Formatif: Jurnal Ilmiah Pendidikan MIPA, March 2025, 15 (1), 241-252
http://dx.doi.org/10.30998/formatif.v15i1.27696
p-ISSN: 2088-351X e-ISSN: 2502-5457
Accredited (S2) by Ministry of Research and Technology of Indonesia No. 148/M/KPT/2020
Available online at https://journal.lppmunindra.ac.id/index.php/Formatif/index

Optimisation of Android-Based AI Application Using the Design Thinking Framework in Problem-Based Learning to Enhance Students' Problem-Solving Skills

Anton Suwarno*), Supandi, Ida Dwijayanti
Master's Program in Mathematics Education, Universitas Persatuan Guru Republik Indonesia Semarang (UPGRIS), Central Java, Indonesia

Abstract

Problem-solving skills are crucial in modern education and can be improved through Problem-Based Learning (PBL) and AI technology using the Design Thinking framework. This study explores the integration of Design Thinking into the curriculum to develop Android-based AI applications for PBL involving high school students and teachers. The novelty of this research lies in its systematic integration of AI with Design Thinking in a PBL setting, enhancing students' critical and creative thinking skills. Data were collected through interviews, observations, and documentation and analysed thematically to identify key insights. The results show that optimising AI applications with Design Thinking significantly enhances problem-solving skills. This study provides practical recommendations for educators and policymakers while identifying gaps, such as the need for adaptive learning pathways and further empirical validation, offering opportunities for future research in AI-driven PBL models.

Keywords: AI Applications, Design Thinking, Problem-Based Learning, Problem Solving, Digital Education

(*) Corresponding Author: antonsuwarno2@gmail.com

How to Cite: Suwarno, A., Supandi, S., & Dwijayanti, I. (2025). Optimisation of Android-based AI application using the design thinking framework in problem-based learning to enhance students' problem-solving skills. *Formatif: Jurnal Ilmiah Pendidikan MIPA, 15* (1), 241-252. http://dx.doi.org/10.30998/formatif.v15i1.27696

INTRODUCTION

Problem-solving skills are essential competencies in modern education aimed at preparing students to tackle real-world challenges. These skills involve problem identification, information analysis, and the development of effective solutions while fostering critical and creative thinking. They are highly relevant in both academic and professional domains, where deep analysis and data-driven decision-making are key differentiators (Zhou et al., 2024). In this context, technologies such as Android-based AI play a pivotal role in supporting adaptive and personalised learning and enhancing problem-solving processes through features like learning analytics, voice recognition, and virtual tutors (Chen et al., 2020). AI also facilitates more effective learning by providing instant feedback, enabling students to correct mistakes and continuously improve (Holmes et al., 2019). Furthermore, AI boosts motivation, improves the efficiency of student assessments, and offers tailored learning experiences that align with individual learning paces and styles (Lukman Hakim, 2022).

Problem-Based Learning (PBL) is a relevant approach for developing students' problem-solving skills by providing real-world contexts that sharpen their abilities. Through PBL, students not only learn theoretical concepts but also apply them directly to solve relevant problems, thereby increasing motivation and engagement. Research by Pramudita (2020) found that PBL assisted by Prezi is more effective than conventional learning methods. Students using PBL with Prezi not only met the Minimum Competency Criteria (KKM) but also demonstrated better mathematical representation skills and higher learning outcomes. Student activity was also shown to influence learning outcomes positively in both approaches. The integration of AI technology enhances the PBL method by offering interactive guidance, personalised learning, and immediate feedback, helping students gain a deeper understanding of problem-solving processes (Zhou et al., 2024). PBL structures learning around complex problems that students investigate collaboratively. This inquiry-driven approach promotes critical thinking, analytical reasoning, and the development of problem-solving skills (Barrows, 2016). Furthermore, PBL facilitates active learning, bridging theory and practice while simultaneously fostering self-regulated learning skills, including metacognition, motivation, and collaborative teamwork (Hmelo-Silver, 2018).

Design Thinking provides a powerful approach to driving innovation in education through the development of user-centred applications. The iterative stages of Empathize, Define, Ideate, Prototype, and Test facilitate the creation of technology-based solutions that address real learning needs (Brown, 2017). Design Thinking is essential for developing user-centered AI-based educational applications. This approach enables the creation of personalised and interactive learning features refined through user feedback (Zawacki-Richter et al., 2019). Research indicates that applying user experience (UX) and design principles aligned with design thinking are crucial for developing engaging and effective online learning platforms. Platforms like Duolingo and Khan Academy have successfully implemented these principles to create personalised and interactive learning experiences (Bonk & Dennen, 2018). This approach integrates AI principles with problem-based learning methods, fostering a collaborative, adaptive, and reflective learning environment.

The combination of AI, PBL, and Design Thinking significantly enhances innovative technology-based learning. AI serves as a facilitator in PBL by providing data, simulations, and AI-driven guidance, while Design Thinking ensures that the resulting applications are user-centred and intuitive. Collaborative learning facilitated by AI tools can enhance student engagement and improve learning outcomes by allowing them to apply theoretical concepts to real-world problem-solving. This approach fosters both creative thinking and a deeper understanding of the subject matter (Holmes et al., 2019). Thus, integrating these three elements is key to creating an effective and comprehensive learning experience, equipping students with strong critical thinking and problem-solving skills to address real-world challenges.

These limitations indicate a need for a more integrated framework that combines AI, PBL, and Design Thinking to create a more adaptive, engaging, and effective learning environment. Such a framework should leverage AI's capability to provide real-time personalised feedback, PBL's strength in fostering deep learning through real-world problem-solving, and Design Thinking's emphasis on user-centred iterative processes (Chen et al., 2021; Hmelo-Silver, 2019). By integrating these three elements, educators and researchers can develop AI-driven educational tools that not only adapt to individual learning needs but also promote creativity, collaboration, and higher-order thinking skills (Luckin, 2018). Future research should explore how AI can facilitate the implementation of PBL by dynamically adjusting problem scenarios based on student progress and engagement levels. Additionally, incorporating Design Thinking principles into AI-based learning environments could enhance usability, motivation, and learning outcomes by ensuring that the technology is designed with students' needs and experiences at the core (Zawacki-Richter et al., 2019). Empirical studies and experimental designs will be essential to validate the effectiveness of this integration in various educational settings.

This study aims to identify the urgency of problem-solving skills as one of the primary challenges faced by students in modern learning contexts and to explore the potential of optimising Android-based AI applications to enhance these skills. The results of this research are expected to make a tangible contribution to the development of educational technology focused on enhancing students' critical and creative thinking abilities.

METHODS

An exploratory research approach is used to gain a deep understanding of the application of Design Thinking in the development of Android-based AI applications for Problem-Based Learning (PBL). A qualitative approach was deemed appropriate to gain in-depth insights into how application integration can support students' problem-solving development. This methodology is particularly well-suited for exploring complex phenomena in educational settings where quantitative data may be limited (Merriam & Yin, 2019). Design Thinking, with its iterative cycle of empathising, Defining, and ideating, guides the development of user-centred educational applications. This approach prioritises understanding user needs and incorporating feedback throughout the design process to create personalised and relevant learning experiences (Dam & Siang, 2020; Brown, 2017).

This research design is a case study that enables an in-depth analysis of the implementation of Android-based AI applications in PBL learning. Case studies are an effective method for understanding how the application functions in real-world contexts, providing detailed data on the interactions between the application and its users, as well as its impact on students' problem-solving skills (Yin, 2018). The focus of this research aligns with PBL principles, which encourage students to collaboratively solve real-world problems while developing critical, analytical, and creative thinking skills (Hmelo-Silver, 2018). This study also aims to explore how the application of Design Thinking in development can improve learning quality, encourage student innovation, and enhance their engagement in problem-solving processes (Zhou et al., 2024).

The subjects of this study are all high school mathematics students and teachers involved in Problem-Based Learning (PBL) using AI-based technology. The study focuses on four schools: SMA Negeri 16 Semarang, SMA Negeri 4 Semarang, SMA Islam Sultan Agung 1 Semarang, and SMA Unggulan Nurul Islami Semarang, with a purposive sampling of 200 students and six teachers selected to represent the population (Sugiyono, 2018). The sample was selected purposefully based on characteristics such as educational level and experience with technology to ensure the study's validity and generalizability (Palinkas et al., 2015). The study employs an AI-based Android application developed through the design thinking framework, incorporating the stages of empathising, defining, and ideating to support PBL. The application features interactive tools, online collaboration, adaptive feedback, and gamification to enhance the learning experience. It is developed using technologies like Flutter and machine learning to provide personalised learning experiences and improve students' problem-solving skills, aligning with findings that AI can support contextual learning and critical thinking (Hmelo-Silver, 2018; Chen et al., 2020). The AI application includes the following features:

1. Photomath
   A study by Lee and Smith (2021) found that Photomath is highly effective in helping students understand the problem-solving process, as it enables them to learn the logic behind each step of the solution. Moreover, the application's visual learning features make it particularly appealing to digital-native generations, who are more inclined to learn through technology.

2. MalMath
   According to research by Wilson (2022), MalMath is highly beneficial for students who prefer self-directed learning due to its accessible features and ability to demonstrate various approaches to problem-solving.
3. Algebrator
   Research by Roberts et al. (2020) found that Algebrator is highly effective in enhancing students' understanding of algebra topics, particularly for those who struggle with traditional learning methods.

The development of the Android-based application in this study follows three stages of the Design Thinking process. The first stage, empathise, involves identifying problems and building empathy by collecting initial data on the needs and challenges faced by students and teachers in Problem-Based Learning (PBL). Observations and interviews are conducted to understand difficulties in problem-solving and interactions with technology. The second stage, define, focuses on formulating a relevant problem definition based on initial findings, with an emphasis on addressing the primary challenges in PBL and the need for an adaptive and personalised AI application. Lastly, the ideation stage is an iterative process involving the generation, refinement, and evaluation of ideas for the educational application's features. Input from students, teachers, and developers is crucial throughout this process, ensuring that the final product effectively supports problem-solving and learning (Brown, 2017).

The data collection techniques in this study employed three primary methods to obtain a comprehensive understanding of the implementation of the Android-based AI application in Problem-Based Learning (PBL) and its effectiveness in enhancing students' problem-solving skills. The methods included in-depth interviews with students, teachers, and application developers to explore experiences, perceptions, and challenges during the implementation process (Kvale & Brinkmann, 2015). Direct classroom observations were conducted to examine the interactions between students and teachers with the application, including its role in facilitating PBL and increasing student engagement (Creswell & Poth, 2018). Additionally, documentation such as student evaluation results, application development reports, and evidence of Design Thinking integration provided supplementary information that supported findings from the interviews and observations (Bowen, 2009). The combination of these three methods ensured that the data collected was diverse, in-depth, and aligned with the research objectives.

The data analysis techniques in this study employed a thematic analysis approach to ensure rich and valid findings. Thematic analysis was applied to qualitative data obtained from interviews and observations to identify patterns and key themes related to the implementation of the Android-based AI application in Problem-Based Learning (PBL). Quantitative data from student evaluation questionnaires were analysed descriptively to illustrate the application's effectiveness in learning (Creswell & Plano Clark, 2018). To enhance the validity of the findings, data triangulation was conducted by comparing results from questionnaires, interviews, observations, and documentation obtained from various sources, including students, teachers, and application developers (Patton, 2015). This approach ensured that the research findings were verified from multiple perspectives, leading to a comprehensive and credible understanding of the impact of the AI application on problem-based learning.

RESULTS AND DISCUSSION

The Empathize stage in this application development involves a series of user research activities, including interviews, ethnographic studies, and user journey analysis. Through this process, designers gain in-depth insights into user needs, behaviours, and contexts, which are then integrated into the design process (Goodwin, 2018). The primary objective of this stage is to identify the urgency of problem-solving skills and understand the needs, challenges, and preferences of users, specifically students and teachers. The subsequent step in the *empathising* phase involves creating visualisations through an Empathy Map, as illustrated in Figure 1. Empathy mapping is a valuable tool for understanding user needs and perspectives, allowing designers to visualise and synthesise user research data to inform design decisions (Buchenau et al., 2015).

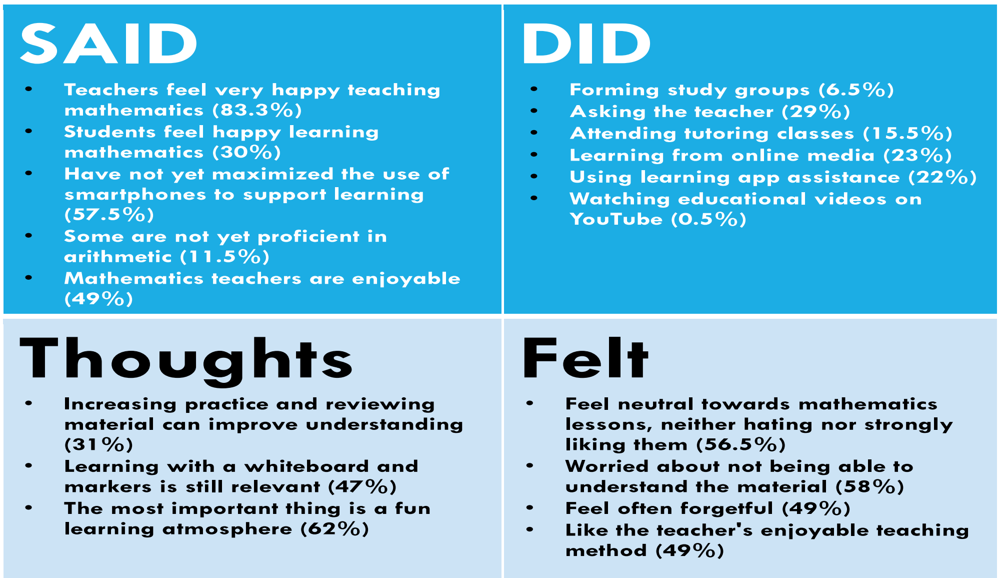

Figure 1. *Empathy mapping*

The **Said** section captures users' expressed opinions and needs. It was found that most teachers enjoy teaching mathematics (83.3%), while only 30% of students enjoy learning it. Additionally, 57.5% of teachers have not maximised smartphone use to support learning, 11.5% of students struggle with basic arithmetic, and 49% perceive their mathematics teachers as engaging. The **Did** section records observed user actions, such as students forming study groups (6.5%), asking questions to teachers (29%), attending tutoring sessions (15.5%), learning through online media (23%), using educational apps (22%), and watching educational videos on YouTube (0.5%). The **Thought** section reflects unspoken thoughts, such as students practising more and revisiting materials to improve understanding (31%), the perception that whiteboards and markers remain relevant (47%), and the belief in the importance of creating an enjoyable learning atmosphere (62%). Lastly, the **Felt** section identifies users' emotions related to their experiences. A total of 56.5% of students felt neutral toward mathematics, 58% were anxious about not understanding the material, 49% often forgot lessons, and 49% appreciated their teachers' enjoyable teaching methods.

Based on the data analysis conducted during the Empathize stage, the next step is the Define stage. In this phase, designers analyse and synthesise the data gathered during the Empathize stage to formulate a clear and focused problem statement. This problem statement must be human-centred and provide clear direction for subsequent steps. The POV is a tool that helps designers to define the problem in a human-centred way. It is a concise statement that captures the essence of the problem, including the user, their needs, and the insights that have been gathered (Dam & Siang, 2020).

From the PoV results, problem statements are then formulated through "How Might We" (HMW) questions, as shown in Table 2. "How Might We" (HMW) is a method of formulating creative questions used in the Define stage of the Design Thinking process. The goal is to transform design challenges into opportunities by crafting open, positive, and solution-oriented questions. HMW helps the design team initiate the Ideation process with a clear focus while remaining flexible enough to allow for a wide range of creative ideas to emerge.

Table 1. *Point of View* (PoV)

User	Need	Insight
Students	Innovative teacher	Understanding the material
Students	Varied learning media	More engaging learning
Students	Applicable curriculum	Aligned with the demands of the times
Teachers	Sufficient facilities	Maximal in delivering the material

Ideation is a collaborative process where diverse perspectives contribute to a rich pool of ideas. Through structured brainstorming and other collaborative exercises, teams explore possibilities, challenge assumptions, and build upon each other's thinking (Dam & Siang, 2020). After understanding user needs in the Empathize stage and formulating a clear problem statement in the Define stage, the Ideate phase encourages the exploration of a wide range of possible solutions without initial constraints. From the analysis of questionnaire data via Google Forms completed by both students and teachers, along with direct observations, several ideas emerged as potential alternative solutions, as shown in Figures 2 and 3.

Table 2. *How Might We* (HMW)

No	Questions	Answers
1	How can we make mathematics more relevant to students' everyday lives?	Connect with interests: Engage students in projects related to their interests (e.g., designing a simple video game involving geometric concepts or analysing data from their favourite social media to understand statistics).
		Use real-life examples: Provide word problems that are close to students' everyday lives, such as calculating the cost of a birthday party or planning a trip.
		Incorporate technology: Use apps and software that allow students to explore mathematical concepts visually and interactively.
2	How can we make mathematics learning more enjoyable and engaging?	Vary teaching methods: Do not rely solely on lectures; also use games, simulations, and group projects.
		Leverage technology: Use videos, animations, and educational games to make learning more engaging.
		Create a collaborative learning environment: Encourage students to work together to solve problems and share ideas.
3	How can we enhance students' motivation to learn mathematics?	Set clear learning objectives: Explain to students why they need to learn mathematics and how it will benefit them in the future.
		Celebrate successes: Provide rewards and recognition for students' achievements.
		Engage students in the learning process: Give students the opportunity to choose topics they want to learn or create their projects.
4	How can we overcome the difficulties students experience in learning mathematics?	Identify difficulties: Conduct assessments to determine where students' difficulties lie.
		Provide additional support: Offer tutoring or study groups for students who need extra help.
		Change the learning approach: If one method does not work, try a different approach.

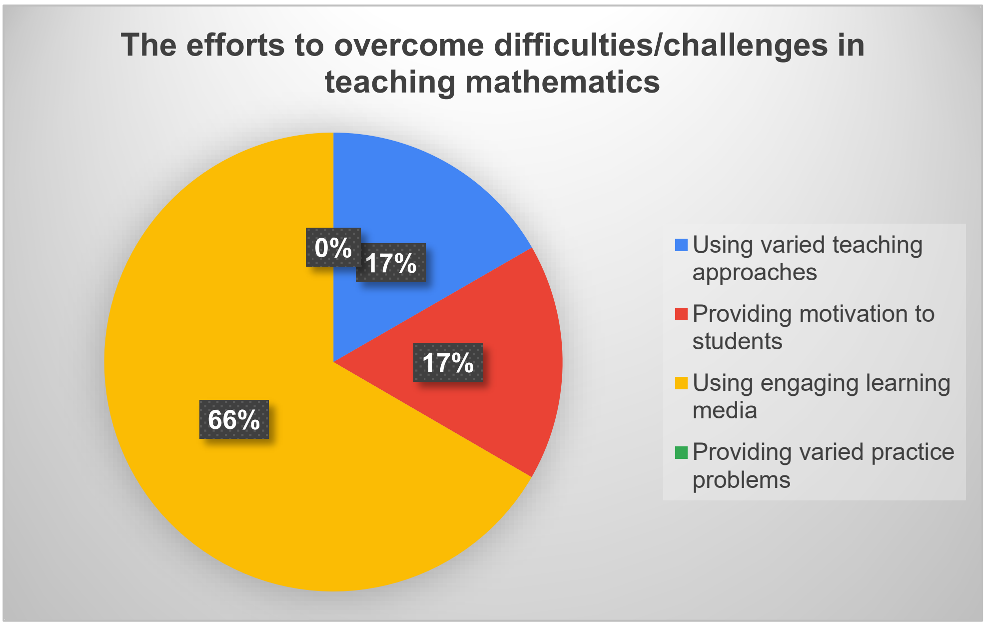

Figure 2. Ideas for solutions from teachers

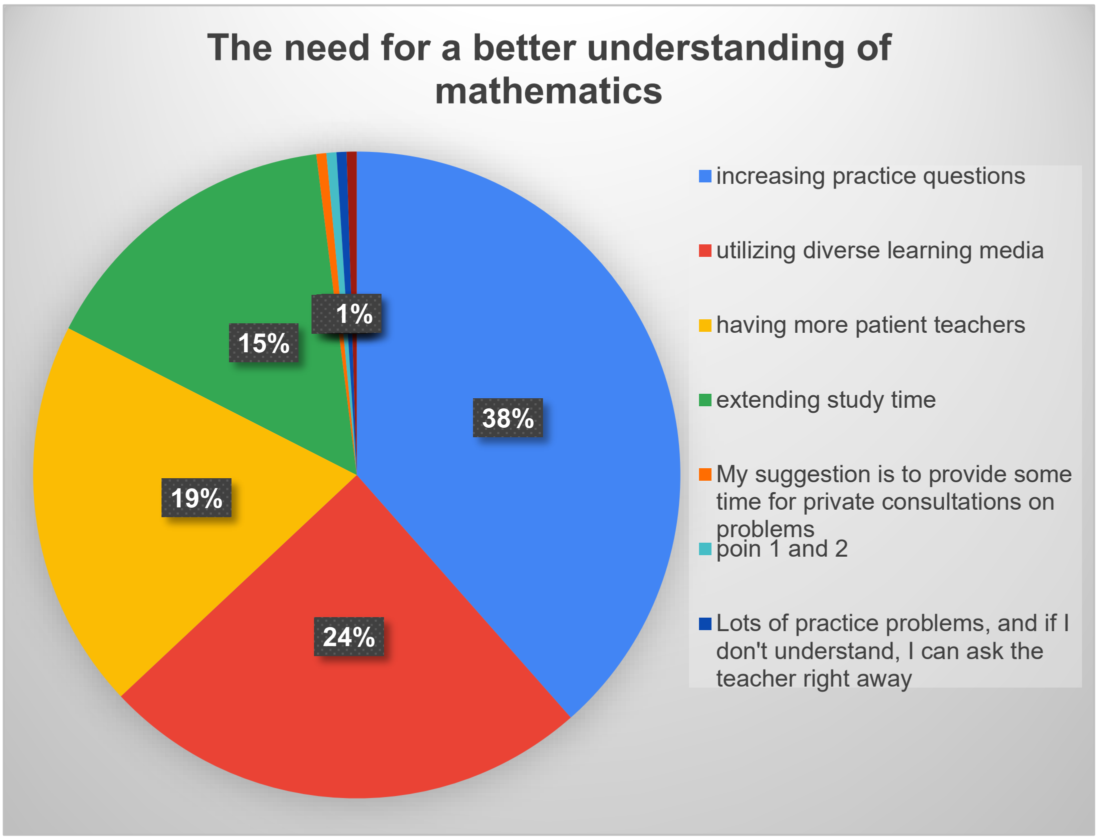

Figure 3. Ideas for solutions from students

From the data, four key solutions proposed by students to enhance their understanding of mathematics are identified: increasing practice questions (38%), utilising diverse learning media (24%), having more patient teachers (19%), and extending study time (15%). On the other hand, the best solutions suggested by teachers to address challenges in mathematics education include using engaging teaching media (66%), adopting varied teaching approaches (17%), and motivating students (17%). The strengths and weaknesses of each proposed solution from both students and teachers analysed through the lens of optimising AI applications, are as follows:

1. Increasing practice questions

Increasing practice questions (38%) hold significant potential for optimisation through AI technologies such as MalMath, Photomath, and Algebrator. These applications provide interactive step-by-step solutions, helping students gain a deeper understanding of mathematical concepts. For instance, Photomath enables students to visualise problem-solving processes, while MalMath offers systematic explanations that enhance analytical and logical skills (Malmath Team, 2022). Additionally, adaptive features in Algebrator allow students to practice questions with varying levels of difficulty, effectively preparing them for evaluations with greater confidence (Johnson & Smith, 2021). Traditional problem-solving practices are often perceived as monotonous and less stimulating for creativity. AI technology addresses this issue by offering interactive interfaces and gamified elements that increase student engagement (Chang et al., 2023). AI-based applications can also incorporate contextual problems to foster creative thinking and leverage augmented reality (AR) to make learning more engaging (Zhao et al., 2023). With strategic integration into the curriculum, AI has the potential to enhance the quality of mathematics education significantly (Holmes et al., 2023).

2. Varied learning media

Varied learning media play a crucial role in enhancing students' interest, motivation, and understanding, especially in mathematics. AI applications such as MalMath, Photomath, and Algebrator support the visualisation of abstract concepts through graphics, simulations, and step-by-step explanations. Research by Mutiarawati (2019) also shows that the use of GeoGebra in Creative Problem Solving (CPS) learning effectively improves students' mathematical problem-solving abilities. However, optimising technology-based media faces challenges such as limited access and the need for teacher training. With targeted integration, applications like MalMath, Photomath, Algebrator, and GeoGebra can create interactive learning that caters to various learning styles (Chang et al., 2023; Zhao et al., 2023; Malmath Team, 2022).

3. Teacher patience

Teacher patience is crucial in enhancing student engagement in mathematics learning, creating a positive learning environment, and providing space to understand difficult concepts without time pressure. AI-based applications such as MalMath, Photomath, and Algebrator can support this by offering step-by-step guidance that is patient and without time constraints. However, while AI can complement the teacher's role, over-reliance on technology may hinder the development of students' independent thinking skills, and the emotional support and motivation provided by teachers are difficult to replace. Therefore, the optimisation of AI's role should support, not replace, the teacher's role, ensuring that students receive a balance of technical guidance and emotional support (Zhao et al., 2023; Chang et al., 2023).

4. Adding extra study time

Adding extra study time has advantages in supporting mathematics learning, particularly in understanding difficult concepts, engaging in discussions, and asking questions to teachers or peers. This additional time allows for more comprehensive learning, especially for topics that require in-depth analysis. AI-based technologies such as

MalMath, Photomath, and Algebrator can maximise study time by providing quick access to math problem solutions, step-by-step explanations, and graphical simulations. These features enable students to learn independently and efficiently (Zhao et al., 2023). However, extending study time also has downsides, such as the risk of physical and mental fatigue, which can reduce learning effectiveness. Students' busy schedules filled with extracurricular activities or family commitments pose additional challenges. Optimising AI applications like Photomath and Algebrator can address these issues. These apps allow students to learn anytime without being tied to specific hours, increasing flexibility without adding to the formal study time burden (Chang et al., 2023; Wang et al., 2023).

5. Using engaging learning media

The use of engaging learning media, such as visual and interactive media, is effective in enhancing students' motivation towards mathematics and facilitating the understanding of complex concepts through visualisation and simulation. AI-based applications like MalMath, Photomath, and Algebrator support learning with detailed solutions and dynamic graphics. Research by Indiati (2021) shows that the use of APKs in online learning during the pandemic improved learning outcomes, particularly in the problem-solving ability of prospective mathematics teachers. While the development of these media faces resource limitations, Android-based AI applications can serve as an effective solution due to their accessibility, cost-effectiveness, and flexibility with the curriculum (Zhao et al., 2023; Chang et al., 2023; Wang et al., 2023).

6. Using different learning approaches

Diverse learning approaches offer flexibility for teachers to adapt strategies to students' needs, enhancing the effectiveness of learning and fostering creativity in designing innovative methods, including the integration of AI technology. Applications like MalMath, Photomath, and Algebrator assist students through step-by-step solutions, concept visualisation, and interactive simulations (Chang et al., 2023; Zhao et al., 2023). However, challenges arise in teacher training and student confusion due to frequent method changes. Applications like Photomath provide consistency in the learning process while optimising AI technology allows teachers to enrich learning without compromising clarity (Wang et al., 2023).

CONCLUSION

This study highlights that students' problem-solving skills remain a significant challenge in modern education, requiring innovative approaches to enhance learning effectiveness. The integration of Android-based AI applications with the Design Thinking framework in Problem-Based Learning (PBL) demonstrates strong potential to foster critical and creative thinking skills. Among various optimisation strategies analysed, increasing the number of practice problems (38%) is identified as a crucial factor in strengthening students' conceptual understanding, improving problem-solving abilities, and boosting confidence in facing evaluations. Despite its promising findings, this research has several limitations. It primarily focuses on a single optimisation strategy, while other potential enhancements—such as AI-driven real-time feedback, gamification, and adaptive learning pathways—remain unexplored. Additionally, the long-term impact of this AI-PBL integration is yet to be assessed, and concerns regarding usability, accessibility, and scalability in diverse educational settings need further investigation. Future research should address these gaps to refine AI-driven PBL models, ensuring they provide effective, inclusive, and adaptive learning solutions for students in various academic contexts.

REFERENCES

Baillifard, Ambroise, et al. (2023). Implementing Learning Principles with a Personal AI Tutor: A Case Study. *arXiv preprint arXiv:2309.13060*.

Barana, Alice, Marina Marchisio, & Fabio Roman. (2023). *Fostering Problem-Solving and Critical Thinking in Mathematics through Generative Artificial Intelligence*. International Association for Development of the Information Society.

Barrows, H. S. (2016). *Problem-based learning applied to medical education*. Southern Illinois University School of Medicine.

Bonk, C. J., & Dennen, V. P. (Eds.). (2018). *The handbook of blended learning: Global perspectives, local practices*. John Wiley & Sons.

Brown, T. (2017). *Change by design: How design thinking transforms organisations and inspires innovation*. Revised and updated edition. Harper Business.

Buchenau, M., Suri, J. F., & Brown, T. (2015). *Experience innovation*. BIS Publishers.

Chang, L., Wang, Y., & Huang, J. (2023). Gamification in Educational Applications: Enhancing Engagement through AI. *Journal of Educational Technology and Innovation*.

Chen, X., Xie, H., Zou, D., & Hwang, G. J. (2020). *Application and theory gaps during the rise of Artificial Intelligence in Education*. Computers & Education, 146, 103751.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). Routledge.

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research* (3rd ed.). Sage publications.

Dam, R. F., & Siang, T. Y. (2020). What is Design Thinking, and Why Is It So Popular? *Interaction Design Foundation*. Retrieved from https://www.interaction-design.org/

Goodwin, K. (2018). *Designing for the digital age: How to create human-centered products and services*. John Wiley & Sons.

Hakim, L. (2022). *Peranan Kecerdasan Buatan (Artificial Intelligence) dalam Pendidikan*. Kemenristek Dirjen Guru Dan Tenaga Kependidikan 1.

Hmelo-Silver, C. E. (2018). *Problem-based learning: A practical guide for educators*. Routledge.

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning.* Center for Curriculum Redesign.

Indiati, I., Supandi, S., Ariyanto, L., & Kusumaningsih, W. (2021). The effectiveness of the problem-posing method based on Android applications in mathematics learning. *Ilkogretim Online*, *20*(1). http://ilkogretim-online.org, doi: 10.17051/ilkonline.2021.01.137

Johnson, R., & Smith, T. (2021). *Algebrator in Modern Classrooms: A Study on Interactive Mathematics Tools*. Mathematics Education Review.

Kvale, S., & Brinkmann, S. (2015). *InterViews: Learning the craft of qualitative research interviewing* (3rd ed.). SAGE Publications.

Luckin, R. (2018). *Machine learning and human intelligence: The future of education for the 21st century*. UCL IOE Press.

Lukman, Lukman, Riska Agustina, and Rihadatul Aisy. (2023). Problematika Penggunaan Artificial Intelligence (AI) untuk Pembelajaran di Kalangan Mahasiswa STIT Pemalang. *Madaniyah* 13.2: 242-255.

MalMath Team. (2022). *MalMath: A Step-by-Step Math Solver*. MalMath Documentation.

Merriam, S. B., & Yin, R. K. (2019). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Möller, Moritz, et al. (2024). Revolutionising Distance Learning: A Comparative Study of Learning Progress with AI-Driven Tutoring. *arXiv preprint arXiv:2403.14642*.

Mutiarawati, I. S., Supandi, S., & Rahmawati, N. D. (2019). Efektivitas Model Pembelajaran CPS Berbantuan Media Geogebra terhadap Kemampuan Pemecahan Masalah Matematis. *Imajiner: Jurnal Matematika Dan Pendidikan Matematika*, *1*(4), 24-29. journal.upgris.ac.id/index.php/imajiner

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). *Purposeful sampling for qualitative data collection and analysis in mixed method implementation research*. Administration and policy in mental health and mental health services research, *42*(5), 533–544.

Patton, M. Q. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (4th ed.). SAGE Publications.

Pramudita, D. A., Supandi, S., & Zuhri, M. S. (2020). Efektivitas Model Pembelajaran Problem Based Learning dan Model Kooperatif Tipe Student Teams Achievement Division terhadap Hasil Belajar Matematika Siswa Kelas VIII SMP N 3 Pamotan. *Imajiner: Jurnal Matematika dan Pendidikan Matematika*, *2*(1), 71-79. journal.upgris.ac.id/index.php/imajiner

Rifky, S. (2024). Dampak penggunaan artificial intelligence bagi pendidikan tinggi. *Indonesian Journal of Multidisciplinary on Social and Technology*, *2*(1), 37–42.

Sajja, Ramteja, et al. (2024). Artificial intelligence-enabled intelligent assistant for personalised and adaptive learning in higher education. *Information* 15.10: 596. https://doi.org/10.3390/info15100596

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows*, *9*(2), 5–15.

Sugiyono. (2018). *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D*. Bandung: Alfabeta.

Syauqi Asy Syuhada, Dohaman Siregar, Anang Jumardi, Darmawati, Saddad Nabbil, Zahid Sholahuddin Al Ayubi, Dodik Prasetyo, Dzaky Setiawan Tauri, Samsudin, Burhan Firdaus, & Muhammad Rizky Albaras. (2024). Dampak AI Pada Proses Belajar Mengajar Di Era Digital . *APPA : Jurnal Pengabdian Kepada Masyarakat*, *2*(1), 20–24. http://jurnalmahasiswa.com/index.php/appa/article/view/962

Wang, H., Zhang, T., & Chen, J. (2023). *AI-Assisted Adaptive Learning: Trends and Challenges in Secondary Education*. Educational Research and Reviews.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). *Systematic review of research on artificial intelligence applications in higher education.* International Journal of Educational Technology in Higher Education, *16*(1), 39.

Zhou, X., Teng, D., & Al-Samarraie, H. (2024). *The Mediating Role of Generative AI Self-Regulation on Students' Critical Thinking and Problem-Solving*. Educational Sciences. ps://www.mdpi.com/2227-7102/14/12/1302).

Zhao, X., Li, M., & Xu, Y. (2023). *Integrating Augmented Reality into Mathematics Learning with AI Tools*. Computers & Education.

This page was intentionally left blank.