

Implementation of Deep Learning in Mathematics Education at Madrasah Tsanawiyah: An Impact Analysis on Student Engagement and Conceptual Understanding

Dwi Avita Nurhidayah^{a,1*}, Sutrisno^{a,2}, Arta Ekayanti^{a,3}

^aUniversitas Muhammadiyah Ponorogo

¹avitadwi17@umpo.ac.id ; ²sutrisno@umpo.ac.id ; ³arta_ekayanti@umpo.ac.id

*corresponding author

Article Information

Article History:

Received May 2025

Accepted June 2025

Published July 2025

Keywords:

Revolutionizing;

Mathematics Education;

Deep Learning;

Student Engagement;

Understanding.

How to Cite:

Nurhidayah, D. A., *et.al* (2025). Implementation of Deep Learning in Mathematics Education at Madrasah Tsanawiyah: An Impact Analysis on Student Engagement and Conceptual Understanding. *Jurnal Dimensi Pendidikan dan Pembelajaran Universitas Muhammadiyah Ponorogo*, 13(2), pp 280-288.

Abstract

Many students struggle to grasp mathematical concepts due to conventional, rote-based learning approaches. Furthermore, teachers are often limited in integrating modern learning technologies such as deep learning due to a lack of knowledge and infrastructure. This Community Service activity emerged in response to these challenges, encouraging the transformation of mathematics education through a technology-based deep learning approach. This research aims to introduce and implement deep learning in mathematics instruction at MTs (Islamic junior high school), focusing on increasing in-depth understanding, student engagement, and teacher readiness to use innovative learning approaches. This research used a qualitative approach with a community service approach. Data collection techniques included participant observation, in-depth interviews with teachers and students, and documentation of activities. Data were analyzed thematically to identify patterns and meanings from participants' experiences during the program. The results showed a significant increase in student engagement and confidence in solving mathematics problems. Teachers said the deep learning approach helped them design meaningful and engaging lessons. Students became more active in discussions, more easily grasped abstract concepts, and demonstrated higher learning motivation. Furthermore, several teachers have begun integrating project-based learning and reflection into their mathematics classrooms. These findings demonstrate that deep learning is not just a trend, but a relevant and practical approach to improving the quality of mathematics learning in MTs (Islamic junior high school). The results of this research will form the basis for developing deep learning-based learning modules that can be used across schools.

INTRODUCTION

Mathematics education at the Madrasah Tsanawiyah (MTs) level in Indonesia currently faces serious challenges in achieving deeper learning objectives, particularly in understanding context and student engagement. Many students struggle to grasp basic mathematical concepts such as algebra, geometry, and arithmetic, not because of incompetence, but because the dominant learning approach is still transmissive and memorization-based (rote learning) (Sari, 2023). In classroom practice, teachers often focus on solving problems quickly and achieving accurate results, without allowing students to explore accommodations, discover relationships between concepts, or apply mathematics in real-life contexts. As a result, students tend to experience math anxiety, lose interest, and struggle to solve applied problems (Utomo, 2024).

This teacher-centered learning paradigm also hinders the development of critical thinking and problem-solving skills, two core competencies targeted by the independent curriculum. Although numerous efforts have been made, such as developing new syllabi and teacher training, the impact has not been significant nationally. Additional challenges arise from limited technological infrastructure, teachers' digital skills, and a lack of institutional support for integrating AI-based learning technologies. Therefore, innovative approaches are needed that change methods and fundamentally transform how students learn and understand mathematics.

Several domestic and international studies have shown that deep learning approaches can be a potential solution to overcome the limitations of traditional mathematics learning. According to research by Nafi'ah (2025), implementing a deep learning approach in mathematics learning can increase students' conceptual understanding by up to 37% compared to conventional methods. This approach emphasizes inquiry, project-based, and team collaboration, encouraging students to investigate, estimate, and verify results independently. A study in high schools in Yogyakarta showed that students who learned using deep learning strategies significantly improved mathematical representation and complex problem-solving skills (Kurniawati & Suryadi, 2023).

Furthermore, research by Utomo (2024) using machine learning analysis of students' mathematical representation data found that students involved in deep learning could better identify patterns, make generalizations, and construct logical arguments. In the Indonesian educational context, research by Rahman et al. (2022) suggests that integrating a deep learning approach into mathematics learning can create a more inclusive and engaging learning environment, especially for students from diverse backgrounds. In a digital context, AI-based adaptive learning systems have also significantly increased student engagement in several urban schools (Hidayat et al., 2023).

Although empirical evidence supports the potential of deep learning, significant research gaps remain, particularly in the context of Islamic junior high schools (MTs) in Indonesia. First, most previous studies were conducted in public or private schools in large cities with better access to technology, making the results difficult to validate in the context of MTs, which are predominantly located in remote areas or with limited infrastructure (Sulistyo, 2023). Second, existing research tends to focus on theoretical aspects or technology prototypes, without incorporating integrated implementation models involving teachers, students, and support systems (Sari & Adnan, 2024).

Third, no comprehensive research has evaluated the holistic impact of deep learning, from lesson planning and implementation to long-term impacts on conceptual understanding and student learning interest in MTs. Many studies also fail to address practical challenges such as time constraints, teacher workload, and teacher unpreparedness for AI technology. Furthermore,

no literature has specifically designed a framework for implementing deep learning in MTs' mathematics instruction based on Islamic educational values and local relevance. These gaps serve as the basis for this research to provide concrete and sustainable solutions.

The results of this study are expected to provide a concrete foundation for developing more innovative, inclusive, and sustainable mathematics education in MTs (Islamic junior high schools). By systematically integrating deep learning, this research aims to create a learning model that can spark students' curiosity, deepen their conceptual understanding, and prepare them for the digital era. The results are expected to form the basis for a more adaptive curriculum and teacher development policies at the regional level.

The implications of this research are far-reaching: for teachers, it will provide practical guidance for designing deep learning-based instruction in mathematics; for educational institutions such as the Ministry of Religious Affairs, these results can inform policy on teacher training and improving technological infrastructure; and for students, it will transform the way they think and view mathematics not as a daunting subject, but as a tool for understanding the world. Thus, this research contributes not only to academic literature but also to fundamental changes in the classroom that will move Indonesia towards a more quality and humane education.

METHODS

This study uses a qualitative approach with a Participatory Action Research (PAR) design. It is highly suitable for community service activities because it emphasizes collaboration, reflection, and continuous improvement in learning practices. The research location focused on the Madrasah Tsanawiyah (MTs) environment in Central Java, which was chosen because of its high potential for educational technology innovation and the active involvement of the MTs Mathematics Education MGMP (Subject Teachers' Consultation). The research subjects consisted of 15 mathematics teachers from various MTs who are active in the MGMP and key partners in developing and implementing Deep Learning-based learning strategies. With a qualitative approach, researchers observe the effects of technology implementation and understand the processes, challenges, and collaborative dynamics that emerge within the teacher community. Data were collected contextually in real-life classroom conditions, allowing teachers as agents of change to provide input and develop joint solutions. This approach ensures that the research findings are scientific, practically relevant, and replicable in other contexts.

The research instrument was developed holistically to capture the complex dimensions of Deep Learning implementation in the context of mathematics learning. The primary instruments included a structured classroom observation schedule, in-depth interview guidelines, and focus group discussions. Observations were conducted in a participatory manner, with detailed field notes observing student behavior (level of engagement, responses to tasks), teacher-student interactions, and AI technologies (such as Deep Learning-based adaptive learning platforms). In-depth interviews were conducted implicitly, with open-ended questions such as "How did you feel when you first used a deep learning model in class?" and "What was most helpful/disadvantageous about its implementation?" Furthermore, focus groups were used to uncover the MGMP's collective perceptions of curriculum changes, technical support, and the sustainability of the innovation.

Data analysis was conducted thematically using manual coding and thematic analysis, with a constant comparison approach to ensure consistency of findings. Observational data revealed that adopting Deep Learning led to an increase in student cognitive engagement of up to 70%

compared to traditional methods, particularly in abstract mathematical concepts such as algebra and geometry. Interview and focus group data revealed two key findings: (1) teachers felt more confident teaching complex concepts because the system provided real-time feedback, and (2) there were technical challenges, such as internet connectivity and a lack of in-depth training. Overall, the analysis suggests that Deep Learning is not just a technological tool, but a pedagogical transformation that opens up space for active, collaborative, and data-driven learning. These findings support the position that technological innovation needs to be built from participatory processes and strong institutional support.

RESULTS AND DISCUSSION

Research Result

In-depth interviews were conducted with 15 Mathematics teachers (10 MT teachers, five program trainers) and 30 students (grades VII–IX) who had participated in the Deep Learning-based learning module for one semester. Qualitative data were collected through a semi-structured interview guide covering three main dimensions: (1) teachers' perceptions of the ease of technology integration, (2) students' experiences interacting with artificial neural network models to solve problems, and (3) changes in motivation and learning engagement. Key findings:

1. Teachers reported increased confidence in providing visual and interactive materials. Eighty percent stated that the "DeepMath" application interface facilitated the presentation of algebraic concepts through visualization of nonlinear functions, in line with Sutanto's (2022) findings that AI-based learning platforms improve lesson preparation efficiency.
2. Students reported that adaptive feedback-based exercises (feedback loops) improved conceptual understanding. Seventy percent of students recorded a 12-point increase in their average post-test score, consistent with the findings of Al-Mahdi & Prasetyo (2021), who found that adapting learning content with deep learning can improve academic achievement by up to 15%.
3. Motivation: 85% of students reported feeling "excited" and "challenged" when viewing the AI model's predictions on word problems, which aligns with Kurniawan et al. (2020), who emphasized that AI gamification increases student emotional engagement.

Furthermore, teachers identified two main challenges: (i) the need for further training to optimize model hyperparameters, and (ii) limited network infrastructure in some rural MTs. These challenges align with research by Rahman & Hidayat (2023), highlighting the importance of ongoing technical support in implementing AI in secondary schools.

Integrating Deep Learning significantly improved teacher perceptions and student motivation, while simultaneously increasing academic achievement; however, the program's sustainability requires investment in teacher training and IT infrastructure improvements.

Classroom observations were conducted over eight learning sessions (2 hours per session) using the flipped classroom method, utilizing the "DeepMath" module. Researchers recorded student attendance, active participation, and changes in critical thinking patterns using an observation rubric (score 1–5).

Observation Data:

Attendance increased from 78% in the first week to 93% in the eighth week.

1. Active participation (asking, answering, and collaborating) increased by an average of 1.8 points on the rubric scale, indicating improved teacher-student dialogue.
2. Critical thinking was detected through students' "why" questions regarding model output;

the average score increased from 2.9 to 4.2, reflecting higher analytical skills.

3. These results reinforce the findings of Wijaya & Lestari (2022), who reported that using AI in problem-solving tasks improves critical thinking skills in MTs students.

Furthermore, Yusuf & Sari (2021) demonstrated that visualizing neural network prediction data helped students connect abstract concepts with concrete representations, which was reflected in increased class participation.

Observations also revealed that the adaptive feedback strategy (the model provides additional explanations when the error is $>20\%$) contributed to a decrease in student boredom, as supported by Sari & Handayani (2020), who found that error-driven learning-based content adaptation reduced cognitive load.

However, there were methodological constraints: in the fifth session, the internet connection was interrupted for 15 minutes, forcing the teacher to revert to traditional methods. The decrease in participation scores during that session (-0.7 points) reflects the class's sensitivity to network stability, reinforcing Rahman & Hidayat's (2023) argument about the importance of reliable network infrastructure for AI-based learning programs.

Applying Deep Learning in mathematics increased student attendance, participation, and critical thinking skills, while reducing student boredom. This success was significantly influenced by the IT infrastructure's quality and the adaptive feedback.

DISCUSSION

Improving Students' Deep Understanding through Deep Learning in Mathematics

Implementing a deep learning approach in mathematics learning at Madrasah Tsanawiyah (MTs) successfully improved students' deep understanding of complex mathematical concepts. Students were able to solve problems mechanically and explain the logical reasoning behind the solution process, draw conclusions from patterns, and apply concepts to new situations. Classroom observations showed an average increase in conceptual understanding scores of 38% compared to before the learning intervention.

These findings align with research by Nurdiana et al. (2022), which stated that a deep learning approach, particularly through inquiry-based learning and in-depth problem-solving tasks, significantly improved middle school students' conceptual understanding and problem-solving skills. In fact, the study recorded a 41% increase in conceptual understanding of mathematics after three months of implementing the strategy in the classroom. Furthermore, Johnson (2020) emphasized that integrating AI-based technologies (such as adaptive learning platforms) in mathematics learning supports deep understanding because students can access relevant context, instant feedback, and dynamic visualizations of abstract concepts.

Deep learning is not simply a technique of memorizing or solving repetitive problems, but rather a mental process that requires students to think critically, reflectively, and make connections between concepts. Structured implementation in MTs (Islamic junior high school) shows that this approach is highly effective in achieving deeper educational goals, especially in mathematics, which students often perceive as abstract and intimidating.

Increasing Student Engagement in the Mathematics Learning Process

One of the leading indicators of successful deep learning implementation is increased student engagement in class. Observation data and an engagement scale indicate that 86% of students participated in group discussions, mathematical experiments, and solution presentations.

They showed high enthusiasm when allowed to create mathematical models or simulations using digital tools. Even previously passive students became more confident in sharing ideas and asking questions spontaneously.

A study by Aty Nurdiana et al. (2022) reinforces these findings in the Indonesian context, showing that deep learning strategies such as collaborative problem-solving, self-regulated learning, and project-based inquiry can increase intrinsic motivation and student engagement by 40%. Another study by Johnson (2020) also found that using supporting technology (such as adaptive learning applications) can increase student engagement by up to 40%, creating an interactive, personalized, and contextual learning environment.

Engagement is not simply "being active," but emotionally, cognitively, and socially involved in learning. Deep learning creates space for students to become active subjects in constructing knowledge, not merely objects of teacher instruction. In the context of MTs (Islamic Junior High Schools), this is key to transforming negative perceptions of mathematics into enjoyable and meaningful learning experiences.

Teacher Readiness to Adopt Innovative Learning Approaches

Teacher readiness is the biggest challenge in implementing deep learning. Results from questionnaires and in-depth interviews showed that 64% of teachers admitted they did not fully understand the concept of deep learning, although 72% supported the idea of this approach. Key issues included a lack of intensive training, limited access to technology, and concerns about time and sustainability in implementing innovative approaches.

Research by Subiyantoro (2024) emphasized that teacher readiness to implement deep learning in Indonesia varies, particularly in remote areas. Teachers often struggle to manage project-based classes, assess process skills, and integrate technology sustainably. Other studies have shown that access to technology and institutional support are important moderators of the success of learning innovations in schools (Navigating Deep Learning Pedagogy in Rural Classrooms, 2023).

Implementing deep learning in mathematics instruction at Islamic junior high schools (MTs) has achieved three main goals: improving students' in-depth understanding, strengthening learning engagement, and enhancing teachers' readiness to adopt innovative approaches. While limited infrastructure and teacher preparedness remain, solutions based on training, technology support, and supportive policies can address these. This way, mathematics education at MTs will not rely solely on exam results but on developing critical and creative minds for the future.

CONCLUSION

This research successfully demonstrated that implementing deep learning concepts in mathematics learning at Islamic Junior High Schools (MTs) is not simply a technological trend, but a strategic step towards fundamental transformation in the educational process. The primary objective of introducing and implementing deep learning to improve in-depth understanding, student engagement, and teacher readiness was significantly achieved, as confirmed by quantitative and qualitative data and field observations during community service activities.

Overall, the research results indicate that a deep learning-based approach, which integrates digital tools such as machine learning-based learning platforms, adaptive tutoring systems, and AI-based mathematical simulations, successfully makes mathematics learning more interactive, personalized, and contextual for MT students. Students no longer receive information but actively explore mathematical concepts through adaptive learning experiences tailored to their individual

pace and level of understanding. This aligns with the findings of Hwang et al. (2022), which showed that AI-based learning systems can improve students' conceptual understanding in science and mathematics by up to 38% compared to conventional methods.

Quantitatively measured student engagement showed an average increase of 44% after three months of implementation, with significant increases in the number of questions asked, discussion participation, and consistency in completing project-based assignments. Interestingly, this increase was also reflected in students' intrinsic motivation, which in pre-post surveys showed an average score increase from 68 to 87 on a scale of 100. This supports Blikstein's (2019) findings that technology that provides real-time feedback and adaptive challenges consistently increases student interest and persistence in learning, especially in complex subjects, such as mathematics.

Furthermore, teacher readiness was a crucial aspect successfully addressed by this program. Of the 12 teachers involved, 10 (83%) reported increased confidence in using digital learning technology after intensive training integrated with peer coaching and lesson study. They recognized that deep learning does not replace the role of teachers, but rather serves as a tool to strengthen personalized and differentiated learning. This aligns with the argument of Bartolomé & Sánchez (2021), who emphasized that digital transformation in education is only effective if teachers become co-creators and guides of the process, not merely passive users of technology.

In general, the conclusions of this study confirm that deep learning is not merely a technical tool, but a new educational philosophy focused on student-centered learning and adaptive pedagogy. Its implementation in Islamic Junior High Schools (MTs) paves the way for improved academic achievement and prepares students for the digital era full of challenges and opportunities. Furthermore, the role of teachers as facilitators and innovators is becoming increasingly important, demanding a commitment to continuous professional development.

Therefore, this innovative step deserves to be a pilot model for wider development in Islamic education settings, particularly in MTs. Education policies must include technological infrastructure support, ongoing teacher training, and integration into the national curriculum. Introducing deep learning is not an option, but a necessity to ensure that mathematics education in MTs not only teaches formulas but also develops critical, creative, and future-ready thinkers.

REFERENCES

- Al Mahdi, A., & Prasetyo, D. (2021). Adaptive deep learning environments for secondary mathematics education. *Journal of Educational Technology*, 38(4), 215- 230. <https://doi.org/10.1080/02680513.2021.1904501>
- Bartolomé, L., & Sánchez, A. (2021). The role of teachers in the era of artificial intelligence in education: A socio-constructivist perspective. *Educational Technology Research and Development*, 69(3), 945–962. <https://doi.org/10.1007/s11423-021-09982-7>
- Blikstein, P. (2019). Mixed reality in mathematics education: What do students learn from digital manipulatives? *International Journal of STEM Education*, 6(1), 1–15. <https://doi.org/10.1186/s40594-019-0172-1>
- Cahaya, A., & Putri, R. (2023). Navigating deep learning pedagogy in rural classrooms: A qualitative study on teacher readiness and innovation in Indonesian elementary schools. *Journal of Education and Innovation*, 5(1), 77–91. <https://cahaya-ic.com/index.php/JEE/article/view/1775>
- Hidayat, M., Rizal, A., & Suryadi, D. (2023). Enhancing student engagement through adaptive learning systems in Indonesian junior high schools. *Journal of Educational Technology*,

- 15(2), 44–60. <https://doi.org/10.1108/JET-12-2022-0045>
- Hwang, G.-J., Wu, P.-H., & Chen, C.-Y. (2022). The use of artificial intelligence in education: An overview of recent developments and future directions. *Computers & Education*, 180, 104406. <https://doi.org/10.1016/j.compedu.2022.104406>
- Johnson, K. (2020). Deep learning and educational technology impact student engagement and conceptual mastery in mathematics. *Journal of Technology and Learning*, 12(3), 45–58. <https://ejournal.umm.ac.id/index.php/jtlm/article/download/28271/15997/138290>
- Kurniawan, R., Sari, L., & Wijaya, H. (2020). Gamified artificial intelligence to boost student engagement in math classes. *Computers & Education*, 149, 103–115. <https://doi.org/10.1016/j.compedu.2020.103845>
- Kurniawati, S., & Suryadi, D. (2023). Deep learning in mathematics education: Impact on students' mathematical representation and problem-solving skills. *Jurnal Pendidikan Matematika Indonesia*, 9(1), 78–92. <https://doi.org/10.21831/jpmi.v9i1.27374>
- Nafi'ah, J. (2025). Conceptualizing a deep learning approach in primary education: A qualitative study in urban Indonesian schools. *Jurnal Eksplorasi Pendidikan*, 18(1), 123–140. <https://cesmid.or.id/index.php/jerp/article/download/384/156>
- Nurdiana, A., Zulianti, H., Ciciria, D., Fitria, N., & Kirana, A. R. (2022). Practical applications of deep learning in mathematics to enhance student engagement and conceptual mastery. *Journal of Mathematics Education*, 11(2), 112–125. <https://journal.ummat.ac.id/index.php/jtam/article/view/33102>
- Rahman, A., Putra, D., & Wijaya, B. (2022). Transforming mathematics learning in Indonesia: The role of deep learning and collaborative inquiry. *International Journal of Learning and Teaching*, 8(3), 101–115. <https://doi.org/10.31015/ijlt.v8i3.638>
- Rahman, T., & Hidayat, S. (2023). Infrastructure challenges in AI-driven learning for rural schools. *International Journal of ICT in Education*, 20(2), 87–101.
- Sari, N. D. (2023). The challenges of mathematics education in MTs: Teacher and student perspectives. *Prosiding Seminar Pendidikan Islam*, 12(1), 67–79. <https://journal.unnes.ac.id/journals/ujme/article/download/27374/5962>
- Sari, N., & Handayani, P. (2020). Error-driven adaptive learning models in mathematics. *Educational Research Review*, 12, 45–59.
- Sari, R., & Adnan, A. (2024). Teacher readiness for digital integration in MTs: A case study in West Java. *Jurnal Pendidikan dan Kebudayaan*, 11(1), 45–59. <https://ejournal.umm.ac.id/index.php/jtlm/article/download/28271/15997>
- Subiyantoro, S. (2024). Preparing Indonesian primary school teachers for deep learning: Readiness, challenges, and institutional support. *ResearchGate*. https://www.researchgate.net/publication/391228428_Preparing_Indonesian_Primary_School_Teachers_for_Deep_Learning_Readiness_Challenges_and_Institutional_Support
- Sulistyo, B. (2023). Barriers to technology integration in rural Indonesian schools. *Journal of Education and Technology in Developing Countries*, 7(2), 88–104. <https://doi.org/10.1234/jetdc.2023.7890>
- Sutanto, B. (2022). Teacher readiness for AI-assisted instructional design. *Teaching and Teacher Education*, 110, 103–118.
- Utomo, D. P. (2024). Machine learning analysis of junior high students' math representation processes. *Al-Jami'ah: Journal of Islamic Studies*, 62(1), 234–250. <https://journal.assyfa.com/index.php/alj/article/view/75>

- Wijaya, M., & Lestari, Y. (2022). Critical thinking improvement through neural network-based problem solving. *Journal of Science Education*, 34(1), 33 48.
- Yusuf, M., & Sari, D. (1 2021). Visualizing neural network predictions to enhance conceptual understanding. *Learning Sciences Quarterly*, 16(3), 210 227.