, focusing on how they identified errors and reordered the proof steps. Observations are a widely used method for collecting data in educational research, allowing researchers to capture real-time behavior and decision-making processes (Thibodeau-Nielsen et al., 2021). After completing the task, each student participated in a semi-structured interview, where they were asked to explain their reasoning behind reordering the proof steps, discuss their perceptions of the AI tool, and reflect on the challenges they faced. Semi-structured interviews provide valuable insights into students' reflective thinking and cognitive strategies during problem-solving tasks (Cohen et al., 2007; Schoenfeld, 2016). Additionally, the students' success in completing the proof was quantitatively assessed by measuring the number of correct steps and evaluating the accuracy of their reordered proof.

For data analysis, a qualitative approach was employed to examine the students' reasoning, their strategies in interacting with AI-generated steps, and how they corrected the errors in the proof process. Thematic analysis was used to identify patterns in the students' feedback and behaviors during the task (Braun & Clarke, 2006b). This approach allows for an in-depth exploration of participants' thoughts, emotions, and actions as they engage with AI-generated content, providing a comprehensive understanding of the cognitive processes involved in mathematical reasoning (Patton, 2002). Interviews were transcribed and analyzed to extract key themes related to the students' understanding of mathematical induction, their critical thinking skills, and their ability to use AI to assist with proof construction.

RESULTS AND DISCUSSION

This study will discuss the results in two ways between subject 1 and subject 2.

Subject 1

The result of subject 1 can be shown in Figure 1.

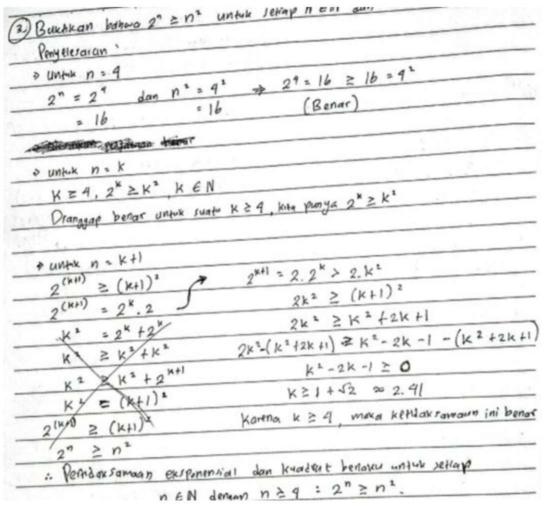

Figure 1 Subject 1 result

Subject 1 began the proof correctly, confirming the base case n = 4 where $2^4 = 16$ and $4^2 = 16$, which satisfied the claim $2^4 \geq 4^2$. After this, Subject 1 proceeded with the induction hypothesis for k and then tackled the step for k+1. Initially, Subject 1 made an incorrect claim, asserting that $2^{k+1} > (k+1)^2$, which did not align with the logical structure of induction. However, Subject 1 quickly identified the mistake and corrected it. They then proceeded to use quadratic roots as an additional method to verify the results and ensure the induction step was valid. This process also shown by subject 1 interview transcript as shown below.

Interviewer: "How did you correct the mistake in the claim $2^{\{k+1\}} > (k+1)^2$ *?"*

Subject 1: "I thought about it again, and realized that it didn't make sense. I used the correct induction steps and checked again using quadratic formulas to fix everything."

Based on this results several points are highlighted,

1. Accuracy in Induction Steps and Correction of Mistakes

Subject 1's approach to the induction proof shows a strong understanding of the mathematical process. Initially, they made an incorrect assumption that $2^{k+1} > (k+1)^2$, but their ability to recognize this mistake and correct it is significant. This ability to self-correct demonstrates the importance of critical thinking and conceptual understanding in using AI for assistance. Despite the AI providing a sequence of steps, Subject 1 took ownership of their work and used their own knowledge, such as the use of quadratic formulas, to verify the proof's validity.

The ability to identify mistakes in AI-generated solutions and then apply the necessary mathematical knowledge to correct them is essential for students, particularly in higher-level mathematics (Sosa-Moguel & Aparicio-Landa, 2021). Subject 1 demonstrated this effectively, showing that AI is a tool that should be used in tandem with independent reasoning (Jianzheng & Xuwei, 2023).

2. Use of Mathematical Knowledge Beyond the AI's Suggestions

Subject 1 went beyond merely following AI's suggestions and incorporated additional knowledge, such as quadratic methods, to verify and correct the steps. This shows that even when AI provides a good starting point, the student's deeper understanding of the material is crucial. In this case, Subject 1's engagement with the AI-generated content was not passive. They actively assessed the steps, identified the flaw, and used alternative methods to verify the logic. This interaction highlights the need for students to actively participate in the learning process and not rely solely on AI tools (Wang et al., 2025).

3. The Role of AI in Supporting Rather Than Replacing Student Reasoning

In this case, AI supported Subject 1 in the early stages of proof development but was ultimately supplemented by the student's own insights. This confirms the idea that AI should function as an educational aid, offering structure and guidance, but not replacing the cognitive skills necessary for learning (Bastani et al., 2025; Davis, 2022). Subject 1's ability to adjust and correct AI-generated steps shows that, while AI can be helpful, it still requires the student to use their judgment and mathematical reasoning skills (Kaya & Yavuz, 2025).

Subject 2

The result of subject 2 can be shown in Figure 2.

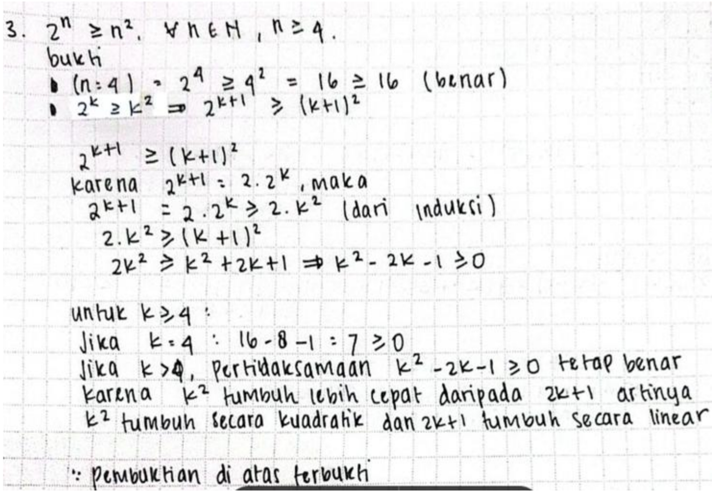
3. $2^n \geq n^2, \forall n \in N, n \geq 4$.
bukti
• $(n=4) \rightarrow 2^4 \geq 4^2 = 16 \geq 16$ (benar)
• $2^k \geq k^2 \Rightarrow 2^{k+1} \geq (k+1)^2$
$2^{k+1} \geq (k+1)^2$
karena $2^{k+1} = 2.2^k$, maka
$2^{k+1} = 2.2^k \geq 2.k^2$ (dari induksi)
$2.k^2 \geq (k+1)^2$
$2k^2 \geq k^2+2k+1 \Rightarrow k^2-2k-1 \geq 0$
untuk $k \geq 4$:
Jika $k=4$: $16-8-1 = 7 \geq 0$
Jika $k>4$, pertidaksamaan $k^2-2k-1 \geq 0$ tetap benar
karena k^2 tumbuh lebih cepat daripada $2k+1$ artinya
k^2 tumbuh secara kuadratik dan $2k+1$ tumbuh secara linear
∴ pembuktian di atas terbukti

Figure 2 Subject 2 result

Subject 2 began by confirming the base case n = 4 correctly, verifying that $2^4 = 16$ and $4^2 = 16$, which was accurate. Subject 2 then moved on to the induction hypothesis for k and proceeded to the step for k+1, where they tried to compare the growth of k^2 and 2k+1. Subject 2 claimed that k^2 grows faster than 2k+1, but they did not provide a proper mathematical proof for this comparison. While this assertion is intuitively correct, it is not substantiated with a formal proof, particularly the comparison $k^2 - (2k+1) \geq 0$ for $k \geq 4$, which should have been shown explicitly. This process is supported by following transcript.

Interviewer: "Why did you say that k^2 grows faster than 2k+1 without proof?"
Subject 2: "Oh yeah, I just felt that k^2 must grow faster because it's squared, so I didn't check it further."

This study highlighted subject 2 process in following points.

1. Unsubstantiated Claims and Over-reliance on Intuition

In contrast to Subject 1, Subject 2 made a critical error by claiming that k^2 grows faster than 2k+1 without providing a formal proof. While this statement is mathematically true, Subject 2 failed to justify their reasoning with appropriate proof. They relied on intuition rather than a rigorous mathematical argument, which is problematic in mathematical proofs where precision and logical structure are essential (Basturk, 2010). This reliance on intuition rather than proof highlights a gap in Subject 2's understanding of the importance of formal justification in mathematical reasoning. By making unproven claims, Subject 2 missed the opportunity to deepen their understanding of mathematical induction and logic (Lestari et al., 2022).

2. Lack of Mathematical Rigor in the Induction Process

Although Subject 2 correctly identified the base case and hypothesis, they failed to properly complete the induction step by not demonstrating that $k^2 - (2k+1) \geq 0$ for $k \geq 4$. This omission is crucial because it represents a fundamental flaw in their reasoning process. In mathematical induction, every step, including the transition from k to k+1, must be rigorously justified (Schoenfeld, 2016). Subject 2’s failure to formally prove this comparison weakened their argument and demonstrates the importance of attention to detail in mathematical proofs.

3. The Need for AI-Enhanced Critical Thinking

The experience of Subject 2 demonstrates a potential pitfall when using AI in mathematical learning. While AI can suggest solutions, it is still crucial for students to critically evaluate the generated steps and apply their own knowledge to fill in gaps and correct errors. Subject 2’s lack of formal justification and their over-reliance on intuition show that AI alone cannot provide the complete learning experience (Tashtoush et al., 2025). Instead, students must actively engage with the AI’s suggestions and use their mathematical reasoning to verify and refine them.

4. Implications for Improving Student Engagement with AI

To improve AI's effectiveness in education, it is essential that AI tools encourage critical engagement from students. AI should not only provide solutions but also help students to understand the logic behind those solutions. This will foster deeper learning and help students develop the critical thinking skills needed to complete proofs successfully. Additionally, students like Subject 2 should be taught to approach AI-generated content with more caution and a more systematic review of each step (Davies et al., 2021; Fulton et al., 2022).

CONCLUSION

In summary, this study highlights the potential of AI tools in enhancing students' learning, particularly in complex mathematical tasks such as mathematical induction. However, it also underscores the importance of critical engagement and mathematical reasoning from the students themselves. The findings suggest that while AI can provide valuable guidance and structure, students must actively engage with the generated steps and critically evaluate the solutions. In particular, students should not rely solely on AI to complete proofs. Instead, they must use their own mathematical knowledge to verify, adjust, and correct the steps where necessary. This combination of AI assistance and independent thinking is crucial for students to develop a deeper understanding of mathematical concepts and improve their problem-solving skills.

Furthermore, the study demonstrates that over-reliance on intuition without formal justification, as seen in the case of one student, can lead to errors in reasoning. This highlights the need for students to approach AI-generated solutions with a healthy degree of skepticism, ensuring that they provide the necessary mathematical rigor and proofs for every step. For AI to be more effective in education, it must not only offer solutions but also encourage students to reflect on and understand the reasoning behind those solutions. Educators should emphasize the importance of critical thinking and the verification of AI-generated content to foster a more robust learning experience. Ultimately, AI should be viewed as a valuable tool that can support but not replace human reasoning, particularly in disciplines like mathematics where logical structure and accuracy are paramount.

The findings of this study carry several implications for mathematics education. First, teachers can integrate AI systems as scaffolding tools that provide initial structure in proofs, while guiding students to refine and validate the steps independently. Classroom practices should also cultivate critical engagement, encouraging students to question, critique, and reorganize AI-generated outputs to strengthen their logical reasoning and proof-writing skills. Furthermore, educators must highlight the distinction between intuitive reasoning and formal proof, training students to transform intuitive insights into rigorous arguments. By reflecting on their interactions with AI, students can develop metacognitive awareness, becoming more conscious of their own reasoning processes to support deeper learning and self-regulated problem solving. To achieve this, teacher professional development is essential; educators must be equipped with strategies to integrate AI meaningfully, ensuring its use enhances rather than diminishes students' cognitive engagement. Thus, the pedagogical implication is clear: AI should be positioned not as a replacement for human reasoning, but as a catalyst for active learning environments where students critically engage, validate, and extend their mathematical understanding.

In the other hand, this study acknowledges its limitations, particularly the small sample size of only two undergraduate students, which restricts the generalizability of the findings. The qualitative design, while rich in detail, also means that the results are context-specific and may not fully capture the diversity of student experiences across different institutions or levels of mathematical proficiency. Future research should therefore involve larger and more varied populations, explore different mathematical domains, and examine long-term impacts of AI integration to provide a more comprehensive understanding of its pedagogical potential.

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REFERENCES

Arnesen, K. K., & Skartsæterhagen, Ø. I. (2025). Mathematical induction in education research: a systematic review. Educational Studies in Mathematics, 119(1), 79–100. https://doi.org/10.1007/s10649-024-10373-x

Back, R. J., Mannila, L., & Wallin, S. (2010). "It takes me longer, but I understand better" - student feedback on structured derivations. International Journal of Mathematical Education in Science and Technology, 41(5), 575–593. https://doi.org/10.1080/00207391003605221

Bastani, H., Bastani, O., Sungu, A., Ge, H., Kabakcı, Ö., & Mariman, R. (2025). Generative AI without guardrails can harm learning: Evidence from high school mathematics. Proceedings of the National Academy of Sciences, 122(26), e2422633122. https://doi.org/10.1073/pnas.2422633122

Basturk, S. (2010). First-year secondary school mathematics students' conceptions of mathematical proofs and proving. Educational Studies, 36(3), 283–298. https://doi.org/10.1080/03055690903424964

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Cohen, L., Manion, L., & Morrison, K. (2007). Research Methods in Education (6th ed.). Routledge.

Davies, A., Veličković, P., Buesing, L., Blackwell, S., Zheng, D., Tomašev, N., Tanburn, R., Battaglia, P., Blundell, C., Juhász, A., Lackenby, M., Williamson, G., Hassabis, D., & Kohli, P. (2021). Advancing mathematics by guiding human intuition with AI. Nature, 600(7887), 70–74. https://doi.org/10.1038/s41586-021-04086-x

Davis, R. (2022). The Role of AI in Education: A Cognitive Perspective. Journal of Educational Technology, 34(3), 45–58.

Fulton, R., Fulton, D., & Kaplan, S. (2022). The Framework of Artificial Intelligence (FAI): Driving Triggers, State of the Art Over Time and Industry Adoption Influencers. International Journal of Artificial Intelligence & Applications, 13(3), 85–108. https://doi.org/10.5121/ijaia.2022.13307

Gabriel, F., Kennedy, J., Marrone, R., & Leonard, S. (2025). Pragmatic AI in education and its role in mathematics learning and teaching. Npj Science of Learning, 10(1), 26. https://doi.org/10.1038/s41539-025-00315-4

Jianzheng, S., & Xuwei, Z. (2023). Integration of AI with Higher Education Innovation: Reforming Future Educational Directions. International Journal of Science and Research (IJSR), 12(10), 1727–1731. https://doi.org/10.21275/SR231023183401

Kaya, D., & Yavuz, S. (2025). Can Generative AI and ChatGPT Break Human Supremacy in Mathematics and Reshape Competence in Cognitive-Demanding Problem-Solving Tasks? Journal of Intelligence, 13(4), 43. https://doi.org/10.3390/jintelligence13040043

Lestari, S., Marom, S., & Rochmad, R. (2022). Intuition and Its Role in Students' Mathematical Reasoning Ability. Hipotenusa : Journal of Mathematical Society, 4(1). https://doi.org/10.18326/hipotenusa.v4i1.7289

Patton, M. Q. (2002). Qualitative research & evaluation methods : integrating theory and practice (4th ed.). Sage Publications. https://books.google.com/books?hl=en&lr=&id=ovAkBQAAQBAJ&oi=fnd&pg=PP1&dq=qualitative+research+%26+evaluation+methods+Patton&ots=ZS-Y3uuCA-&sig=hE9o-_BCPNFnnmGml7zrozOkf2g

Schoenfeld, A. H. (2016). Mathematical thinking and problem solving. Routledge.

Sosa-Moguel, L. E., & Aparicio-Landa, E. (2021). SECONDARY SCHOOL MATHEMATICS TEACHERS' PERCEPTIONS ABOUT INDUCTIVE REASONING AND THEIR INTERPRETATION IN TEACHING. Journal on Mathematics Education, 12(2), 239–256. https://doi.org/10.22342/jme.12.2.12863.239-256

Stylianides, A. J., & Stylianides, G. J. (2009). Proof constructions and evaluations. Educational Studies in Mathematics, 72(2), 237–253. https://doi.org/10.1007/s10649-009-9191-3

Tashtoush, M. A., Qasimi, A. B., Shirawia, N. H., & Hussein, L. A. (2025). The Efficacy of Utilizing Artificial Intelligence Techniques in Developing Critical Thinking in Mathematics among Secondary School Students and their Attitudes Toward it. Iraqi Journal for Computer Science and Mathematics, 6(1), 103942. https://doi.org/10.52866/2788-7421.1231

Thibodeau-Nielsen, R. B., White, R. E., & Palermo, F. (2021). Advancements in observing behavior in preschool classrooms: A new audiovisual approach. Social Development, 30(4), 899–909. https://doi.org/10.1111/sode.12543

Van Vaerenbergh, S., & Pérez-Suay, A. (2022). A Classification of Artificial Intelligence Systems for Mathematics Education. In Mathematics education in the age of artificial intelligence: How artificial intelligence can serve mathematical human learning. (pp. 89–106). https://doi.org/10.1007/978-3-030-86909-0_5

Walkington, C. (2025). The implications of generative artificial intelligence for mathematics education. School Science and Mathematics, 56(1), 45–67. https://doi.org/10.1111/ssm.18356

Wang, K., Cui, W., & Yuan, X. (2025). Artificial Intelligence in Higher Education: The Impact of Need Satisfaction on Artificial Intelligence Literacy Mediated by Self-Regulated Learning Strategies. Behavioral Sciences, 15(2), 165. https://doi.org/10.3390/bs15020165

Yoon, H., Hwang, J., Lee, K., Roh, K. H., & Kwon, O. N. (2024). Students' use of generative artificial intelligence for proving mathematical statements. ZDM – Mathematics Education, 56(7), 1531–1551. https://doi.org/10.1007/s11858-024-01629-0

Zhao, M., Poulsen, S., & Silva, C. (2025). Autograding mathematical induction proofs with natural language processing. Computers in Education, 89, 101–115. https://doi.org/10.1007/s40593-025-00498-2