Integrating Principal Leadership and Teacher Roles with AI-Based 'Merdeka' Curriculum Innovation: The Quantitative Research

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***Abstract*— The integration of artificial intelligence (AI) into educational frameworks has encouraged innovative approaches to curriculum development, particularly in vocational high schools in Indonesia. This research investigates the integration between principals' leadership styles, teachers' roles, and the implementation of AI-driven 'Merdeka' curriculum innovations in this context. Using a correlational method with a quantitative approach, data were collected from vocational high schools in Padang using a proportional random sampling technique. As a research instrument was a questionnaire that underwent content and construct validity assessments and was tested for reliability using Cronbach's alpha. Data analysis used Pearson product moment correlation and multiple correlation. By analyzing the dynamics in a vocational high school, the study aims to provide valuable insights into the effective integration of AI technologies in education, offering theoretical contributions to the educational leadership discourse and practical guidance for stakeholders in navigating the complexities of curriculum innovation in Indonesia's vocational education sector.**

***Keywords*— Teacher's role, principal leadership, 'Merdeka' curriculum innovation, AI, quantitative research.**

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1. Introduction

The integration of artificial intelligence (AI) into educational systems has ushered in a new era of innovation [1], challenging traditional paradigms of curriculum development and instructional delivery. Within the dynamic landscape of vocational education in Indonesia, where the demand for industry-relevant skills is pressing, the convergence of AI-driven curriculum innovation and effective school leadership holds significant implications [2]. This study explores the intricate interplay between principal leadership styles, teacher roles, and the implementation of AI-based 'Merdeka' curriculum initiatives within vocational high schools across Indonesia.

The unique context of vocational education presents specific challenges and opportunities for curriculum innovation. Vocational high schools in Indonesia face demands for curricula that are responsive to industry needs, incorporate hands-on learning experiences, and foster entrepreneurial skills among students.

Understanding the socio-cultural, economic, and institutional factors shaping vocational education in Indonesia is essential for designing AI-based curriculum innovations that are contextually relevant and sustainable [3].

Vocational high schools serve as vital conduits for preparing students with the practical skills and knowledge necessary to thrive in diverse career pathways. In recent years, the rapid advancement of AI technologies has presented opportunities to enhance curriculum offerings, fostering a learning environment that aligns closely with the demands of the modern workforce [4]. However, the successful integration of AI-based curriculum innovations hinges not only on technological proficiency but also on the strategic leadership and collaboration among school administrators and teachers.

Previous research [5], seeks to explore the various dimensions of integrating principal leadership and teacher roles with AI-based curriculum Innovation. By conducting a comprehensive case study analysis, this research seeks to uncover the strategies, challenges, and outcomes associated with the adoption and implementation of AI-based 'independent' curriculum initiatives in vocational high schools in Indonesia. Through this nuanced exploration of dynamics, this study aims to contribute theoretical insights and practical recommendations to the discourse of educational leadership and curriculum development in the context of AI-based education.

In line with research [6], which offers valuable insights into the complexity and dynamics of educational change processes. By examining real-world contexts, similar research [7], provides rich descriptive data explaining the interactions between stakeholders, organizational structures and external factors that influence curriculum innovation efforts. The research case study conducted in a vocational high school in Indonesia can provide specific examples of how principals' leadership and teachers' roles align with AI-based curriculum innovation, highlighting successes, challenges, and lessons learned.

The significance of this study lies in its potential to inform educational stakeholders, including principals, teachers, policymakers, and curriculum developers, about the effective strategies for integrating AI technologies into vocational education settings. By elucidating the roles of school leaders and educators in navigating the complexities of AI-based curriculum innovation, this research aims to foster a deeper understanding of the transformative potential of AI in enhancing vocational education outcomes and preparing students for success in the evolving landscape of the 21st-century workforce.

2. Methodology

This study utilized a correlational research design within a quantitative framework, where specific theories are examined by analyzing the relationships between different variables [8]. The variables are explored without any intervention or manipulation by the researcher.

This methodological approach aims to determine the degree of association between principal leadership and teacher roles in the context of AI-based 'Merdeka' curriculum innovation in vocational high schools.

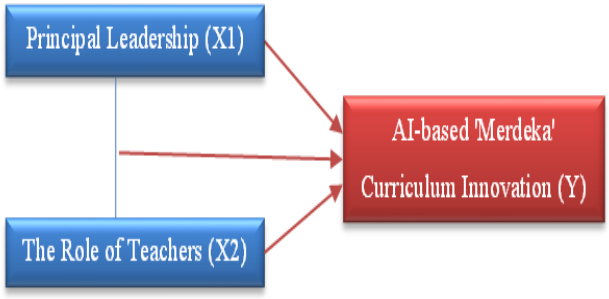

Figure 1. Quantitative research design with a correlational approach

2.1. Participants

The research population was selected based on specific characteristics that align with the study's objectives. In this study, the population comprises 364 vocational high school teachers from 42 vocational high schools in Padang. Due to the size of this population, the researcher opted to select a sample to serve as the primary data source for the investigation.

The population is further divided into a research sample. The sample was selected using a proportional random sampling technique to provide equal chances of inclusion for all members of the population [9]. To determine the sample size (n) with a 5% margin of error, the following general formula is typically employed in proportional random sampling:

$$s = \frac{\lambda^2 . N . P . Q}{d^2 (N-1) + \lambda^2 . P . Q}$$

$$s = \frac{3{,}841 . 364 . 0{,}5 . 0{,}5}{0{,}05^2 (364-1) + 3{,}841 . 0{,}5 . 0{,}5}$$

$$s = \frac{349{,}53}{1{,}86}$$

$$s = 187{,}91$$

$$s = 188$$

Using the formula, a sample size of 188 teachers was determined for the study.

After establishing the total sample size, the distribution of samples for each school was calculated proportionally based on the number of teachers in each school.

3. Research Results

The study included 188 respondents who were teachers at Vocational High Schools in Padang. Data collection was conducted from February 3 to May 5, 2024, through the distribution of questionnaires to the respondents. The respondents were categorized based on their characteristics, specifically by gender and length of service.

These characteristics were gathered through the questionnaires. The collected data is presented in Table 1 below.

Table 1. Demographic profile of research participants

Gender	**Freq.**	**Percent. (%)**
Female	84	44.86 %
Male	104	55.31 %
Total	188	100 %
Working	**Freq.**	**Percent. (%)**
≥5 years	63	43 %
3-5 years	60	32 %
≤3 years	65	25 %
Grand total	188	100 %

As shown in Table 1, most respondents were female teachers, totaling 104 individuals or approximately 55.31%, while male teachers constituted 84 respondents or 44.68%. Regarding tenure, the largest group of respondents had more than 5 years of service, comprising 43 individuals, followed by those with 3-5 years of service, numbering 32 individuals, and those with less than 3 years of service, totaling 25 individuals.

This study examines three research variables, focusing on principal leadership and teachers' roles in relation to AI-Based 'Merdeka' curriculum innovation. The analysis of respondents' responses to each variable, based on the study's findings, is as follows:

Principal Leadership (x1) - data on principal leadership were gathered using a questionnaire containing 40 statements. The questionnaire utilized a Likert scale with five response options, each scored on a scale from 1 to 5. A statistical summary of the principal leadership data, analyzed using SPSS-25 software, is provided below.

Table 2. Descriptive analysis of principal leadership

Statistical analysis	
N (sample quantity)	188
mean	132.16
standard deviation	6.59
variance	32.25
range	24
minimum	123
maximum	146

Additionally, the scores obtained from the principal leadership questionnaire are organized into a frequency distribution chart, as shown in Figure 2.

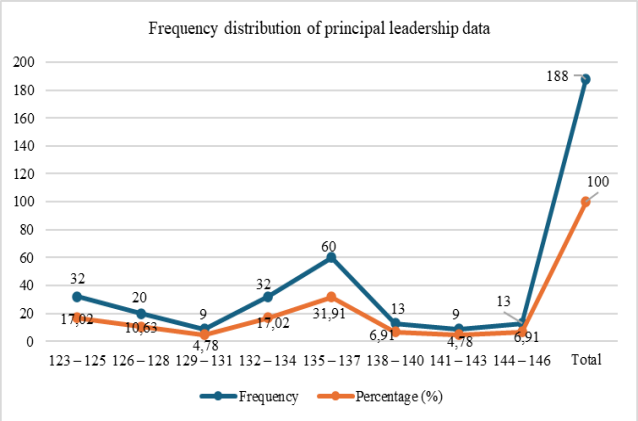

Figure 2. Frequency distribution of principal leadership data

Upon obtaining the frequency distribution table, the next step is to construct a score tendency table for the principal leadership variable. This table will help identify score ranges and the number of respondents categorized as less, adequate, or good. The categorization is based on calculations of the mean and standard deviation. The results of the score tendency analysis for the principal leadership variable are then presented in Table 3 as follows:

Table 3. Categorization of principal leadership data trends

Criteria	**Freq.**	**Percent. (%)**	**Descript.**
x<123.76	34	18.08 %	Less
123.76<x<140.54	135	71.80 %	Adequate
x>140.54	19	10.10 %	Good

According to Table 3, most principal leadership scores fall into the adequate category (71.80%), with 10.10% categorized as good and 18.08% as less effective.

Teacher's Role (x2) - Data on teachers' roles were gathered using a questionnaire with 45 statement items. This questionnaire employed a Likert scale with five response options, each assigned a numerical value ranging from 1 to 5. The statistical summary of the teacher role data, analyzed with SPSS-25 software, is presented below.

Table 4. Descriptive analysis of teacher role data

Statistical analysis	
N (sample quantity)	188
mean	125.35
standard deviation	7.10
variance	38.27
range	28
minimum	116
maximum	143

Moreover, the scores from the teacher role questionnaire have been compiled into a detailed frequency distribution table, as illustrated in Figure 3 below.

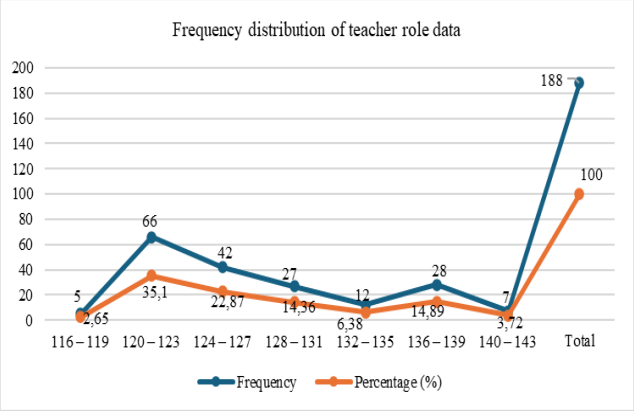

Figure 3. Frequency distribution of teacher role data

Following the creation of the frequency distribution table, the next step is to develop a score tendency table for the teacher role variable. This table is designed to identify score ranges and categorize respondents into good, sufficient, and less effective groups, based on calculations of the mean and standard deviation. The results of the score tendency analysis for the teacher role variable are presented in Table 5 as follows:

Table 5. Categorization of teacher role data trends

Criteria	Freq.	Percent. (%)	Descript.
x<117.20	16	8.51	Less
117.20<x<133.97	140	74.46	Adequate
x>133.97	32	17.02	Good

According to the data in Table 5, most teacher role scores fall into the adequate category (74.46%). Additionally, 17.02% are classified as good, while only 8.51% are categorized as less effective.

AI-Based 'Merdeka' Curriculum Innovation (y) - Data on the 'Merdeka' curriculum innovation was collected using a questionnaire with 45 statement items. This questionnaire employed a Likert scale with five response options, each assigned a numerical value ranging from 1 to 5. The statistical summary of the AI-based 'Merdeka' curriculum innovation data, analyzed using SPSS-25 software, is presented in Table 6.

Table 6. Descriptive analysis of AI-based 'Merdeka' curriculum innovation

Statistical analysis	
N (sample quantity)	188
mean	102.07
standard deviation	4.026
variance	16.221
range	18
minimum	95
maximum	115

Furthermore, the scores from the demographic questionnaire have been compiled into a detailed frequency distribution table, as shown in Figure 4 below.

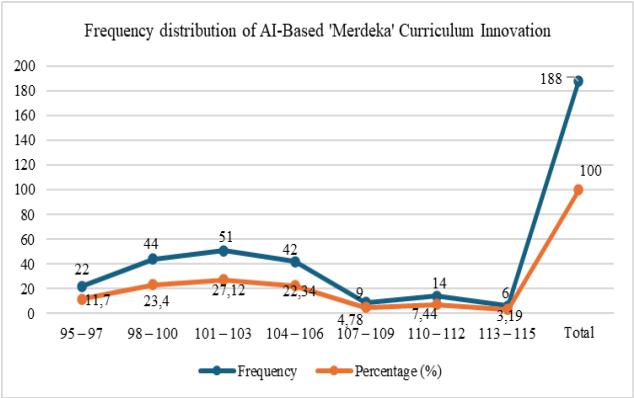

Figure 4. Frequency distribution of AI-Based 'Merdeka' Curriculum Innovation

Following the creation of the frequency distribution table, a score trend table for the AI-based 'Merdeka' curriculum innovation variable is developed. This table is designed to identify score ranges and categorize respondents into good, sufficient, and insufficient groups, based on the mean and standard deviation values. The results of the score trend analysis for the AI-based 'Merdeka' curriculum innovation variable are presented in Table 7 as follows:

Table 7. Categories for AI-based 'Merdeka' curriculum innovation

Criteria	Freq.	Percent. (%)	Descript.
x<96.03	28	14.89	Less
96.03<x<108.11	131	69.68	Adequate
x>108.11	29	15.42	Good

According to the data in Table 7, most of the AI-based 'Merdeka' curriculum innovation scores fall into the adequate category (80.21%). Additionally, 15.42% are classified as good, and 14.89% are categorized as less.

4.1. Hypothesis Analysis Prerequisite Test

Normality Test - This test assesses whether the research data follows a normal distribution. The Kolmogorov-Smirnov test was performed on unstandardized residuals using SPSS-25. A significance value (2-tailed) greater than 0.05 indicates that the data is normally distributed, while a significance value less than 0.05 suggests a deviation from normality. The results of the normality test are presented in Table 8.

Table 8. Results of the normality test

Kolmogorov Smirnov test		
		unstandardized residual
N (sample quantity)		188
normal parameters	$\bar{x}$	.000
	s	4.5584
most extreme differences	absolute	.03
	positive	.03
	negative	-.02
test statistic		.03
asymp. sig. (2-tailed)		.202

According to Table 8, the Asymp. Sig (2-tailed) value is 0.202, which is above the 0.05 threshold. This indicates that the data in this study follows a normal distribution.

Linearity Test - this test assesses whether there is a significant linear relationship between the independent and dependent variables. A strong correlation indicates linearity. The test is conducted by examining the significance value, where a Sig. value greater than 0.05 suggests a linear relationship, whereas a Sig. value less than 0.05 indicates the absence of such a relationship. The results of the linearity test are detailed in Table 9.

Table 9. Results of the linearity test

Variable Relationship	Sig.	Probability	Descript.
x1–y	.105	.05	Linearity
x2–y	.768	.05	Linearity

According to Table 9, principal leadership, teacher roles, and AI-based 'Merdeka' curriculum innovation demonstrate a significant linear relationship, as all Sig. values are greater than 0.05.

Multicollinearity Test - this test evaluates the correlations among independent variables. In an ideal model, independent variables should not exhibit significant correlations with each other. The test is conducted using tolerance and variance inflation factor (VIF) values. Tolerance values greater than 0.10 and VIF values less than 10.00 indicate the absence of multicollinearity, while tolerance values below 0.10 and VIF values above 10.00 suggest the presence of multicollinearity. The results of the multicollinearity test are presented in Table 10.

Table 10. Results of the multicollinearity test

Variable	Collinearity statistic		Descript.
	Tolerance	VIF	
Principal leadership (x1)	.856	1.168	No multicollinearity
Teacher's role (x2)	.856	1.168	No multicollinearity

According to Table 10, the tolerance value for both principal leadership (x1) and teacher roles (x2) is 0.856, which is above the 0.10 threshold. Additionally, the VIF value for both variables is 1.168, well below the 10.00 limit. Thus, it can be conclusively determined that there is no multicollinearity between the independent variables.

Heteroscedasticity Test - this test aims to detect variance disparity among observations. Ideally, a robust correlation model should exhibit no heteroscedasticity. In this study, the Glejser test was used by regressing the independent variable on the absolute residual values (Abs-RES). The significance value (Sig.) indicates the presence of heteroscedasticity; a Sig. value greater than 0.05 suggests no heteroscedasticity, while a Sig. value less than 0.05 indicates its presence. The results of the heteroscedasticity test are presented in Table 11.

Table 11. Results of the heteroscedasticity test

Variable	Collinearity Statistic		Description
	Tolerance	VIF	
Principal leadership (x1)	.428	0.05	No-heteroscedasticity
Teacher's role (x2)	.371	0.05	No-heteroscedasticity

According to Table 11, the significance values for both independent variables are greater than 0.05. Therefore, it can be concluded that heteroscedasticity is not present.

4.2. Hypothesis Test

The analytical methods employed for hypothesis testing include Pearson product-moment correlation analysis and multiple regression analysis. The results of these tests are detailed as follows:

Pearson Product-Moment Correlation - analyzes the relationship between the independent variables, principal leadership (x1) and teacher roles (x2), and the dependent variable, AI-based 'Merdeka' curriculum innovation (y). A significance value (Sig.) less than 0.05 indicates a correlation, whereas a Sig. (2-tailed) value greater than 0.05 suggests no correlation. The results of the Pearson product-moment correlation analysis are shown in Table 12.

Table 12. Results of the correlation test

Variable Relationship	Correlation coefficient (R)	Sig. (2-tailed)
x1–y	.453	.000
x2–y	.447	.000

The first correlation test in Table 12 shows an R value of 0.453 with a significance value of 0.000, indicating a significant correlation between principal leadership and AI-based 'Merdeka' curriculum innovation in vocational high schools. The second correlation test reveals an R value of 0.447 with a significance value of 0.000, demonstrating a significant relationship between teacher roles and AI-based 'Merdeka' curriculum innovation in vocational high schools.

This is evidenced by the significance value of 0.000, which is less than 0.05. Additionally, the correlation coefficient of 0.453 falls within the 0.40-0.599 range, indicating a moderate relationship between principal leadership and AI-based 'Merdeka' curriculum innovation. Thus, the data supports the validity of the first working hypothesis.

The analysis demonstrates a positive relationship between principal leadership and AI-based 'Merdeka' curriculum innovation, suggesting that stronger principal leadership is associated with greater innovation in the 'Merdeka' curriculum at the school.

Multiple Correlation - analysis assesses the simultaneous relationship between principal leadership and teacher roles (independent variables) and AI-based 'Merdeka' curriculum innovation (dependent variable). The significance of the overall relationship is indicated by the Sig. F change value, where a value less than 0.05 suggests a significant relationship, while a value greater than 0.05 indicates no significant relationship. The results are detailed in Table 13.

Table 13. Results of the multiple correlation test

Variable Relationship	Correlation coefficient (R)	Sig. F change
x1, x2–y	.541	.000

According to Table 13, the Sig. F value of 0.000, which is less than 0.05, indicates that principal leadership (x1) and teacher roles (x2) together have a significant relationship with AI-based 'Merdeka' curriculum innovation (y). The Correlation Coefficient data are presented in Table 14.

Table 14. Correlation coefficient

Coefficient level	Relationship description
0.80–1.000	very strong
0.60–0.799	strong
0.40–0.599	medium
0.20–0.399	low
0.00–0.199	very low

Table 14 further shows an R value (correlation coefficient) of 0.541 for the examined variables. This suggests that the relationship between principal leadership (x1) and teacher roles (x2) with AI-based 'Merdeka' curriculum innovation (y) is moderately strong. The findings highlight the importance of understanding the dynamics of educational change and assessing the effectiveness of leadership strategies in advancing curriculum innovation.

This research confirms the important role of principal leadership in determining the direction and success of AI-based 'Merdeka' curriculum innovation in Vocational High Schools. Principals who demonstrate visionary leadership traits, such as having a strategic vision, taking risks, and supporting innovation, are important catalysts in driving a culture of innovation in vocational high schools [10]. This aligns with prior research [11], which emphasizes that articulating a clear vision for AI integration and providing strategic direction for innovative pedagogical practices are essential for driving educational progress.

This assertion is substantiated by a significance value of 0.000, which is less than 0.05. Furthermore, the correlation coefficient of 0.453, within the 0.40 - 0.599 range, suggests a moderate relationship between principal leadership and AI-based 'Merdeka' curriculum innovation, thus validating the first working hypothesis. The data also indicates that higher levels of principal leadership are associated with a deeper understanding of the 'Merdeka' curriculum within schools.

Effective leadership involves empowering teachers to engage actively in curriculum innovation and providing the necessary support and resources [12], [13]. This study underscores the importance of fostering teacher autonomy, creativity, and collaboration in the development and implementation of AI-based 'Merdeka' curriculum initiatives. Principals play a pivotal role by offering professional development opportunities, creating collaborative platforms for best practice sharing, and recognizing teachers' contributions to curriculum innovation efforts [14], [15]. The analysis reveals a significant relationship between teachers' roles and AI-based 'Merdeka' curriculum innovation, as indicated by a significance value of 0.000 and a correlation coefficient (R) of 0.447, which also reflects a moderate level of relationship. Thus, the data supports the validity of the second working hypothesis, showing that increased teacher involvement in the 'Merdeka' curriculum innovation leads to greater adoption of AI-based innovations.

The study also identifies challenges to implementing AI-based 'Merdeka' curriculum innovation, such as limited technology infrastructure, resistance to change, and concerns about equity and accessibility, in line with research results from [16], [17]. However, it highlights opportunities to address these challenges through strategic leadership, collaborative partnerships, and targeted interventions. By proactively tackling these issues and leveraging opportunities, vocational high schools can enhance their ability to prepare students for success in the digital age. The results show a significant relationship between principal leadership, teacher roles, and AI-based 'Merdeka' curriculum innovation, with a correlation coefficient of 0.541, indicating a moderate level of association. This supports the validity of the third working hypothesis and illustrates those higher levels of principal leadership and teacher involvement correlate with increased adoption of AI-based 'Merdeka' curriculum innovation.

Future research should explore the long-term effects of AI-based 'Merdeka' curriculum innovation on student learning outcomes, workforce readiness, and educational equity.

Additionally, studies on leadership development programs, community engagement initiatives, and cross-sector partnerships could provide valuable insights into advancing vocational education practices in Indonesia and beyond. This research aims to drive transformative change in vocational high schools by integrating principal leadership and teacher roles with AI-based 'Merdeka' curriculum innovation. By addressing challenges, seizing opportunities, and fostering collaboration among stakeholders, educational leaders can enhance their ability to navigate curriculum innovation and prepare students for success in the digital era.

4. Conclusion

This study examines the integration between principals' leadership and teachers' roles in the context of AI-based 'Merdeka' curriculum innovation in vocational high schools in Indonesia. The data analysis reveals a significant relationship between principal leadership and AI-based 'Merdeka' curriculum innovation, with a correlation coefficient (R) of 0.453 and a significance value of 0.000, which is less than 0.05. Additionally, a significant association is found between teachers' roles and AI-based 'Merdeka' curriculum innovation, indicated by a correlation coefficient (R) of 0.447 and a significance value of 0.000. Moreover, a notable relationship between both principal leadership and teacher roles with AI-based 'Merdeka' curriculum innovation is observed, supported by a correlation coefficient (R) of 0.541 and a significance value of 0.000. These findings underscore the critical role of principal leadership and teacher involvement in advancing AI-based 'Merdeka' curriculum innovation in vocational education settings. Effective leadership is essential for the successful implementation of innovative curriculum initiatives, with visionary leadership, support for teacher autonomy, and stakeholder collaboration being key drivers. Additionally, providing teachers with sufficient support, resources, and professional development opportunities is crucial for the effective use of AI technologies in teaching. Despite challenges such as limited technology infrastructure and resistance to change, strategic investments in AI-driven curriculum innovations offer promising opportunities to enhance vocational education outcomes. This study contributes valuable insights to the literature on educational leadership and curriculum development, providing recommendations for policymakers, school administrators, and educators seeking to improve vocational education practices in the digital era. Further research is needed to assess the long-term impact of AI-based 'Merdeka' curriculum innovations on student learning outcomes, workforce readiness, and educational equity in vocational high schools.

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