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Implementation of an Artificial Intelligence-Based Adaptive Learning System in Improving the Competence of Islamic Religious Education Teachers in Labuhanbatu

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ABSTRACT

This research is motivated by the increasing role of artificial intelligence (AI) in transforming the world of education, which brings challenges as well as opportunities for educators to improve the quality of learning. This research aims to: (1) determine the improvement of the competence of Islamic Religious Education Teachers (PAI) in Labuhanbatu through the application of an AI-based adaptive learning system, (2) evaluate the effectiveness of the system in improving the competence of PAI teachers, and (3) identify obstacles, challenges and solutions in its implementation. This research method was carried out using a mixed-method technique using a Sequential Exploratory design, which combines qualitative data collection through interviews, observations, documentation, and Focus Group Discussions (FGD), with quantitative data through pre-test and post-test, satisfaction surveys, and statistical analysis. The study involved 50 PAI teachers at the junior high school level in Labuhanbatu with a saturated sample technique. The results showed that AI-based adaptive learning had a significant positive influence on teachers' pedagogic competence, with a correlation coefficient of 0.794 and an effectiveness level of 69% ($R^2 = 0.69$, $p < 0.05$). The integration of AI technology through structured workshops has been proven to strengthen the capacity of PAI teachers in designing innovative and responsive learning strategies. However, its implementation still faces obstacles in the form of limited technological infrastructure, unstable internet access, and low digital literacy, which can be overcome through infrastructure strengthening, tiered training, and the formation of technology-based teacher learning communities. The conclusion of this study is that AI-based adaptive learning has a positive impact on the pedagogic competence of PAI teachers in Labuhanbatu, in addition to that this learning is effective in PAI learning in Labuhanbatu, but the obstacle in this learning is the limitation of technological infrastructure in the region.

ABSTRAK

Penelitian ini dilatarbelakangi oleh semakin besarnya peran kecerdasan buatan (Artificial Intelligence/AI) dalam

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mentransformasi dunia pendidikan, yang membawa tantangan sekaligus peluang bagi para pendidik untuk meningkatkan kualitas pembelajaran. Penelitian ini bertujuan untuk : (1) mengetahui peningkatan kompetensi Guru Pendidikan Agama Islam (PAI) di Labuhanbatu melalui penerapan sistem pembelajaran adaptif berbasis AI, (2) mengevaluasi efektivitas sistem tersebut dalam meningkatkan kompetensi guru PAI, dan (3) mengidentifiikasi hambatan, tantangan dan solusi dalam penerapannya. Metode penelitian ini dilakukan dengan teknik mix-methode yang menggunakan desain Sequential Exploratory, yang menggabungkan pengumpulan data kualitatif melalui wawancara, observasi, dokumentasi, dan Focus Group Discussion (FGD), dengan data kuantitatif melalui pre-test dan post-test, survei kepuasan, dan analisis statistik. Penelitian melibatkan 50 guru PAI tingkat SMP di Labuhanbatu dengan teknik sampel jenuh. Hasil penelitian menunjukkan bahwa pembelajaran adaptif berbasis AI memberikan pengaruh positif signifikan terhadap kompetensi pedagogik guru, dengan koefisien korelasi sebesar 0,794 dan tingkat efektivitas sebesar 69% ($R^2 = 0,69$, $p < 0,05$). Integrasi teknologi AI melalui workshop terstruktur terbukti memperkuat kapasitas guru PAI dalam merancang strategi pembelajaran yang inovatif dan responsif. Namun demikian, implementasinya masih menghadapi hambatan berupa keterbatasan infrastruktur teknologi, akses internet yang tidak stabil, dan rendahnya literasi digital, yang dapat diatasi melalui penguatan infrastruktur, pelatihan berjenjang, dan pembentukan komunitas belajar guru berbasis teknologi. Adapun kesimpulan dari penelitian ini adalah pembelajaran adaptif berbasis AI memberikan dampak positif terhadap kompetensi pedagogik guru PAI di Labuhanbatu, selain itu pembelajaran ini efektif dalam pembelajaran PAI di Labuhanbatu, namun menjadi hambatan dalam pembelajaran ini adalah keterbatasan infrastruktur teknologi di wilayah tersebut.

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A. Introduction

Artificial intelligence (AI) has now become one of the main forces reshaping educational practice in many parts of the world, and research on AI-based adaptive learning continues to grow sharply as a mainstream of global educational transformation (Vasileva, 2024). Adaptive learning systems use learner data to dynamically adjust content, pace, and learning pathways, so that the one-size-fits-all approach is gradually being replaced by personalized learning experiences (Akintola et al., 2024). These benefits can only be realized when teachers, as managers of learning, have the competence to interpret data-driven feedback and integrate it meaningfully into their teaching practice (Gligorea

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et al., 2023) (Tammets & Ley, 2023). This demand is highly relevant for Islamic Religious Education (PAI) teachers, who need to master pedagogical, professional, and digital competencies at the same time (Arif et al., 2025), especially in rural areas such as Labuhanbatu Regency, which still faces limited infrastructure and a digital divide (Mustafa et al., 2024). On this basis, this study examines the implementation of an AI-based adaptive learning system in improving the competence of PAI teachers in Labuhanbatu by investigating competence improvement, system effectiveness, and the obstacles to and solutions for its implementation.

In the Indonesian context, the integration of AI technology is becoming increasingly crucial given the challenges of equitable education quality and the competence gap between teachers in urban and rural areas. For Islamic Religious Education (PAI) teachers in particular, mastery of pedagogical and professional competencies together with digital competence has become a necessity in the Society 5.0 era. AI-based adaptive learning systems collect and analyze learner data to dynamically adjust instructional content and learning pathways, thereby offering personalized learning experiences and ultimately improving learning outcomes (Akintola et al., 2024). This technology also enables real-time monitoring of learning pace while identifying users' strengths and weaknesses, producing feedback that helps educators adjust their teaching methods and approaches (Gligorea et al., 2023).

Various studies have explored teachers' engagement in using AI technology for professional development. Rather than viewing teachers' adoption of AI solely from a technological standpoint, a number of researchers have taken the teachers' perspective and examined how these tools are meaningfully integrated into teaching practice (Tammets & Ley, 2023). A strong professional vision has proven to be an important prerequisite for adaptive teaching, because teachers need to accurately interpret their students' learning needs and behaviors before they can make optimal use of data-driven insights (Tammets & Ley, 2023). Another study confirms that AI platforms based on adaptive training are able to learn teachers' instructional patterns, pedagogy, and performance metrics in order to design personalized professional development programs (Shezad et al., 2025).

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Studies on improving the digital competence of PAI teachers in Indonesia have also developed rapidly. A systematic review of seventy-five articles concluded that PAI teachers need to maximize the development of their professional and pedagogical competencies while also improving their digital competence, a need that is universal and not unique to Indonesia (Arif et al., 2025). A case study of Islamic education teachers in primary schools likewise found that limited mastery of technology remains a major obstacle to implementing digital teaching strategies, so comprehensive and continuous professional training is urgently needed (Azman & Hamzah, 2025).

Although various studies have examined AI in education and teacher competence development separately, there is a significant gap concerning the implementation of AI-based adaptive learning systems specifically designed for PAI teachers, particularly in rural areas. High-speed internet access is essential for using AI tools effectively, yet many rural areas still face inadequate connectivity (Kim & Wargo, 2025). This digital divide between urban and rural schools challenges efforts to integrate technology into education and contributes to the growing educational inequality in many contexts (Mustafa et al., 2024), including aspects of infrastructure, socioeconomic status, and geographical location that shape how the digital divide is experienced by teachers and students (Ahiaku et al., 2025).

This study seeks to fill this gap by developing and implementing an AI-based adaptive learning system specifically designed to improve the pedagogical and professional competencies of PAI teachers in Labuhanbatu Regency. The novelty of this study lies in three aspects: first, the development of an adaptive learning model that integrates Islamic content with AI technology; second, the application of a mixed-methods approach with a Sequential Exploratory Design that combines a quasi-experiment with an in-depth exploration of teachers' experiences; and third, the contextualization of the research in a rural area with limited infrastructure, thereby providing insights into AI implementation strategies under suboptimal conditions that can be replicated in other regions facing similar challenges.

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Based on the above description, this study aims to: (1) determine the improvement in the competence of Islamic Religious Education teachers in Labuhanbatu through the implementation of an AI-based adaptive learning system; (2) evaluate the effectiveness of the AI-based adaptive learning system in improving the competence of Islamic Religious Education teachers in Labuhanbatu; and (3) identify the obstacles, challenges, and possible solutions in implementing the AI-based adaptive learning system to improve the competence of Islamic Religious Education teachers in Labuhanbatu.

B. Methods

This study used a *Mixed Method* technique with a *Sequential Exploratory Design* approach. In *mixed-methods* research, the researcher collects data, analyzes data, and integrates both qualitative and quantitative findings to answer research questions comprehensively (Hadju et al., 2022). Qualitative data were collected through interviews, observation, documentation, and *Focus Group Discussions* (FGD), while quantitative data were collected through pre-tests and post-tests of teacher competence, a system-use satisfaction survey, and statistical analysis of improvement and system effectiveness.

The variables of this study consist of the independent variable, namely the AI-based adaptive learning system (X), and the dependent variable, namely PAI teacher competence (Y), particularly pedagogical and professional competence. The research design used was a Quasi-Experimental Design in the form of a Nonequivalent Control Group Design. The research population comprised all 50 junior high school (SMP) PAI teachers in Labuhanbatu, using a saturated sampling technique, that is, all members of the population were used as the research sample (Sugiyono, 2013). The collected data were then analyzed using simple linear regression analysis with SPSS version 27, through classical assumption tests (normality, multicollinearity, and heteroscedasticity) and hypothesis tests (t-test, F-test, and the coefficient of determination R^2).

The quantitative data were collected using a questionnaire consisting of two instruments. The first instrument measured AI-based adaptive learning (Variable X) through 15 items. These items assessed the extent to which teachers use AI platforms to adjust

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learning materials to students' abilities, identify the different learning styles of each student, provide *real-time feedback*, and automatically analyze students' learning progress. The items also covered the use of AI to create variations of questions and exercises tailored to students' levels, conduct formative *assessment*, use AI *analytics* data to modify teaching strategies, provide personalized learning, and support students outside class hours through AI *chatbots*. In addition, the instrument examined whether AI systems help teachers map each student's learning difficulties, optimize learning time based on students' needs, manage digital PAI content, generate detailed student progress reports, and differentiate instruction, as well as how consistently teachers use AI *tools* in the PAI learning process.

The second instrument measured PAI teacher competence (Variable Y), also through 15 items. These items assessed teachers' ability to design PAI lesson plans (RPP) that integrate digital technology, use a variety of innovative learning methods, manage the classroom using a technological approach, and evaluate students' learning outcomes using digital *tools*. The instrument also measured teachers' ability to use multimedia to explain PAI concepts, adapt PAI materials to students' characteristics, integrate Islamic values with modern technology, communicate effectively with students through digital platforms, and collaborate with fellow teachers in using learning technology. Furthermore, it examined teachers' positive attitude toward innovation in PAI learning, their continuous self-development in educational technology, their ability to solve technical problems when using AI platforms and to guide students in using learning technology, their understanding and application of the ethics of AI use in Islamic education, and their ability to measure the effectiveness of AI use in improving PAI learning outcomes.

C. Results and Discussion

Labuhanbatu Regency is one of the regions on the East Coast of North Sumatra, with 9 districts, 33 junior high schools (SMP), and 50 PAI teachers. The geographical characteristics of Labuhanbatu, with schools spread over a fairly wide area and varying levels of access to technology, make the implementation of an AI-based adaptive learning

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system highly relevant as a solution for the equitable distribution of PAI teacher competence in the region.

1. Implementation of AI-Based Adaptive Learning on the Pedagogical Competence of PAI Teachers

Based on in-depth interviews with 10 PAI teachers in Labuhanbatu Regency, all informants stated that they experienced an improvement in pedagogical competence after attending the workshop. Given the curriculum requirement to become familiar with technology and AI, the PAI teachers were pleased because the workshop on AI broadened their insight. This was also examined through statistical data collection, particularly in the form of a questionnaire. The following are the PAI teachers' responses regarding AI-based adaptive learning:

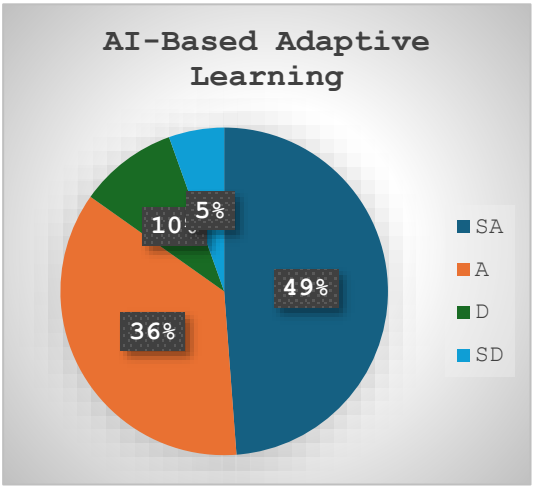


Figure 1. PAI Teachers' Responses to AI-Based Adaptive Learning

The data above show that the teachers responded positively to AI-based adaptive learning. The responses indicate that PAI teachers benefited from the AI-based adaptive learning workshop, particularly the introduction to AI tools (*ChatGPT*, *Gamma AI*, *MagicSchool*, *Canva* and *Gimkit*). This result confirms that the integration of AI technology through structured training can increase PAI teachers' capacity to develop learning strategies that are more innovative and responsive to students' needs, as was also found in a

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conceptual model of AI integration in teacher professional learning (Tammets & Ley, 2023).

2. Effectiveness and Influence of AI-Based Adaptive Learning on PAI Teacher Competence

The interviews indicated that PAI teachers experienced a positive influence after implementing AI-based adaptive learning. The effectiveness and influence of AI-based adaptive learning on PAI teacher competence were measured by calculating the data according to the indicators of teacher competence, particularly the pedagogical competence of PAI teachers, namely: a good understanding of students' characteristics, how to design and implement effective learning, and how to evaluate learning outcomes and develop students' potential. The results of the calculation are as follows:

Table 1. Correlation Results

Correlations			
		X	Y
X	Pearson Correlation	1	.832**
	Sig. (2-tailed)		.000
	N	50	50
Y	Pearson Correlation	.832**	1
	Sig. (2-tailed)	.000	
	N	50	50
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 1 shows a correlation coefficient of 0.832 with a significance of 0.000 ($p < 0.05$), indicating a strong and significant relationship between AI-based adaptive learning (X) and the pedagogical competence of PAI teachers (Y). Meanwhile, the linear regression test produced the equation $Y = 9.101 + 0.794X$, with a t-count of 10.377 (t-table = 1.667) and a significance of 0.000, so the alternative hypothesis (Ha), which states that AI-based adaptive learning has a positive effect on the pedagogical competence of PAI teachers in Labuhanbatu, is accepted. These results are presented in the following table:

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Table 2. T-Test Results

Unstandardized Coefficients		Standardized Coefficients	t	Sig.
B	Std. Error	Beta		
9.101	3.845		2.367	.022
.794	.077	.832	10.377	.000

The results are further shown in Table 3 below:

Table 3. ANOVA Test Results

Model	Sum of Squares	df	Mean Square	F	Sig.
Regr	3141.55	1	3141.55	107.675	.000[b]
Resid	1400.453	48	29.176		
Total	4542.000	49			

The table above shows an F_{count} value of 107.675 with an F_{table} value of 3.19 and Sig. 0.000, confirming that the regression model is simultaneously significant. The coefficient of determination (R^2) of 0.692 indicates that the AI-based adaptive learning variable explains 69% of the variation in the pedagogical competence of PAI teachers in Labuhanbatu, while the remaining 31% is explained by other variables outside this research model.

Table 4. Kolmogorov-Smirnov Normality Test Results

One-Sample Kolmogorov-Smirnov Test			
			Unstandardized Residual
N			50
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		5.34608956
Most Extreme Differences	Absolute		.111
	Positive		.065
	Negative		-.111
Test Statistic			.111
Asymp. Sig. (2-tailed)[c]			.166
Monte Carlo Sig. (2-tailed)[d]	Sig.		.121
	99% Confidence Interval	Lower Bound	.112
		Upper Bound	.129
a. Test distribution is Normal.			
b. Calculated from data.			
c. Lilliefors Significance Correction.			
d. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 957002199.			

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Table 5. Multicollinearity Test Results

Coefficients[a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	X	1.000	1.000
a. Dependent Variable: Y			

Tables 4 and 5 show that the classical assumption tests indicate the data are normally distributed (Asymp. Sig = 0.166 > 0.05), there is no multicollinearity (VIF = 1.000 < 10; tolerance = 1.000 > 0.1), and there is no heteroscedasticity based on the pattern of points in the scatterplot.

This finding reinforces the results of a meta-analytic review showing that AI-based adaptive learning systems consistently increase user engagement and learning achievement across educational contexts (Wu et al., 2024), and is also consistent with the finding that AI-based personalization can improve teachers' understanding of their specific learning needs (Gligorea et al., 2023).

Based on the calculation, AI-based adaptive learning was found to have an effectiveness of 69% on the pedagogical competence of PAI teachers. This is in line with the findings of a study on the relationship between digital professional development and instructional integration among STEM teachers (Liu et al., 2024), which showed that active involvement in technology-based learning communities also strengthens the impact of AI-based professional development.

3. Obstacles, Challenges, and Solutions in Implementing the AI-Based Adaptive Learning System

As noted above, this study found a positive impact on the pedagogical competence of PAI teachers and effectiveness in learning; however, the main obstacle faced by PAI teachers is the limited technological infrastructure in Labuhanbatu. Many schools still have difficulty accessing stable and adequate internet, while the availability of computers and laptops is also limited. This condition is in line with the finding that limited access to

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high-speed internet can hinder the use of cloud-based AI platforms in rural areas (Kim & Wargo, 2025), and it reinforces the conclusion of a systematic review that the digital divide between urban and rural schools continues to challenge efforts to integrate technology into education (Mustafa et al., 2024).

Another challenge faced by PAI teachers in Labuhanbatu is low technological literacy and minimal experience in operating AI-based platforms, which makes it difficult for them to fully understand the concept of adaptive learning. This condition is consistent with the finding that teachers' digital literacy and ethical readiness affect the effectiveness of AI implementation in professional training (Shezad et al., 2025), and it underscores the importance of developing PAI teachers' digital competence simultaneously with their pedagogical and professional competencies (Arif et al., 2025).

Possible solutions include strengthening technological infrastructure through partnerships with local government and the private sector, tiered and continuous training and mentoring for teachers, and the establishment of technology-based PAI teacher learning communities as forums for sharing experiences and solutions. This strategy is in line with the finding that professional learning communities significantly mediate the relationship between digital professional development and technology integration in learning (Liu et al., 2024), as well as the recommendation that collaborative, multi-stakeholder efforts are needed to develop affordable solutions that make adaptive learning equitably accessible (Ahiaku et al., 2025).

D. Conclusion

Based on the results and discussion, it can be concluded that the implementation of AI-based adaptive learning has a positive and significant impact on the pedagogical competence of PAI teachers in Labuhanbatu, with a correlation coefficient of 0.832 and an effectiveness level of 69% ($R^2 = 0.692$). This finding indicates that the integration of AI technology through structured training can increase PAI teachers' capacity to develop learning strategies that are more innovative and responsive to students' needs. Neverthe-

less, its implementation still faces obstacles in the form of limited technological infrastructure and low teacher digital literacy, which can be addressed by strengthening technological infrastructure, providing tiered training, and establishing technology-based teacher learning communities. This study recommends that Islamic education stakeholders in regions with similar rural characteristics adopt the AI-based adaptive learning model gradually, prioritizing infrastructure strengthening and continuous mentoring for teachers.

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