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Development Of Artificial Intelligence Numeracy (Aira) Learning Media In Mathematics Learning With A Deep Learning Approach To Improve Students' Numeracy Skills

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Abstract

Numeracy competence is an important life skill, supporting mathematical problem-solving and everyday life (OECD, 2016). In Indonesia, many students still struggle with non-routine math problems or numeracy problems. This study aims to develop an artificial intelligence-based learning application called "AIra" and test its validity, practicality, and effectiveness in improving junior high school students' numeracy skills. The method used isResearch and Developmentwith modelSoftware Development Life Cycle(SDLC) through a prototyping approach, including needs analysis, prototype design, expert assessment, development, and testing. The application was assessed by material and media experts, tested for practicality on 15 students, and tested for effectiveness on 30 eighth-grade students using a pretest-posttest design. Data analysis used a normality test.Shapiro-Wilk And uji Paired Samples t-Test. The results showed that AIra has high validity: the average score of material experts was 89.375 ("Very Valid") and media experts was 78.33 ("Valid"). The application proved to be practical (average score of 79.70) and highly effective, with students' scores increasing from 43.65 (pretest) to 81.28 (posttest), as well as a statistically significant difference (Say. 0.000 < 0.05). Thus, AIra is proven to be valid, practical, and effective as a numeracy learning medium, while also positioning artificial intelligence as an innovative solution in revolutionizing the process.

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INTRODUCTION

In this era of globalization and rapid technological development, numeracy skills have become a crucial basic competency for every individual. As an integral part of 21st-century basic literacy, numeracy is not only limited to the ability to calculate, but also includes the ability to understand, use, and reason with numbers in various real-life contexts. Globally, numeracy is increasingly recognized not only as a mathematical skill, but also as a critical competency for workplace readiness and citizen participation in the 21st century (Geiger et al., 2015). These skills enable students to analyze quantitative information and make informed decisions in everyday life.

Unfortunately, the current state of Indonesian students' numeracy skills is at a very low level and far behind other countries, which is a matter of great concern. Data from the Programme for International Student Assessment (PISA) consistently confirms this problem. Indonesia's numeracy score has experienced a significant decline, from 386 in 2015, to 379 in 2018, and dropped again to 366 in 2022. This worrying downward trend indicates a significant gap in the national education system in equipping students with adequate numeracy competencies. Various other studies also align with PISA's findings, confirming that Indonesian students' numeracy skills are indeed low, a fact that demands innovative and efficient solutions. One of the identified root causes is students' difficulty in dealing with non-routine math problems, now known as numeracy problems. This problem is exacerbated by students' low reading literacy, which is directly correlated with their understanding of math word problems. Numeracy questions are often presented in lengthy narratives that require strong analytical and interpretive skills. Students who are not accustomed to careful reading tend to miss important details, leading to incorrect answers. Therefore, a learning approach is needed that not only trains cognitive skills but also facilitates in-depth contextual understanding.

In the context of ever-evolving digitalization, artificial intelligence (AI) offers transformative potential in addressing these educational challenges. Research literature shows that the application of Information and Communication Technology (ICT) in education can have a positive impact. Previous studies have demonstrated the effectiveness of video-based learning media (Putra & Mukhtar, 2022), ebook modules (Cahyadi et al., 2023), and e-learning (Sutarna et al., 2021) in improving numeracy skills. Leading Indonesian journals have also emphasized the relevance of this topic among academics (e.g., Agustina & Vahlia, 2017; Farman & Chairuddin,

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2020; Lu'luilmaknun & Wutsqa Urwatul, 2018). Studies of students' mathematical errors in literacy and numeracy assignments reveal substantial difficulties that can be minimized through AI-based resources. Research shows that students often experience difficulties at various stages of problem solving, such as reading, comprehension, transformation, process skills, and answer writing (encoding), as described in Newman's error analysis framework (Logistica & Awalludin, 2024) (Nurmawanti et al., 2023) (Sulaiman et al., 2024). These errors are found at various levels of ability, with comprehension and process skills errors being the most common (Nurmawanti et al., 2023) (Sulaiman et al., 2024).

However, further exploration of more advanced technologies, such as artificial intelligence (AI), is still needed to address this issue. AI offers unique capabilities in personalized learning and provides adaptive feedback that conventional media cannot. A review by The Guardian noted that, just as the advent of calculators shifted the direction of the mathematics curriculum from mere calculation to reasoning, AI has the potential to be a catalyst that drives a paradigm shift from product-based learning to process-based learning. The AIra app is explicitly designed to fill this gap by providing “artificial intelligence-based practice questions” specifically designed to improve numeracy competency. Based on a needs analysis that showed that students are still “not accustomed to dealing with numeracy problems,” the app aims to provide a learning experience focused on such problems. Through a mechanism that allows the app to “measure students’ mathematical numeracy skills based on the problem level,” AIra not only presents material but also functions as a diagnostic and guiding tool that helps teachers more effectively assess student progress.

This approach directly addresses the challenges identified in the research, namely students' lack of understanding of word problems and in-depth numeracy concepts. Therefore, a learning approach is needed that not only trains cognitive skills but also facilitates deep contextual understanding. This aligns with the growing global consensus that mathematics education must shift from rote learning to fostering higher-order thinking and problem-solving skills (Gravemeijer et al., 2017).

This research focuses on the design and evaluation of the AIra application to fill this gap. The main objectives of this research are to: (1) develop an artificial intelligence-based numeracy learning application, AIra, using the SDLC model; (2) test the validity of the application through assessments by subject matter experts and media experts; (3) assess the practicality of the application from a user perspective; and (4) analyze the application's effectiveness in improving students' mathematical numeracy skills. Artificial Intelligence in Education (AIEd) has developed

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rapidly, offering a variety of sophisticated tools capable of simulating one-on-one tutoring and providing personalized scaffolding for students (Luckin et al., 2016). Although previous studies have demonstrated the effectiveness of video- and ebook-based learning media in improving numeracy skills, further exploration of more sophisticated technologies is still needed. A recent systematic review showed that AI-based adaptive learning systems significantly improve student performance by tailoring content to each individual's ability level (Chen et al., 2020). Specifically, Intelligent Tutoring Systems (ITS) equipped with deep learning algorithms can diagnose student misconceptions in real-time, offering a level of interactivity that static media lacks (Hwang & Tu, 2021).

METHODS

This study applies a design *Research and Developmen t*with a model approach*Software Development Life Cycle*(SDLC) combined with prototyping methods. Integrating a systematic engineering model like the SDLC into educational design research is crucial to ensuring both technical robustness and pedagogical validity (Richey & Klein, 2014). This model was chosen because it allows for an iterative development cycle, where feedback from users and experts can be integrated repeatedly to refine the product.

The SDLC development model with prototyping consists of six stages: analysis, prototyping, evaluation, development, testing, and implementation.*(deployment).*During the needs analysis phase, interviews were conducted with teachers and several students to identify specific needs in mathematics learning. The analysis revealed that students were experiencing difficulties with numeracy problems. Based on these findings, a product specification document was prepared to guide application development. Next, during the prototyping phase, an initial prototype of the application was created, based on the analyzed needs, as a visual and functional representation. Figure 1 presents the method. *Research and Development*(R&D) used in this study, which adopts the SDLC model with a development approach. *prototyping*.

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Figure 1. SDLC Method Pie Chart

This prototype includes initial layouts, a list of materials, and other basic features. This prototyping approach is crucial because it allows stakeholders to see and interact directly with the product early on, providing crucial feedback before full-scale development begins. *Prototyping* Iterative approaches are widely recommended in educational technology development to enhance user experience (UX) and ensure interfaces meet learners' cognitive needs (Plass et al., 2015). The integration of artificial intelligence, numeracy, deep learning, and mathematical literacy has been systematically designed since the development stage of the AIra media prototype.

Numeracy and mathematical literacy serve as the pedagogical foundation for developing learning content based on the OECD and AKM frameworks, presenting non-routine problems based on real-life contexts that require mathematical reasoning, representation, and problem-solving. Deep learning is implemented through the use of artificial neural network models (*artificial neural network*) that analyzes student response patterns to identify levels of numeracy mastery and conceptual errors, while artificial intelligence plays a role in the system's adaptive mechanism that provides automatic feedback, material recommendations, and adjustments to the difficulty level of questions according to students' learning profiles. These four aspects are concretely integrated in the prototype flow design, adaptive evaluation features, and visualization of student numeracy development, and validated by material experts and media experts to ensure alignment between learning objectives, mathematical literacy principles, and the implementation of AI technology.

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In the evaluation stage, the prototype that has been created is then validated by two subject matter experts and two media experts to obtain feedback. These validators, consisting of mathematics teachers and lecturers, provide comprehensive assessments and suggestions for improvement. Validator assessment is carried out using a validation instrument developed based on the criteria for the suitability of learning media and the suitability of numeracy materials. Validators consist of subject matter experts and media experts, with assessment criteria including aspects of the suitability of numeracy content and mathematical literacy, conceptual accuracy, integration with learning objectives, clarity of presentation, and relevance of questions to real-life contexts. In addition, media assessment includes aspects of interface design, ease of navigation, readability, interactivity, and functionality of artificial intelligence-based systems. Overall, the validation instrument consists of 24 assessment items, with 14 items for subject matter experts and 10 items for media experts, each of which is assessed using a four-level Likert scale.

This process ensures that the application concept and design align with sound pedagogical and technical principles. After the evaluation phase is complete, the process proceeds to the development phase. At this stage, the application prototype is revised according to the suggestions provided by the validators. This phase involves writing code using a programming language to build the "AIra" application. Next, the testing or implementation phase includes system-level testing and the application of the developed application to students in the experimental class. The final phase is deployment. If the test results indicate that the application is complete and ready for implementation, the "AIra" application will be disseminated more widely. The population of this study included all students of SMP Negeri 1 Kadugede. The research sample consisted of all 30 students of class VIII D. This study was conducted in the first semester of the 2025/2026 academic year. This study used test and non-test data collection methods. Test data collection included final test questions to measure students' numeracy skills through the "AIra" application that had been developed. Data collection methods used included field observations, structured interviews, and questionnaires.

This study employed a mixed-method analysis of qualitative and quantitative data. Quantitative data analysis was conducted to test the validity, feasibility, and effectiveness of the data and model. The "AIra" application was validated by subject matter and media experts. The effectiveness of "AIra" was assessed based on the results of a student questionnaire. Effectiveness was analyzed by observing the increase in numeracy skills based on the increase in pretest and posttest scores of the numeracy test using*Paired Samples Test*.

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RESULTS AND DISCUSSION

At this stage, the researcher conducted a student needs analysis by interviewing teachers and several students to obtain research data. The results of the analysis showed that students still had great difficulty in solving non-routine mathematics problems, which are now better known as numeracy problems. In the analysis stage, interviews were used to explore in depth the learning experiences of students and teachers, especially regarding mathematical literacy difficulties that cannot always be identified through quantitative data. The results of the initial diagnostic test of numeracy literacy given to 30 eighth-grade students showed an average score of 42.80, with a minimum score of 25 and a maximum score of 65. A total of 21 students (70%) were below the Minimum Completion Criteria (KKM = 70), while only 9 students (30%) achieved or were close to completing the criteria. Based on the analysis per indicator, the students' greatest difficulty lies in the context-based mathematical reasoning indicator, with a success rate of only 38%, followed by interpreting data representations at 41%, and solving non-routine problems at 35%.

Meanwhile, the basic calculation indicator showed a relatively higher success rate, at 62%. This descriptive statistical data supports the interview findings, which indicated that students tended to have difficulty understanding the context of the problem and formulating problem-solving strategies. Thus, the diagnostic test and interview results complement each other in identifying initial learning needs.

Therefore, researchers attempted to address this issue by developing an AI-based application to help students learn numeracy, named "AIra." This application is comprehensively designed to meet students' needs, including materials, sample questions, and AI-based practice questions. Furthermore, the application can be accessed via laptop or mobile phone in software form. The output of this process is a product specification document with the achievement indicator "100% availability of the specification document." This process involved discussions between the principal researcher and potential users, namely students and teachers.

Prototype Making

Based on the analysis of the needs of teachers and several students, a prototype was created as the initial design concept for "AIra." AIra is designed to help students learn numeracy anywhere with the help of artificial intelligence. It is hoped that after students learn mathematical numeracy using this application, their numeracy skills will improve. The use of learning media can foster effective learning and facilitate student understanding of the concepts being studied (Winarni et al., 2021). The AIra prototype can be seen in the following images:

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Figure 2. AIra Initial Display Prototype



Figure 3. AIra Material List Display Prototype

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Evaluation

The developed application was then evaluated by subject matter experts, media experts, and potential users, namely students, to obtain feedback. Feedback from the validators was used as assessment material or for refinement in application development. The "AIra" prototype received initial validation from two subject matter experts and two media experts. The two subject matter expert validators were a high school mathematics teacher and a mathematics lecturer. The results of the validation evaluation conducted by the subject matter experts and media experts are presented in Tables 1 and 2.

Table 1. AIra Validation Assessment by Material Experts

Aspect	Validator 1	Validator 2
Language	83	82
Head	82	84
Presentation	79	80
Benefit	93	94
Total	337	340
Rate-rate	84,25	85
Validity	Valid	Valid

Table 2. AIra Validation Assessment by Media Experts

Aspect	Validator 1	Validator 2
Appearance	83	81
Head	79	78
Writing	81	80
Total	243	239
Rate-rate	81	80
Validity	Valid	Valid

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The AIra prototype, as the initial stage of the "AIra" application development process, was assessed by material experts and media experts. The results of the material expert validation obtained an average score of 84.25 and 85 with the "valid" category, accompanied by several notes. This indicates that the AIra application material content is valid and feasible in terms of material, although it still requires some revision. Furthermore, the average validation assessment from media experts was 81 and 80 with the "valid" category. This indicates that the AIra application is valid and feasible in terms of media indicators, with several notes that need to be followed up. Based on the results of the media development revision, several improvements were made to enhance the quality of the application's appearance and usability. The visual design of the media was enhanced with the use of more attractive and varied colors to increase user appeal and comfort. The application interface layout was also improved so that pages and media components are connected more systematically and consistently. In addition, the background and icons were updated with a more attractive design and adapted to the characteristics of the mathematics material presented.

In terms of content, the list of subtopics has been expanded to ensure a more comprehensive and structured learning experience. Furthermore, all materials have been reviewed to correct typographical errors, ensuring the information presented is clearer, more accurate, and easier for users to understand.

Development

During the development phase, the integration of artificial intelligence, numeracy skills, deep learning, and mathematical literacy was explicitly designed and implemented in every key feature of AIra's learning media. Artificial intelligence serves as an adaptive mechanism that analyzes student responses and provides automated feedback and material recommendations tailored to each student's numeracy skill profile.*Deep learning*implemented through an artificial neural network model that forms the basis of a system for analyzing answer patterns and adjusting question difficulty levels. Meanwhile, numeracy and mathematical literacy skills are demonstrated through learning activities and non-routine questions based on real-life contexts that require reasoning, interpretation of representations, and mathematical problem-solving.

The integration of these four aspects is visualized through media screenshots showing the user interaction flow, adaptive evaluation features, and the results of the analysis of student numeracy development. Each image is presented in high resolution and accompanied by clear captions to facilitate reading and directly represent the research variables being studied. In

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accordance with recommendations for improvement from material experts and media experts, the previously developed AIra application prototype was revised. For example, revisions were made to use more attractive and varied colors. These color and layout adjustments refer to Mayer's multimedia learning principles, which state that visual coherence can reduce cognitive load and improve information processing (Mayer, 2020).

This stage involves writing code using programming languages to develop the application. The programming languages used are HTML, CSS, JavaScript, and PHP, with a MySQL database, as this application functions as a web application. There were six revision suggestions: two from subject matter experts and four from media experts. The revised AIra application was then tested on students. The developed AIra application consists of several parts. The first part is the cover or initial display of AIra, which briefly explains mathematical numeracy, as seen in Figure 4.



Figure 4. Initial Display of the AIra Application

The second section of the AIra application is the content section, which consists of the Material List. This list covers four chapters: Numbers, Geometry/Measurement, Algebra, and Statistics or Data & Uncertainty. This section includes learning pages per topic, example pages, and exercises that have been adapted to the junior high school curriculum and are assisted by

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artificial intelligence. The cognitive levels in numeracy have been aligned with the government-established curriculum. This will make it easier for teachers to assess students' mathematical numeracy abilities based on the level of questions in the AIra application. For more details, see Figures 5, 6, 7, and 8.



Figure 5. AIra Application Material List Display

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Figure 6. AIra Application Learning Page Display



Figure 7. AIra Application Material Search Page Display

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Figure 8. AIra Application Material Page Display

The third section is the closing or final section. This section concludes the AIra application, including a dedicated section detailing the researcher's identity. Students who are still unsure about the material in the AIra application can inquire directly through the phone number provided within the application, as shown in Figure 9.

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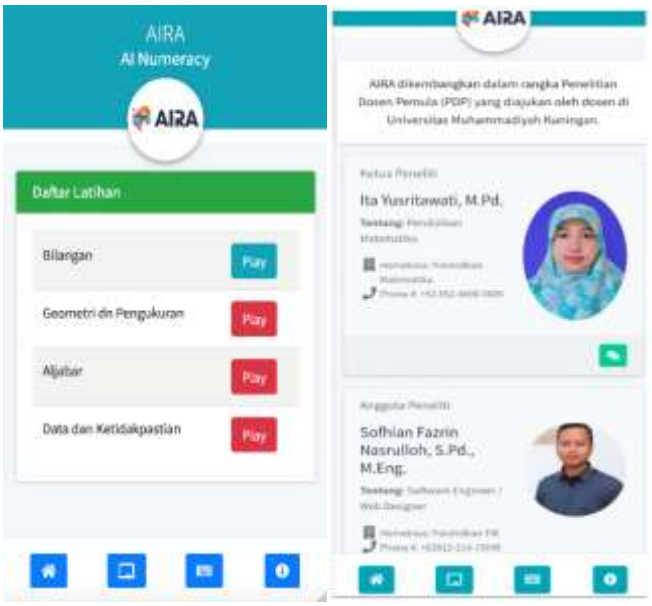


Figure 9. AIra Application Closing View

For more details, the fully developed AIra application can be accessed via the linkhttps://aira.guru/This application can be accessed via smartphone, laptop, or PC anytime and anywhere.*mobile learning (m-learning)*facilitate learning that can be done anywhere*(ubiquitous),*thus enabling students to learn mathematical concepts outside the confines of the traditional classroom (Crompton & Burke, 2018).

Testing and Implementation

After the application is completed during the development phase, system-level testing is conducted, followed by small-scale and large-scale user testing. System-level testing is conducted to verify functionality and ensure the application operates properly. Next, during the small-scale testing phase, a select group of users is asked to use the application and provide feedback, essentially serving as user acceptance testing.*(user acceptability test)*. At the large-scale testing stage, the application was used as a numeracy learning tool in experimental classes.

A limited-scale assessment was conducted on 15 students. Students were instructed to use the AIra application for one week, then provide feedback by filling out a questionnaire. The average score of the student questionnaire was 79.70. The AIra application that had been built was considered practical for use in student learning activities in the classroom. For large-scale testing, researchers implemented the AIra application directly in the classroom. Implementation was carried out in class VIII D as an experimental class, with a total of 30 students. In this class,

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the learning process used the AIra application. This trial phase was carried out for 6 meetings, with topics taught including numbers, algebra, geometry and measurement, and data & uncertainty.

Before being given the treatment using the AIra application, students were first given a pretest to measure their initial numeracy skills. The average pretest score was 43.65. During the implementation phase, from the second to the sixth meeting, the material was delivered directly in the classroom with the help of the AIra application. The teacher explained the material and provided example questions at the cognitive level of understanding, application, and reasoning. Students were then encouraged to study independently at home using the AIra application. They were also given practice tasks to do at home, with questions available in the AIra application.

In the eighth and final meeting, students were given a posttest after six learning sessions. This test was administered to the experimental class and consisted of eight essay questions. The average score on the final exam or posttest was 81.28. Analysis*Paired Samples Test*used to assess the effectiveness of the AIra application in improving students' mathematical numeracy skills. This test was conducted to determine the difference in class averages before and after the intervention using the AIra program. A normality test was conducted before the t-test as a prerequisite. The results of the normality prerequisite test are as follows:

Table 3. Normality Test

Class	Statistics (K-S)	df	Sig. (K-S)	Statistics (S-W)	df	Sig. (S-W)
Pretest	.122	30	.092	.941	30	.074
Posttest	.105	30	.198	.954	30	.206

Based on the table above, the Sig. value for the pretest class is 0.074 > 0.05 and the Sig. value for the posttest is 0.206 > 0.05. Therefore, based on the Shapiro-Wilk test decision-making criteria, it can be concluded that the pretest and posttest data are normally distributed. Since both data sets meet the normality requirements, a Paired Samples Test was conducted. The results of the Paired Samples Test can be seen in Table 4.

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Table 4. Hasil Paired Samples Test

Partner	Rate-rate	Standard Deviation	Std. Error Mean	Lower 95% CI	95% Upper CI	t	df	Sig. (2-tailed)
Pretest – Posttest	-42,235	5,388	.924	-42,105	-41,152	-42,405	29	.000

Mark *Sig. (2-tailed),*As shown in the table above, the value is 0.000, which is less than 0.05. Therefore, based on the paired samples test decision-making criteria, it can be determined that the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted. Thus, it can be concluded that there is a substantial difference between the average student numeracy learning outcomes before and after the intervention. The AIra application has been proven to be beneficial in improving students' mathematical numeracy skills. These results are in line with several previous studies showing that ICT-assisted learning or e-learning has a beneficial impact. Research conducted by Putra & Mukhtar (2022) showed that mathematics learning supported by educational videos has a positive effect on improving the numeracy skills of junior high school students. The development of an ebook module application can significantly improve students' numeracy skills (Cahyadi et al., 2023). E-learning-assisted learning is an effective method for improving students' numeracy skills (Sutarna et al., 2021).

E-learning media serves as an alternative to foster student independence in mathematics learning (Lu'luilmaknun & Wutsqa Urwatul, 2018). E-learning media in education is very effective and efficient in improving learning outcomes (Farman & Chairuddin, 2020). There are quite significant differences in numeracy skills between grade levels when given different treatments (Ameer & Singh, 2013). Valério and Ferrara showed that numeracy universally develops from concrete number concepts to abstract number concepts (Valério & Ferrara, 2022). The AIra application aims to assist educators in improving students' mathematical numeracy skills in educational settings.

Deployment(implementation). If the test results indicate that the application is complete and declared valid, practical, and effective, the final stage is publication to all teachers and students in need at the junior high school level. Researchers hope for constructive suggestions and input from readers to improve the development of the AIra application. These excellent

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effectiveness test results can be caused by several factors. The effectiveness of AIra media is in line with other previous studies that show the positive impact of technology or e-learning on mathematics learning. Technology-assisted learning, such as AIra, has been shown to have higher flexibility and accessibility, allowing students to develop independent learning anytime and anywhere.

This finding is also supported by other studies which show that media*e-learning*can be an effective alternative for improving numeracy competency. More than just a digital medium, AIra's strength lies in the integration of artificial intelligence with a deep learning approach. This approach allows the application to adapt to students' learning needs, a concept known as personalized or differentiated learning (*personalized/differentiated learning*). Rather than simply presenting static material, AIra is able to provide learning content tailored to student achievement, offering example problems and exercises that gradually challenge students' understanding, application, and reasoning. This capability directly addresses a national challenge faced by students, namely difficulty understanding non-routine or story-based numeracy problems. The questions generated by AIra's artificial intelligence are designed to help students become accustomed to unusual problem formats, an approach not available in conventional textbooks.

DISCUSSION

The significant increase in posttest scores demonstrates the effectiveness of the AIra app as a numeracy learning tool. This effectiveness is likely due to the speed of feedback provided by AI, which is a crucial factor in improving learning outcomes according to a meta-analysis of feedback interventions (Wisniewski et al., 2020). Furthermore, expert validation ensured the app's content was relevant. Expert validation remains a crucial element in the development of serious games and educational apps to ensure digital content remains pedagogically appropriate and mathematically accurate (Zhai et al., 2021). The positive results found in this study reinforce recent findings that intelligent tutoring systems can significantly outperform traditional learning in improving mathematical abilities (Kulik & Fletcher, 2016).

The results of this study align with previous research demonstrating the positive impact of ICT-based learning media. Research conducted by Putra & Mukhtar (2022) and Cahyadi et al. (2023) showed that technology-based mathematics learning, utilizing videos and ebook modules, can significantly improve students' numeracy competencies. This study reinforces this notion by demonstrating that more advanced technologies, such as AI, can provide equivalent or even

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superior benefits. Meanwhile, practicality testing ensured that the application was easy to access and use by students, thus encouraging engagement and motivation to learn. Digital learning tools that integrate interactive elements have been shown to significantly improve behavioral and cognitive engagement in secondary school students (Bond et al., 2020).

A crucial aspect that distinguishes AIra from conventional digital media is the integration of artificial intelligence. This study shows that AIra is designed to facilitate use with a thinking and reasoning framework designed based on human commands. The AI feature in this application allows teachers to more easily assess students' mathematical numeracy skills based on the level of the problem. This shows that the role of AI here is not to replace teachers, but rather to serve as a diagnostic tool and guide that personalizes the learning process. With this feature, the application can manage numeracy practice problems independently, allowing teachers to focus more on more complex pedagogical tasks, such as explaining the material directly and providing example problems at the cognitive levels of understanding, application, and reasoning. While ebooks and videos are passive, AI-based applications offer adaptive scaffolding, which dynamically adjusts the difficulty level of tasks to keep students within their zone of proximal development (Peng et al., 2019).

The findings regarding the improvement of students' numeracy skills through the use of AI-assisted learning media are in line with previous research findings that suggest that integrating AI technology into mathematics learning can improve conceptual understanding, student engagement, and problem-solving skills (OECD, 2019; Holmes et al., 2019). Furthermore, the effectiveness of the adaptive learning approach supported by deep learning is also consistent with research showing that deep learning-based systems can personalize learning to suit individual needs and positively impact student learning outcomes (Zawacki-Richter et al., 2019; Chen et al., 2020).

The AI features in this app also support the concept of Precision Education, where AI analytics are used to identify at-risk students and provide targeted interventions tailored to their specific learning profiles (Yang et al., 2021). This view aligns with modern perspectives on the role of AI in education, which view it as a catalyst for change, not a threat. Rather than eroding students' thinking skills, AI can be a tool that encourages critical reflection. For example, students using AI for assignments can be asked to critique the AI's output by comparing it to primary sources, which in turn hones their critical reading skills. In the context of AIra, the app helps students practice numeracy independently, and teachers can then use the data from the app to identify areas of student difficulty and provide more targeted interventions. This represents a shift

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from product-based assessment to process-based evaluation, a significant shift in education. Furthermore, interacting with an AI tutor can provide a non-judgmental learning environment, reducing math anxiety, which is often a barrier to traditional face-to-face remedial sessions (Kim et al., 2022). This type of AI-based self-paced practice fosters self-regulated learning (SRL) strategies, which empower students to control their own learning pace and progress (Chiu, 2021). Accessibility and ease of use are important determinants of technology acceptance, directly influencing students' intrinsic motivation and self-regulated learning behavior (Chiu et al., 2023).

However, several challenges were encountered during the research, particularly because most students were unfamiliar with AI-based learning activities. This limitation underscores the need to develop teachers' Technological Pedagogical Content Knowledge (TPACK) to effectively integrate AI tools into their teaching practices (Chai et al., 2021). AIra, as a Learning Environment System (LENS) that integrates all student needs into a single platform, demonstrates how technological innovation can be a key pillar in creating a more interactive, adaptive, and responsive learning environment. This shift toward intelligent learning environments reflects a broader trend in EdTech toward creating ecosystems that support seamless learning between physical and digital spaces (Kukulska-Hulme, 2021). Furthermore, the integration of deep learning approaches allows the application to adapt to students' learning needs. In the context of educational algorithms, deep learning models have been shown to have superior accuracy in predicting student performance and recommending appropriate learning paths compared to traditional statistical methods (Luan & Tsai, 2021). This research is part of a broader and ongoing roadmap.

The next phase of research includes the development of AI-integrated learning content to create a Learning Environment System (LENS) by 2025. Future plans also include integration with Augmented Reality (AR) technology and learning models such as Problem-Based Learning integrated with Sociomathematical Norms in the 2026–2028 period. These steps demonstrate a commitment to continuously improving the application and expanding the scope of research to address evolving educational challenges. Furthermore, scalable AI solutions like AIra can help bridge the educational equity gap by providing high-quality tutoring resources to students in under-resourced areas (Pedro et al., 2019).

These findings are relevant not only to educators but also to policymakers seeking to leverage AI for innovative and inclusive educational transformation. This research contributes to the field of mathematics education in Indonesia by providing strong empirical evidence regarding the effectiveness of AI-based learning media with a deep learning approach in a local context. While

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there is a wealth of research on the effectiveness of technology, few explicitly address how cutting-edge technologies like AI can impact students' cognitive and affective outcomes. These findings are relevant not only to educators but also to policymakers and researchers seeking to leverage AI for innovative and inclusive educational transformation.

CONCLUSION

Based on the entire series of research stages and data analysis that have been carried out, it can be concluded that the learning media*Artificial Intelligence Numeracy*The developed AIra application has met the criteria for validity, practicality, and effectiveness. In terms of materials and media, the application prototype was deemed feasible and valid by experts. From a user perspective, the application has proven practical for use in the learning process. Most importantly, through testing,*Paired Samples Test*, statistically proven that the use of AIra can significantly improve students' mathematical numeracy skills. The increase in the average score from 43.65 (pretest) to 81.28 (posttest) indicates that AIra is a highly effective solution to address students' numeracy problems in Indonesia. Thus, AIra learning media is a relevant innovation and can be a valuable tool for teachers and students in improving numeracy competency in the digital era.

Based on the findings of this study, several recommendations can be put forward. For teachers, it is recommended to integrate the AIra application as a supplement to mathematics learning, particularly for practicing non-routine numeracy problems, along with strengthening competencies.*Technological Pedagogical Content Knowledge*(TPACK) to ensure optimal use of AI technology in the classroom. For schools and policymakers, the results of this study can serve as a basis for consideration in expanding the implementation of artificial intelligence-based learning media to support equitable access to quality education, particularly in areas with limited resources. For future researchers, it is recommended to develop AIra into a*Learning Environment System*(LENS) more comprehensively, as well as exploring integration with Augmented Reality (AR) technology and learning models*Problem-Based Learning*combined with*Sociomathematical Norms,*as planned in the next research roadmap.

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