The Influence of Principals' Technological Leadership and Teachers' Digital Competence on The Readiness For Implementing Coding and Artificial Intelligence-Based Learning in Senior High Schools in Langowan District

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***Abstract*.**

This study aims to analyze the influence of principals' technological leadership and teachers' digital competence on the readiness for implementing coding and artificial intelligence-based learning in senior high schools in Langowan District. Employing a quantitative approach with a survey method, the study involved 79 teacher respondents through questionnaire data collection that had been tested for validity and reliability. The data analysis technique used was multiple linear regression assisted by SPSS software. The results indicate that principals' technological leadership has a positive and significant effect on implementation readiness. Furthermore, teachers' digital competence is also proven to have a positive and significant effect on such readiness. Simultaneously, these two variables contribute a significant influence of 68.8% to the readiness for implementing coding and artificial intelligence-based learning. These findings conclude that strengthening technological leadership and enhancing teachers' digital competence are strategic factors in successfully advancing educational transformation in the digital era
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Keywords: *Technological leadership; teachers' digital competence; coding-based learning; artificial intelligence and implementation readiness.*

I. INTRODUCTION

The rapid development of information and communication technology in the 21st century has transformed the global educational paradigm, necessitating fundamental changes in organizational culture and management systems at the school level. Effective school leadership in the digital era is characterized by the ability to establish a clear technological vision and to provide continuous support for teachers' professional development (Dexter S. & Richardson J., 2020). In line with this, modern educational management must be adaptive to technological advancements in order to enhance the quality of educational services and ensure sustained stakeholder satisfaction (Watulingas et al., 2024; Katuuk, 2024). This digital transformation positions teachers as the primary agents of instruction who must continuously improve their professionalism through mastery of educational technology and pedagogical innovation (Saerang et al., 2023).The current focus of the Indonesian government, as outlined in Law No. 59 of 2024 concerning the National Long-Term Development Plan (RPJPN) 2025–2045, is the development of high-quality human resources in the digital sector through the integration of coding and artificial intelligence (AI) learning, in order to address global competition in the era of the Industrial Revolution 4.0 and Society 5.0.The successful implementation of technology-based innovations is highly influenced by the quality of school leadership and the digital competence of teachers as key actors. Technological leadership refers to the ability of school leaders to direct, facilitate, and inspire the use of technology in both instructional processes and school management (Anderson & Dexter, 2021).

Meanwhile, teachers' digital competence encompasses pedagogical abilities in designing interactive and meaningful digital-based learning experiences (Redecker, 2021). However, conditions in senior high schools in Langowan District indicate that despite the availability of infrastructure such as Chromebooks, teachers' digital competence remains uneven. Additionally, policies restricting mobile phone usage limit students' opportunities to independently practice AI-based applications. Other challenges include the lack of specific training in computational thinking and coding, as well as the absence of systematic measurement regarding the extent to which schools are prepared to adopt digital transformation based on coding and artificial intelligence.Therefore, this study aims to empirically analyze the influence of principals' technological leadership and teachers' digital competence on the readiness for implementing coding and artificial intelligence-based learning. The scope of the study is limited to three schools in Langowan District—SMA Negeri 1 Langowan, SMA Negeri 2 Langowan, and SMA Yadika Langowan—with a focus on introductory-level programming curriculum and the use of educational AI platforms. Through a quantitative approach, this study is expected to demonstrate the contribution of each variable both partially and simultaneously to school readiness in facing future challenges. The findings are anticipated to provide theoretical contributions to the field of educational management as well as practical benefits for school principals in evaluating technology-based transformational leadership strategies, and to serve as a policy foundation for the government in developing technology training programs in secondary education.

II. LITERATURE REVIEW

A. Principals' Technological Leadership (X1)

Technological leadership is a dimension of educational leadership that focuses on the principal's ability to integrate digital technology into all aspects of school management and instructional processes. According to Anderson and Dexter (2021), technological leadership encompasses vision, strategy, and the principal's capacity to mobilize human resources in optimizing technology as an instrument for improving educational quality. Principals play a strategic role as change agents who guide the school community toward an innovative and adaptive culture in response to technological advancements.Operationally, the International Society for Technology in Education (ISTE) standards categorize technological leadership into five main dimensions. First, as an Equity and Digital Citizenship Advocate, where leaders ensure equitable access to technology and promote its ethical use. Second, as a Visionary Planner who formulates a strategic vision for systematic technology integration. Third, as an Empowering Leader who provides support and professional development opportunities for teachers. Fourth, as a Systems Designer who ensures the availability of infrastructure and effectively manages technological resources. Fifth, as a Connected Learner who continuously develops personal competencies and builds technology-based professional networks. School management support through policies and ICT facilities is a key determinant of successful innovation in the digital era.

B. Teacher's Digital Competence (X2)

Teachers' digital competence is defined as the ability to use information and communication technology effectively, ethically, and creatively within the professional context of education. This competence extends beyond technical skills, encompassing pedagogical and professional capabilities in integrating technology into the teaching and learning process.Based on the DigCompEdu framework, teachers' digital competence is categorized into six main areas: professional engagement through digital platforms, creation of relevant digital resources, implementation of digital teaching practices to support active learning, utilization of digital assessment to monitor student progress, empowerment of learners, and facilitation of students' digital literacy in a critical and ethical manner.Enhancing this competence serves as a foundation for enabling teachers to integrate computational thinking and artificial intelligence concepts into the curriculum. Teachers with a high level of digital competence are more likely to adopt innovations and design effective learning experiences by leveraging various programming platforms and data-driven applications.

C. Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning (Y)

Implementation readiness refers to the level of preparedness of individuals and organizations to effectively carry out a particular change or innovation. According to Weiner (2020), such readiness involves commitment, capacity, and environmental conditions that enable change to be successfully implemented. In the educational context, readiness for implementing coding and artificial intelligence-based learning encompasses four main aspects. First, individual teacher readiness (pedagogical), which includes attitudes, knowledge, and skills related to digital innovation. Second, organizational readiness (psychological), which involves policy support and an innovative school culture. Third, technical readiness, referring to the availability of adequate devices, networks, and digital resources. Fourth, collaborative readiness among teachers, students, and stakeholders.The TPACK (Technological Pedagogical Content Knowledge) model emphasizes that the effective integration of technology is influenced by the balance among technological knowledge, pedagogical knowledge, and content knowledge. Therefore, readiness is not merely about the availability of hardware, but also about users' ability to optimally utilize technology to enhance educational quality. Systemically, implementation readiness is the result of the interaction between appropriate managerial policies and the technical competencies of educators.

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III. METHODS

This study employs a quantitative approach using a survey method, in which data were collected by administering a series of questions to research subjects to obtain information regarding the phenomenon under investigation (Sugiyono, 2017). The research design is explanatory in nature, aiming to examine the influence of independent variables—principals' technological leadership and teachers' digital competence—on the dependent variable, namely readiness for the implementation of coding and artificial intelligence-based learning, analyzed using multiple linear regression (Hair et al., 2022).The study was conducted in three senior high schools in Langowan District—SMA Negeri 1, SMA Negeri 2, and SMA Yadika Langowan—over the period from January to March 2026. The population consisted of all teachers in these schools, totaling 99 individuals. The sample size was determined using the Taro Yamane formula (1967), resulting in 79 respondents with a precision level of 5%. A simple random sampling technique was employed to ensure that each member of the population had an equal probability of selection (Sugiyono, 2019).Primary data were obtained directly from respondents through a closed-ended questionnaire using a 5-point Likert scale, developed based on variable indicators derived from theoretical constructs (Sugiyono, 2022).

Prior to the main study, the instrument underwent validity testing using the Pearson Product Moment correlation and reliability testing using Cronbach's Alpha to ensure internal consistency (Ghozali, 2021). Items that did not meet validity criteria were excluded from further analysis to enhance measurement quality and maintain construct validity (Tabachnick & Fidell, 2021; Hair et al., 2022). Data analysis began with descriptive statistics to provide an overview of minimum, maximum, mean, and standard deviation values for each variable.Subsequently, classical assumption tests were conducted, including the normality test to ensure unbiased residual distribution (Field, 2020), the multicollinearity test to detect strong correlations among independent variables (Ghozali, 2016; Hair et al., 2022), and the heteroscedasticity test to examine the homogeneity of residual variances (Tabachnick & Fidell, 2021). The final stage involved hypothesis testing using multiple linear regression, including the t-test to assess partial effects, the F-test to evaluate simultaneous effects, and the coefficient of determination (R^2) to measure the extent to which independent variables explain variation in the dependent variable (Hair et al., 2022; Field, 2020).

IV. RESULT AND DISCUSSION

Result

A. Description of Research Data

Table 1. Statistical Data

Descriptive Statistics									
	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
X1	79	11	38	49	3464	43.85	.283	2.517	6.336
X2	79	12	37	49	3552	44.96	.276	2.452	6.011
Y	79	14	35	49	3301	41.78	.354	3.145	9.889
Valid N (listwise)	79								

The descriptive analysis of data from 79 respondents indicates that all variables fall within relatively high categories. Principals' Technological Leadership (X1) has a mean score of 43.85 (high category) with a homogeneous data distribution, suggesting that the majority of respondents perceive technological leadership as good to very good. Teachers' Digital Competence (X2) has a mean score of 44.96 (high category) with the smallest variation, indicating consistent responses and a strong level of digital competence among teachers. Meanwhile, Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning (Y) has a mean score of 41.78 (moderately high), but with greater variability compared to X1 and X2, reflecting differences in readiness levels among respondents.

Table 2. Descriptive Summary

Variabel	N	Minimum	Maximum	Mean	Standar Deviasi
Principals' Technological Leadership (X1)	79	38	49	43,85	2,517
Teachers' Digital Competence (X2)	79	37	49	44,96	2,452
Implementation Readiness (Y)	79	35	49	41,78	3,145

The results of the descriptive analysis indicate that the variables of Principals' Technological Leadership (X1) and Teachers' Digital Competence (X2) fall within the high category, while the variable of Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning (Y) is categorized as moderately high with greater variability. These findings demonstrate a strong alignment with the theoretical framework presented in the literature review.

B. Classical Assumption Tests

1. Normality Test

The normality test is conducted to determine whether the data are normally distributed for each variable analyzed. This test was performed using SPSS version 31, applying the One-Sample Kolmogorov-Smirnov Test method.

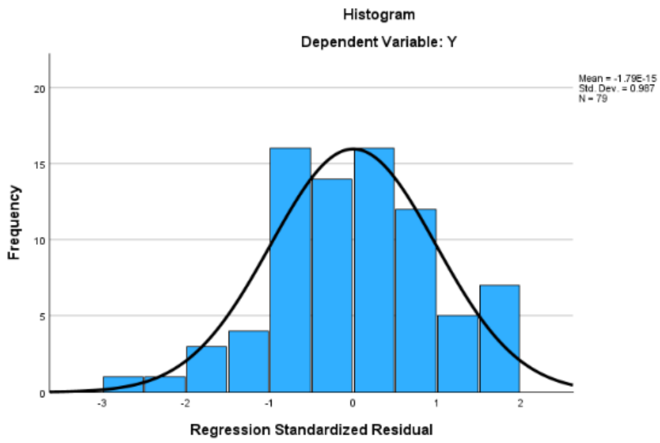

Fig 1. Histogram of Independent Variables

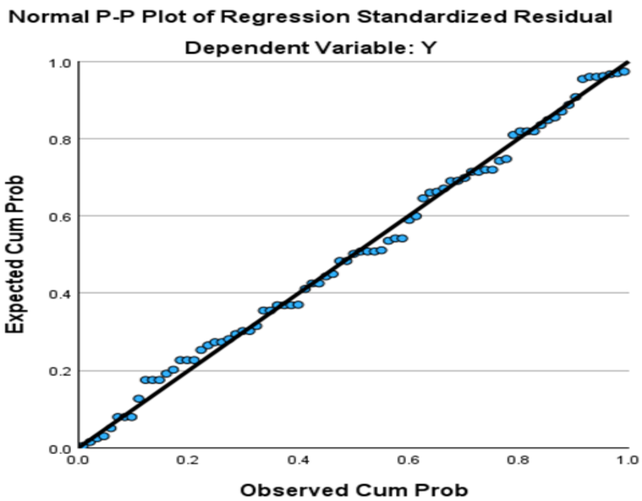

Fig 2. P-Plot Test

One-Sample Kolmogorov-Smirnov Test

			Unstandardized Residual
N			79
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		1.75707084
Most Extreme Differences	Absolute		.058
	Positive		.053
	Negative		-.058
Test Statistic			.058
Asymp. Sig. (2-tailed)[c]			.200[d]
Monte Carlo Sig. (2-tailed)[e]	Sig.		.731
	99% Confidence Interval	Lower Bound	.719
		Upper Bound	.742

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.
e. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 2000000.

Fig 3. Kolmogorov-Smirnov Test

If the Asymp. Sig. (2-tailed) value is ≥ 0.05, the data are considered normally distributed. Conversely, if the Asymp. Sig. (2-tailed) value is ≤ 0.05, the data are considered not normally distributed. Based on the SPSS 31 analysis results, the Asymp. Sig. value obtained is 0.200. Since 0.200 ≥ 0.05, it can be concluded that H_0 is accepted and the data are normally distributed.

2. Multicollinearity Test

The multicollinearity test is conducted to determine whether there is a correlation among independent variables in the regression model (Ghozali, 2016). The criteria are as follow:

- If the tolerance value is greater than or ≥ 0.10, it indicates that multicollinearity does not occur
  If the variance inflation factor (VIF) value is ≤ 10, it indicates that multicollinearity does not occur.

Table 3. Multicollinearity Test

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7.173	3.958		-1.813	.074		
	X1	.849	.108	.679	7.889	<,001	.554	1.806
	X2	.261	.110	.204	2.364	.021	.554	1.806
a. Dependent Variable: Y								

Based on Table 3, the tolerance values for X1 (0.554 ≥ 0.10) and X2 (0.588 ≥ 0.10) indicate acceptable levels. Additionally, the VIF values for X1 (1.806 ≤ 10.0) and X2 (1.806 ≤ 10.0) are within the acceptable range. Therefore, it can be concluded that no multicollinearity is present in the data.

3. Heteroscedasticity Test

The heteroscedasticity test is conducted to examine whether there are unequal variances among residuals across observations.

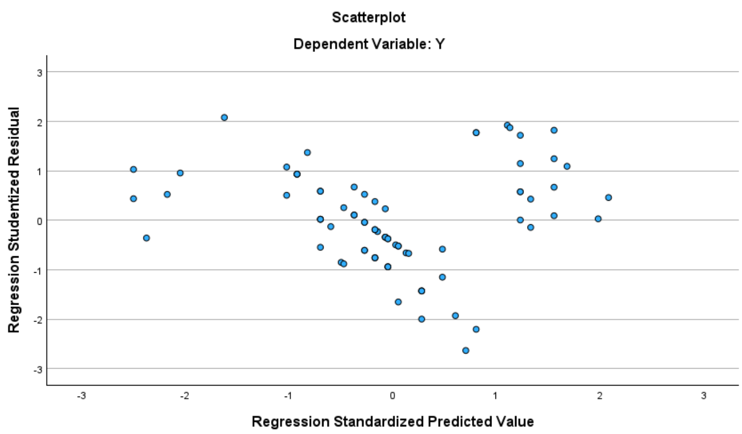

Fig 4. Scatterplot

Interpretation: If the data points are evenly dispersed, it indicates the absence of heteroscedasticity. Conversely, if the points cluster in a particular area, it suggests the presence of heteroscedasticity. Based on the analysis above, it can be concluded that the data are normally distributed and do not exhibit heteroscedasticity.

Tabel 4. Heteroscedasticity Test

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-.796	2.268		-.351	.727
	X1	.205	.062	.478	3.321	.001
	X2	-.151	.063	-.344	-2.390	.019
a. Dependent Variable: ABS						

Using the Glejser test (significance value > 0.05), a significance value of 0.727 > 0.05 was obtained. Therefore, it can be concluded that there is no indication of heteroscedasticity.

C. Multiple Linear Regression Analysis

Table 5. Multiple Linear Regression

Coefficients[a]								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7.173	3.958		-1.813	.074		
	X1	.849	.108	.679	7.889	<,001	.554	1.806
	X2	.261	.110	.204	2.364	.021	.554	1.806
a. Dependent Variable: Y								

Based on the results of data processing using SPSS, the regression equation is obtained as follows:

$$Y = 7,173 + 0,849X_1 + 0,261\ X_2 + e$$

These results indicate that principals' technological leadership has a substantially greater influence (0.849) compared to teachers' digital competence (0.261) on the readiness for implementing coding and artificial intelligence-based learning.

D. Hypothesis Testing

Hypothesis testing using multiple linear regression analysis can be conducted in two way:

- By examining the significance value, where sig < 0.05 indicates a significant effect, and sig > 0.05 indicates no significant effect.
- By comparing the calculated values, where $t_{(value)} \geq t_{(table)}$ (t-test for partial effects) and $F_{(value)} \geq F_{(table)}$ (F-test for simultaneous effects).

1. t-Test / Partial Test / Coefficients

Table 6. Partial Test Data (t-Test)

Coefficientsa								
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	-7.173	3.958		-1.813	.074		
	X1	.849	.108	.679	7.889	<,001	.554	1.806
	X2	.261	.110	.204	2.364	.021	.554	1.806
a. Dependent Variable: Y								

If the significance value (Sig.) ≤ 0.05, it indicates a statistically significant effect. Likewise, if the calculated t-value ($t_{(value)}$) ≥ the critical t-value ($t_{(table)}$), it is considered to have a significant effec..

Table 7. Comparison of Significance Values at the 0.05 Level

Variable	Sig		Criteria
X1	<,001	< 0.05	Significant effect on Y
X2	0.021	< 0.05	Significant effect on Y

The significance value for X1 (< 0.001 ≤ 0.05) indicates that X1 has a significant effect on Y. Similarly, the significance value for X2 (0.021 ≤ 0.05) indicates that X2 has a significant effect on Y.

Table 8. Comparison of t-Values

Variable	t_{value}	t_{table}	Criteria
X1	7.889	1.665	Significant effect on Y
X2	2.364	1.665	Significant effect on Y

Df = n-k

Df : degree of freedom

n : number of respondents

k : number of variables

Df = 79 - 3 = 76

For Df = 76, the $t_{(table)}$ value is 1.665.

The calculated t-value for X1 is 7.889 ≥ 1.665, indicating that X1 has a significant effect on Y.

The calculated t-value for X2 is 2.364 ≥ 1.665, indicating that X2 has a significant effect on Y.

2. **F-Test / Simultaneous Test / ANOVA**

Criterion: If the significance value (Sig.) ≤ 0.05, it indicates a significant simultaneous effect on Y.

Table 9. F-Test (Simultaneous)

ANOVA[a]						
	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	530.533	2	265.266	83.719	<,001[b]
	Residual	240.809	76	3.169		
	Total	771.342	78			
a. Dependent Variable: Y						
b. Predictors: (Constant), X2, X1						

Based on the table, the significance value of 0.001 ≤ 0.05 indicates that, simultaneously, X1 and X2 have a positive effect on Y.

If the calculated F-value ($F_{(calculated)}$) ≥ $F_{(table)}$, it is considered to have a significant effect on Y.

Df1 = k-1   k : number of variables

Df2 = n-k   n : number of respondents

Df1 : 3 - 1 = 2

Df2 : 79 - 3 = 76

Using the F-table, the critical value obtained is 3.12.

Since the significance value is 0.001 ≤ 0.05, it can be concluded that X1 and X2 have a significant effect on Y. Furthermore, because $F_{(value)}$ = 83.719 ≥ $F_{(table)}$ = 3.12, it indicates that X1 and X2 simultaneously have a significant effect on the dependent variable Y. Therefore, the F-test requirements in this study have been satisfied.

3. **Coefficient of Determination (R^2 Test)**

Table 10. Coefficient of Determination

Model Summary									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.829a	.688	.680	1.780	.688	83.719	2	76	<,001
a. Predictors: (Constant), X2, X1									

Based on the results from the model summary table, the correlation coefficient (R) is 0.829 and the coefficient of determination (R^2) is 0.688. Therefore, based on the SPSS 31 for Windows output and the applied formula:

KP = 0,688 x 100% = 68,8 %.

This indicates that the contribution of the independent variables (X1 and X2) to the dependent variable (Y) is 68.8%, while the remaining 31.2% is influenced by other variables outside the model.

Discussion

The descriptive analysis in this study aims to provide a general overview of the data characteristics for each research variable based on 79 valid respondents. The variables examined include Principals' Technological Leadership (X1), Teachers' Digital Competence (X2), and Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning (Y).Principals' Technological Leadership (X1) has a mean score of 43.85, which falls into the high category. The relatively small standard deviation (2.517) indicates a homogeneous data distribution. Teachers' Digital Competence (X2) has a mean score of 44.96, also categorized as high, suggesting that teachers possess a consistent level of digital competence as a prerequisite for implementing coding and AI-based curricula.

Meanwhile, Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning (Y) has a mean score of 41.78, which falls into the moderately high category. The variation in this variable (standard deviation of 3.145) is greater compared to the other variables.The findings indicate that school readiness in implementing advanced learning approaches such as coding and artificial intelligence is highly dependent on the strategic role of the principal as a technological leader, as well as the digital competence of teachers. This is consistent with educational management theory, which positions leadership as a primary catalyst for organizational change. Strong technological leadership fosters a supportive environment, while teachers' digital competence ensures the effective execution of technical instruction. Although implementation readiness is categorized as moderately high, the greater variability in variable Y suggests the presence of technical or infrastructural factors that may require further evaluation.

Based on the results of multiple linear regression analysis and significance testing, the following section discusses the verification of the research hypotheses:

1. **There is a positive and significant influence of Principals' Technological Leadership on the Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning.** The results of the t-test show a calculated t-value of 7.889, which is substantially higher than the critical t-value (1.665), with a significance level of 0.000 < 0.05. Therefore, H1 is accepted. This finding demonstrates that the stronger the principal's technological vision and support, the higher the school's readiness to adopt new curricula. Theoretically, this supports the Digital Leadership model discussed in Chapter II, where the role of the principal extends beyond that of an administrative manager to become a driver of digital innovation (a catalyst).
2. **There is a positive and significant influence of Teachers' Digital Competence on the Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning.** Based on the results of the t-test, the calculated t-value is 2.364, which is greater than the critical t-value (1.665), with a significance level of 0.021 < 0.05. Therefore, H2 is accepted. This finding provides empirical evidence that technical readiness at the classroom level is highly dependent on teachers' digital competence. Although the effect is significant, the lower t-value compared to variable X1 indicates that, without strong leadership support, teachers' competence alone is not sufficient to drive the systemic implementation of coding and artificial intelligence in schools.
3. **Principals' Technological Leadership and Teachers' Digital Competence simultaneously have a significant influence on the Readiness for the Implementation of Coding and Artificial Intelligence-Based Learning.** The results of the F-test show a calculated F-value of 83.719 with a significance level of 0.000 < 0.05. Therefore, H3 is accepted.

This result indicates that the two independent variables function as an integrated ecosystem. The readiness for implementing coding and artificial intelligence-based learning in senior high schools in Langowan District is not the result of individual efforts (either teachers or principals alone), but rather the outcome of collaboration between appropriate managerial policies and the technical readiness of educators.

V. CONCLUSION

The findings of this study indicate that principals' technological leadership has a positive and significant influence on the readiness for implementing coding and artificial intelligence-based learning, thereby reinforcing the role of the principal as a leader of digital transformation within schools. In addition, teachers' digital competence also demonstrates a positive and significant effect, highlighting that teachers' ability to master and integrate technology is a crucial factor in supporting the implementation of digital-based learning. Simultaneously, both variables exert a significant influence, indicating that implementation readiness is not determined by a single factor, but rather is the result of a synergy between visionary leadership and adequate teachers' digital competence.

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