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Analysis of Vocational High School Teachers' Abilities in Sarolangun to Integrate 21st Century Skills Through School Leadership Perception

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Abstract: This study aims to analyze the ability of vocational teachers in Sarolangun to integrate 21st century skills based on school leaders' perceptions. A descriptive quantitative approach using Partial Least Square-Structural Equation Modeling (PLS-SEM) was employed, involving 110 respondents from 24 vocational high schools in Sarolangun Regency. Results revealed that teachers demonstrated high proficiency in critical thinking and innovation (82.64), information literacy (82.64), and communication and collaboration skills (79.85). Structural analysis identified significant relationships between skill aspects, with information literacy exerting the strongest influence on critical thinking and problem solving (path coefficient 0.788). The research model explained 67.2% of the variation in teachers' technological literacy skills. The findings conclude that developing 21st century skills among vocational teachers requires a holistic and comprehensive approach to teacher training and professional development, as these skills are highly interrelated.

Keywords: 21st Century Skills; Educational Technology; Information Literacy; Technological Literacy; Vocational Teachers

Introduction

21st Century Skills framework supports individual learning and development in the digital age through three main pillars: learning and innovation skills, information-media-technology skills, and life and career skills (Trilling & Fadel, 2009). The first pillar encompasses critical thinking, problem-solving, communication, collaboration, creativity, and innovation essential components for vocational education students facing complex workplace challenges (Mutohhari et al., 2021; Nuryanto & Eryandi, 2020). Critical thinking enables in-depth information analysis and informed decision-making, while communication and collaboration emphasize effective teamwork using various technologies (Trilling & Fadel, 2009; Hidayatulloh & Ashoumi, 2022).

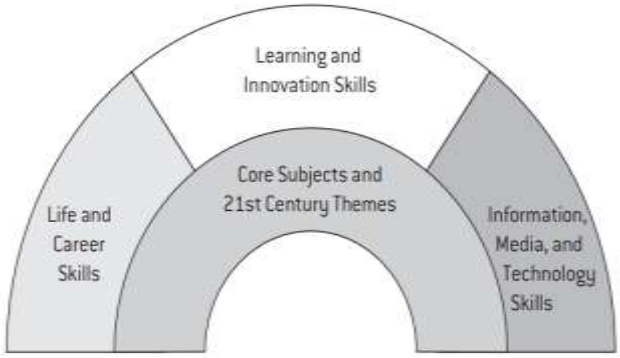

Figure 1. Rainbow of 21st Century Knowledge and Skills

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In vocational education context, these skills enable efficient information access, evaluation, and creative utilization (Budiarto et al., 2024; Jalinus et al., 2021). Media literacy supports understanding media messages, while ICT literacy equips students with digital technology skills for research, communication, and content creation (Trilling & Fadel, 2009; Adi et al., 2023). The third pillar, life and career skills, complements the framework by developing flexibility, adaptability, initiative, social skills, and productivity, preparing learners for dynamic work environments (Eryandi & Nuryanto, 2020). Quick adaptation, cross-cultural communication, and leadership are prerequisites for global success (Trilling & Fadel, 2009; Salleh & Puteh, 2017). The implementation of 21st Century skills in vocational schools faces significant challenges across all three dimensions (Papier, 2021; Ridwan et al., 2024). In learning and innovation, teachers struggle to design experiences that foster critical thinking, collaboration, and creativity, with conventional teaching methods hindering adaptive abilities and complex problem-solving development (Novalinda et al., 2020; Chuntala, 2019). The information-media-technology dimension reveals more pronounced gaps, with teachers' limited digital literacy resulting in insufficient technology integration (Wahyuni & Sugihartini, 2021). Their capacity to develop interactive digital content, utilize current technology platforms, and guide information evaluation remains restricted, potentially creating a technological competency gap between educators and students (Wahyuni et al., 2020). Regarding life and career skills, teachers face difficulties preparing students for modern workplace dynamics due to limited capacity in developing adaptability, cross-cultural communication, and leadership (Bunyamin et al., 2022; Rosina et al., 2021; Afandi, dkk., 2019).

Vocational education stands at a critical juncture in Indonesia's education system (Indarta et al., 2022). SMK teachers need to develop all three pillars of 21st century skills to meet contemporary demands (Wagiran et al., 2017). This is particularly important in Sarolangun Regency, with its 14 public and 10 private SMKs across various specializations, requiring teachers who master both vocational content and modern technology integration (Rifdarmon et al., 2023). The national education system demands fundamental transformation in learning and competency development approaches (Rifdarmon et al., 2024). Teachers must master information literacy, effective communication, critical thinking, problem-solving, collaboration, creativity, and innovation (Ramadona et al., 2024; Real, 2022). Emphasize that these skills are essential for preparing students for increasingly complex future challenges—critical given rapid technological advancement and evolving job market demands (Lynch, 2000; Hidayatulloh et al., 2024). Sarolangun Regency's developing industrial and agricultural sectors make this research strategically significant, as vocational education must align with local economic priorities while preparing students for broader opportunities (Samsudi et al., 2019). Without proper 21st century skills implementation, graduates may be inadequately prepared for both local and global employment markets (Syaifullah et al., 2024).

Several studies reinforce the urgency of mastering 21st century skills in contemporary education. Makhrus et al. (2018) revealed that teachers' learning design abilities significantly determine learners' skill development. Sari et al. (2023) found that academic blog-based inquiry approaches improve conceptual understanding and 21st century learning attitudes. Kamila et al. (2024) analyzed local potential integration in science learning and its effect on 21st century skills and cultural awareness. Information and communication technology (ICT) represents a key component in 21st century skills development (Jalinus et al., 2021; Budiarto et al., 2024). Virijai & Asrizal (2023) demonstrated that augmented reality-based teaching materials support 21st century learning and improve teaching quality. Ernest & Suyanta (2024) strengthened this through research on ICT literacy profiles in Google Sites-assisted science learning. Wijanarko et al. (2024) examined natural schools' role in developing 4C skills (Communication, Collaboration, Critical Thinking, Creativity) for 21st century challenges, while Syaifullah et al. (2024) validated an e-learning model for improving student outcomes and 4C skills through structural equation modeling. Additional national studies support 21st century skills integration importance. Rusadi et al. (2019) analyzed students' learning and innovation skills through scientific approaches, while Mantau & Talango (2023) conducted a literature review on 21st century skills integration in learning processes. Sulistyaningrum et al. (2019); Jufriadi et al. (2022) examined prospective teachers' initial 21st century skills abilities and independent learning curriculum implementation. Pertiwi et al. (2021) analyzed elementary school teachers' technological abilities, and Sridana et al. (2024) examined prospective teachers' ability to develop student worksheets building 21st century skills.

Research gaps exist where 21st century skills integration in vocational education presents complexities not fully explored, particularly in analyzing teacher capabilities through school leaders' perspectives (Wahyuni & Sugihartini, 2021). Most research has focused on primary and secondary education, leaving significant gaps in understanding vocational school dynamics, especially in Sarolangun (Rifdarmon et al., 2023). While various studies have examined 21st century skills, comprehensive

approaches considering interactions between teacher abilities, technology, and leadership strategies remain limited (Syaifullah et al., 2024). School leaders' perceptions of vocational teachers' skills development have received insufficient attention despite strategic leadership's decisive role in transforming educational practices (Real, 2022). Sarolangun SMKs' locality context and specific characteristics remain underexplored. Geographical, social, and infrastructure differences potentially create unique variations in 21st century skills implementation requiring systematic investigation (Ridwan et al., 2024). Previous research tends toward generality, lacking consideration for regional specificities. Implementation factors both inhibiting and supporting have not been thoroughly identified in vocational contexts (Mutohhari et al., 2021; Papier, 2021).

This research urgently addresses knowledge gaps through comprehensive analysis of SMK Sarolangun vocational teachers' ability to integrate 21st century skills as perceived by school leaders. Its urgency stems from digital-era educational challenges demanding fundamental vocational education transformation (Indarta et al., 2022; Jalinus et al., 2021; Hidayatulloh et al., 2024; Ramadona et al., 2024). Sarolangun Regency's 24 SMKs face pressing needs for systematic 21st century skills integration, with school leaders playing key roles in transforming educational practices amid dynamic global demands (Ridwan et al., 2024). The competency gap across all three 21st century skills dimensions represents a critical focus (Wahyuni et al., 2020). Teachers' limited abilities in developing critical thinking, digital literacy, and adaptation skills require school leaders' deep understanding to design effective professional development strategies (Bunyamin et al., 2022). Additionally, insufficient technology integration in learning processes, stemming from limited digital literacy, potentially creates technological gaps between educators and learners, significantly impacting graduate quality (Budiarto et al., 2024). This research will provide comprehensive mapping of vocational teacher competencies, enabling evidence-based policymaking to improve Sarolangun's vocational education quality. School leaders' perceptions will provide strategic insights into professional development needs. Within national education transformation context, this research contributes to systematic efforts preparing SMK graduates to compete globally with beyond-technical competencies (Adi et al., 2023; Nuryanto & Eryandi, 2020). From policy perspectives, understanding 21st century skills implementation challenges through school leaders' perspectives provides valuable insights for policymakers, potentially informing targeted interventions and resource allocations addressing specific deficiencies in teacher preparation and development programs (Real, 2022). Therefore, research on "School Leaders' Perceptions of the Ability of Vocational Teachers of SMK Sarolangun in Integrating 21st Century Skills" is critically important. This study aims to determine vocational teachers' learning-innovation skills and information-media-technology skills in addressing challenges to produce competitive, quality graduates.

Method

This research uses a descriptive quantitative approach to analyze the ability of vocational teachers of SMK Sarolangun in integrating 21st century skills. The quantitative descriptive method was chosen because it allows researchers to describe, examine, and explain observable phenomena using numerical data, with the aim of obtaining an objective picture of the level of teacher ability in implementing 21st century skills. The research process was designed systematically, starting from the preparation stage in March-June 2024, followed by data collection in August-November 2024, data analysis in December 2024, and report preparation in December-January 2025. The main research instrument was a questionnaire that was tested for validity and reliability using SmartPLS version 4, involving 52 respondents in the instrument trial. Figure 2 shows the stages or flow in this study.

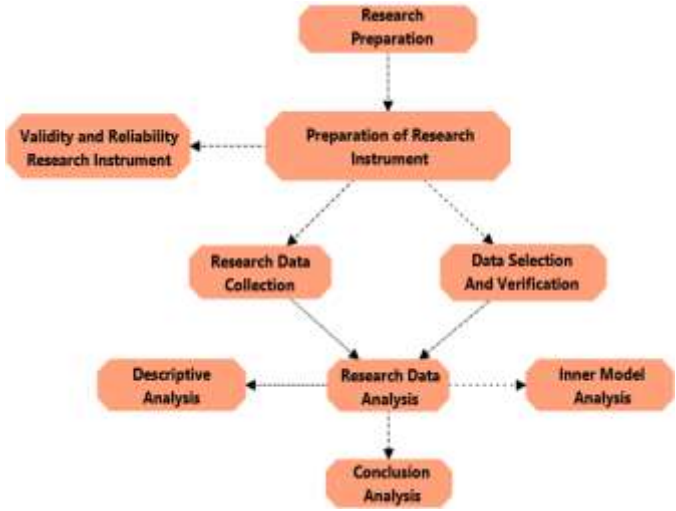

Figure 2. Research Flow

The research population included all principals, vice principals, and heads of expertise competencies from 14 state and 10 private vocational schools in Sarolangun district, totaling 157 people. Sampling was done proportionally using probability sampling techniques, resulting in 110 respondents representing various ranks and schools. The proportional sampling method ensured a balanced representation of all SMKs in the Sarolangun region.

The data analysis technique uses the Partial Least Square-Structural Equation Modeling (PLS-SEM) approach, which allows comprehensive analysis through several stages. First, validity and reliability analyses were conducted to test the quality of the instrument. Second, descriptive analysis was used to describe the level of teacher ability by interpreting the scores based on the percentage of achievement. Structural model analysis was conducted through several critical stages, including R-Square analysis to measure the predictive accuracy of the model, F-Square to determine the relative effects of variables, collinearity analysis, Q-Square to evaluate predictive relevance, and path coefficient and indirect effects analysis. Each stage aims to provide an in-depth understanding of the mechanism of integrating 21st century skills by vocational teachers.

The criteria for interpreting the research scores were divided into five categories: very high (81%-100%), high (61%-80%), moderate (41%-60%), low (21%-40%), and very low (0%-20%). The use of SmartPLS version 4 enables complex statistical analysis, providing a strong empirical basis for understanding and developing vocational teachers' abilities to deal with the demands of 21st century education.

Result and Discussion

The results of the research instrument trial involving 52 respondents using the Smartpls version 4 application using the Partial Least Square-Structural Equation Modeling (PLS-SEM) method. The visualization results of the analysis are shown in Figure 4.1 which shows the complete measurement and structural models.

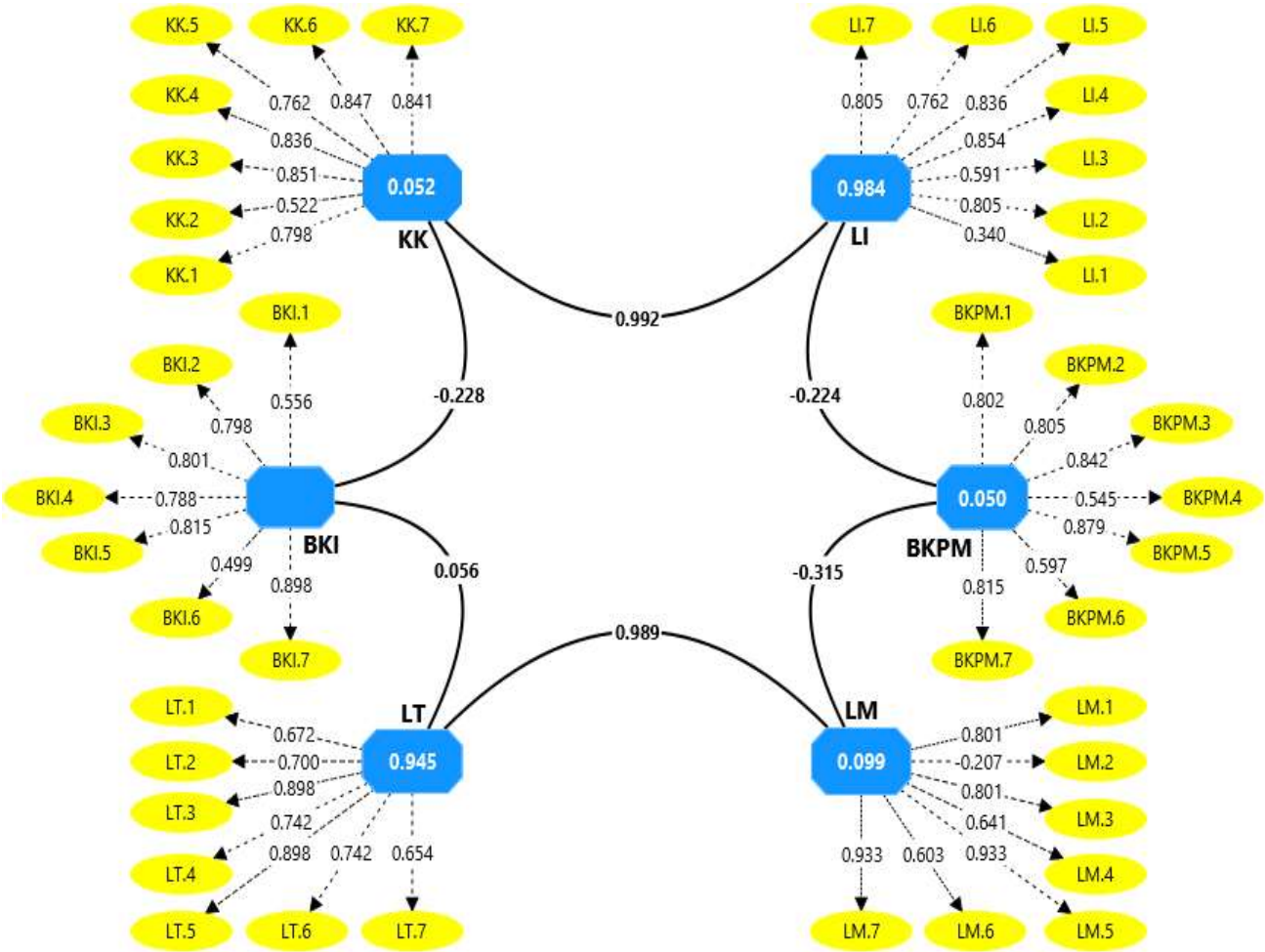

Figure 3. Graphical Output SEM-PLS Instrument Test

Based on Figure 3, it can be seen that the research model consists of 6 main constructs that are interconnected, including KK, LI, BKI, BKPM, LT, and LM. Each construct is measured using 7 indicators which are indicated by their respective loading factors. The strength of the relationship between constructs is shown

through the path coefficient value, where there are several significant relationships such as the relationship between KK and LI (0.992) and LT and LM (0.989). The model also shows the R^2 value for each endogenous construct, with LI having the highest value of 0.984, followed by LM (0.099), KK (0.052), and LT (0.045). Loading factors for each indicator show varying values, but most are above 0.5, indicating good convergent validity. This is in line with the Average Variance Extracted (AVE) value previously reported, where all constructs have values above 0.5. The model structure shown in Figure 4.1 provides a strong basis for further analysis, given the reliability test results previously shown with satisfactory Cronbach's Alpha and Composite Reliability values for all constructs. This indicates that the research instrument has good measurement quality and can be relied upon for further research data collection. More details can be seen in Table 1.

Table 1. *Validity and Reliability Construct*

Variable	*Cronbach's Alpha*	*Composite Reliability*		*Average Variance Extracted* (AVE)
		Rho_a	Rho_c	
BKI	0.898	1.080	0.896	0.561
BKPM	0.898	1.080	0.906	0.584
KK	0.893	0.902	0.918	0.620
LI	0.848	0.885	0.885	0.539
LM	0.804	0.879	0.865	0.549
LT	0.882	0.905	0.906	0.583

Based on the data presented in Table 4.1, it can be explained that the measurement model analysis was carried out to evaluate the two main research constructs, namely Learning and Innovating Skills and Information, Media and Technology Literacy Skills. The results of the construct validity and reliability analysis show very satisfactory values for all research variables. In terms of internal reliability measured by Cronbach's Alpha, all variables show high consistency with values above 0.8. The BKI and BKPM variables have the same highest value of 0.898, followed by KK (0.893), LT (0.882), LI (0.848), and LM (0.804). These values indicate that all constructs have a very good level of reliability.

The composite reliability measurement using two indicators, rho_a and rho_c, also showed very good results. The highest rho_a values are held by BKI and BKPM (both 1.080), while other variables have values above 0.8. For the rho_c value, all variables show high consistency with values above 0.85, where KK has the highest value (0.918), followed by BKPM (0.906) and LT (0.906). Convergent validity measured through Average Variance Extracted (AVE) shows that all constructs have values above the 0.5 threshold. The KK construct has the highest AVE value of 0.620, followed by BKPM (0.584), LT (0.583), BKI (0.561), LM (0.549), and LI (0.539). This shows that each construct is able to explain more than 50% of the variance of its indicators, which indicates good convergent validity. Overall, the results of validity and reliability testing show that all constructs in this study have excellent psychometric properties, so the research instruments can be relied upon for further data collection.

The next data, namely the results of the Learning and Innovation Skills and Information Media and Technology Skills research data involving 105 respondents from 24 SMKs in Sarolangun Regency, can be described as the graphical explanation shown in Figure 4.

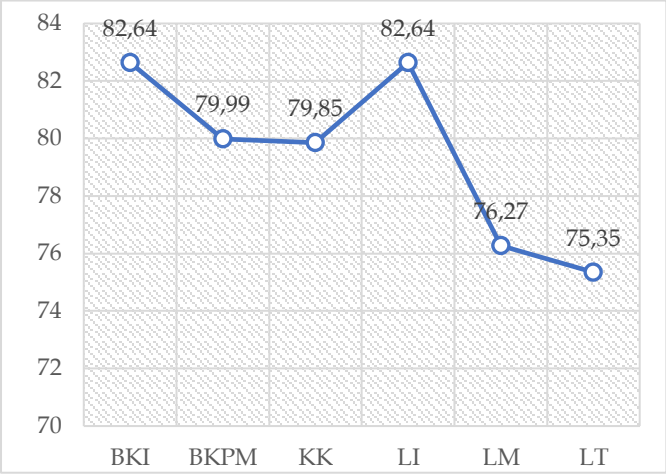

Figure 4. Research Data Graph

Based on Figure 4, it can be seen that the research data graph illustrates the results of the assessment of various 21st century skills based on the perceptions of school leaders in SMK Sarolangun Regency. It can be seen that BKI (Critical Thinking and Innovation) has the highest score of 82.64, followed by BKPM (Critical Thinking and Problem Solving) of 79.99, KK (Communication and Collaboration) of 79.85, LI (Information Literacy) of 82.64, LM (Media Literacy) of 76.27, and LT (Technology Literacy) of 75.35. This graph provides an overall picture of the ability of vocational teachers in SMK Sarolangun to integrate 21st century skills through the perceptions of school leaders. Furthermore, this data will be analyzed using structural model analysis using smartpls version 4 software using the Partial Least Square-Structural Equation Modeling (PLS-SEM) analysis method which is carried out through several critical stages, including R-Square analysis to measure the predictive accuracy of the model, F-Square to determine the relative effect of variables, collinearity analysis, Q-Square to evaluate predictive relevance, as well as path coefficient analysis and indirect effects. The graphical output of the

structural data model analysis (inner model) in this study can be seen in Figure 5.

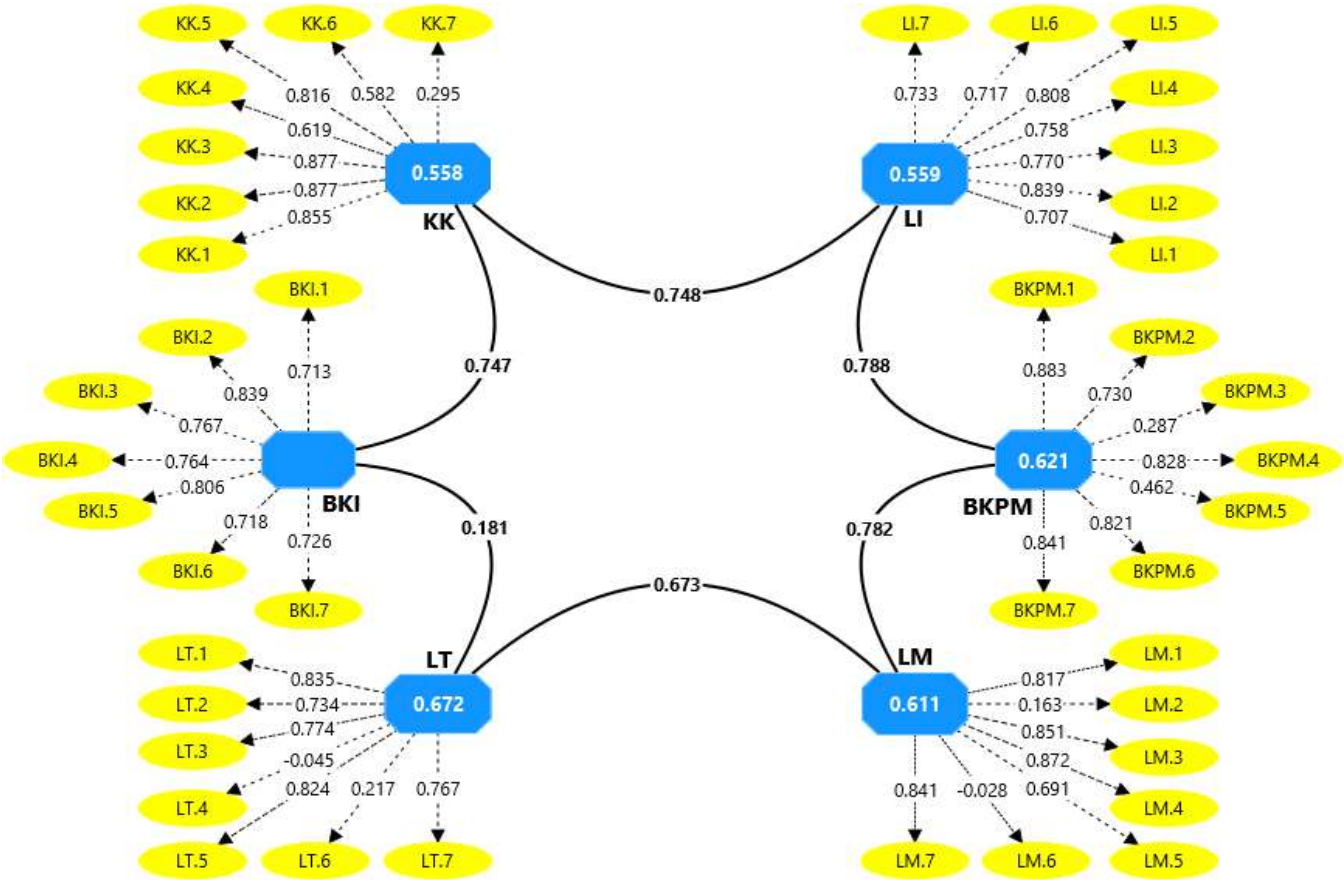

Figure 5. Graphical Output Inner Model Analysis

Based on Figure 5 regarding the results of the structural model analysis (inner model), a complex relationship between the various latent variables in this study can be seen. The model shows the interaction between the four main components, namely Creative Thinking and Innovation (BKI), Information Literacy (LI), Media Literacy (LM), and Technological Literacy (LT), which were analyzed using smartPLS software version 4. In terms of the strength of the relationship between variables, the analysis results show some important findings. The strongest relationship was shown between Information Literacy (LI) and BKPM with a path coefficient of 0.788, followed by the relationship between LI and KK of 0.748. A fairly strong relationship was also seen between KK and LT with a coefficient of 0.747, and between LM and BKPM of 0.782. Meanwhile, the relationship between LM and LT has a path coefficient of 0.673, and between BKI and LT of 0.781, both of which also show a substantial relationship.

This structural model also reveals the R-square (R^2) value for each endogenous latent variable, which illustrates how well the model can explain variations in the data. Technological Literacy (LT) has the highest R^2 value of 0.672, followed by BKPM with 0.621, and Media Literacy (LM) with 0.611. Meanwhile, Information Literacy (LI) and KK have R^2 values of 0.559 and 0.558, respectively. Each latent variable in this model is supported by a number of indicators that contribute to the measurement of that variable. These indicators are indicated by specific codes (e.g. BKI.1 to BKI.7 for the BKI variable) and have varying loading factors, indicating different levels of contribution to the latent variable. Overall, the structural model demonstrates significant and interrelated relationships between variables in the context of information, media and technology skills in SMK Sarolangun district.

The structural model analysis (inner model) in this study consists of R-square (R^2), F-square (F^2) and Collinearity, Q-square (Q^2), Path Coefficient, Indirect Effects, and Total Effects analysis. Based on the results of the R-Square (R^2) analysis shown in Table 2, it can be explained that this research model shows substantial predictive ability in explaining variations in endogenous variables.

Table 2. R-Square (R^2) Result

Variable	R-Square	R-Square Adjusted
BKPM	0.621	0.617
KK	0.558	0.554
LI	0.559	0.555
LM	0.611	0.608
LT	0.672	0.666

The results of the analysis show that the Technological Literacy (LT) variable has the highest R^2 value of 0.672 (adjusted R^2 = 0.666), which indicates that 67.2% of the variation in teachers' technological literacy can be explained by the predictor variables in the model. This suggests that the factors influencing teachers' technological literacy can be predicted with a fairly high level of accuracy. The critical thinking and problem solving variable (BKPM) showed an R^2 value of 0.621 (adjusted R^2 = 0.617), indicating that 62.1% of the variation in teachers' critical thinking and problem solving skills can be explained by the model. Meanwhile, the Media Literacy (LM) variable has an R^2 value of 0.611 (R^2 adjusted = 0.608), which means that 61.1% of the variation in teachers' media literacy skills can be explained by the independent variables in the model. For the Information Literacy (LI) and Creativity and Collaboration (KK) variables, they have R^2 values of 0.559 (R^2 adjusted = 0.555) and 0.558 (R^2 adjusted = 0.554), respectively. These values indicate that about 55.9% of the variation in information literacy skills and 55.8% of the variation in teacher creativity and collaboration aspects can be explained by the model. Although this value is slightly lower than the other variables, it still shows moderate predictive ability.

The relatively small difference between R^2 and R^2 adjusted values (ranging from 0.004 to 0.006) indicates a good model stability and absence of overfitting. Overall, the R^2 values for all endogenous variables are above 0.50, which according to PLS-SEM evaluation criteria demonstrates a moderate to substantial predictive capability of the model in explaining the variation of vocational high school teachers' ability to integrate various 21st-century skill aspects in Sarolangun. Furthermore, based on the F-Square (F^2) and Collinearity analysis results shown in Table 4, it can be explained that the variables in the model have varied effect strengths and acceptable Collinearity levels.

Table 4. F-Square (F^2) and Collinearity Result

Variable	F-Square	VIF
BKI → KK	1.262	1.000
BKI → LT	0.041	2.429
BKPM → LM	1.573	1.000
KK → LI	1.269	1.000
LI → BKPM	1.637	1.000
LM → LT	0.568	2.429

The analysis shows that the Information Literacy (LI) variable has the strongest effect on Critical Thinking and Problem Solving (BKPM) with an F^2 value of 1.637, indicating a very large effect in the structural model. The Critical Thinking and Problem Solving (BKPM) variable also demonstrates a very large effect on Media Literacy (LM) with an F^2 value of 1.573. Similarly, Creativity and Collaboration (KK) have a large effect on Information Literacy (LI) with an F^2 of 1.269, and Creative and Innovative Thinking (BKI) shows a large effect on Creativity and Collaboration (KK) with an F^2 of 1.262. All these values far exceed the 0.35 threshold, indicating a large effect in PLS-SEM analysis.

Media Literacy (LM) has a medium to large effect on Technology Literacy (LT) with an F^2 value of 0.568. Meanwhile, Creative and Innovative Thinking (BKI) shows a relatively small effect on Technology Literacy (LT) with an F^2 value of 0.041, but still above the minimal threshold of 0.02, indicating a meaningful effect. In terms of Collinearity, all variables show Variance Inflation Factor (VIF) values within acceptable limits (< 5). The paths BKI → KK, BKPM → LM, KK → LI, and LI → BKPM each have VIF values of 1.000, indicating no multicollinearity issues. The paths BKI → LT and LM → LT have identical VIF values of 2.429, which is still well below the critical threshold of 5, indicating no significant Collinearity problems in the model. Furthermore, based on the Q-Square (Q^2) analysis results shown in Tables 5 and 6, it can be explained that this research model has good predictive relevance. The Construct Cross-Validated Redundancy analysis (Table 4.8) shows that all endogenous variables have Q^2 values > 0, indicating that the model has adequate predictive relevance.

Tabel 5. Construct Corss-Validated Redudancy

Variable	SSO	SSE	Q^2 (=1-SSE/SSO)
BKI	735.000	735.000	0.000
BKPM	735.000	512.112	0.303
KK	735.000	525.861	0.285
LI	735.000	507.465	0.310
LM	735.000	529.047	0.280
LT	735.000	522.745	0.289

In Table 5, the Information Literacy (LI) variable shows the highest Q^2 value of 0.310, followed by Critical Thinking and Problem Solving (BKPM) with a value of 0.303. Technology Literacy (LT) has a Q^2 value of 0.289, Creativity and Collaboration (KK) of 0.285, and Media Literacy (LM) of 0.280. These values range from 0.25 to 0.50, indicating medium predictive relevance for all endogenous variables. The Creative and Innovative Thinking (BKI) variable has a value of 0.000 as it is an exogenous variable in the model. Meanwhile, the Construct Cross-Validated Communality analysis (Table 4.7) shows higher Q^2 values for all variables.

Creative and Innovative Thinking (BKI) and Information Literacy (LI) show the highest Q^2 values of 0.441 and 0.440, respectively, followed by Creativity and Collaboration (KK) at 0.402, and Critical Thinking and Problem Solving (BKPM) at 0.391. Media Literacy (LM) and Technology Literacy (LT) demonstrate lower but still substantial Q^2 values of 0.352 and 0.309, respectively.

Table 6. Construct Corss-Validated Communality

Variable	SSO	SSE	Q^2 (=1-SSE/SSO)
BKI	735.000	410.976	0.441
BKPM	735.000	447.302	0.391
KK	735.000	439.834	0.402
LI	735.000	411.267	0.440
LM	735.000	475.955	0.352
LT	735.000	508.198	0.309

Overall, the Q^2 analysis results from both redundancy and communality confirm that the model has good predictive ability in explaining the variation of vocational high school teachers' ability to integrate 21st-century skills in Sarolangun. The positive and substantial Q^2 values for all variables indicate that the model can accurately predict the indicators in the endogenous variable blocks. Furthermore, based on the Path Coefficient analysis shown in Table 7, it can be explained that the majority of variable relationships in the model show significant and positive influences.

Table 7. Path Coefficient Result

Variable	*Original Sample* (O)	*Sample Mean* (M)	*Standard Deviation* (STDEV)	*T statistics* (|O/STDEV|)	P Values
BKI → KK	0.747	0.757	0.048	15.711	0.000
BKI → LT	0.181	0.182	0.094	1.922	0.055
BKPM → LM	0.782	0.789	0.046	16.906	0.000
KK → LI	0.748	0.758	0.047	16.049	0.000
LI → BKPM	0.788	0.794	0.041	19.049	0.000
LM → LT	0.673	0.677	0.088	7.632	0.000

The analysis shows the strongest relationship between Information Literacy (LI) and Critical Thinking and Problem Solving (BKPM) with a path coefficient of 0.788 (t-statistic = 19.049, $p < 0.001$), indicating that an increase in teachers' information literacy substantially enhances their critical thinking and problem-solving abilities. A strong relationship was also found between Critical Thinking and Problem Solving (BKPM) and Media Literacy (LM) with a path coefficient of 0.782 (t-statistic = 16.906, $p < 0.001$), showing a significant positive influence of critical thinking on teachers' media literacy. Similarly, Creativity and Collaboration (KK) have a strong positive influence on Information Literacy (LI) with a path coefficient of 0.748 (t-statistic = 16.049, $p < 0.001$), and Creative and Innovative Thinking (BKI) has a strong positive influence on Creativity and Collaboration (KK) with a path coefficient of 0.747 (t-statistic = 15.711, $p < 0.001$).

Media Literacy (LM) shows a significant positive influence on Technology Literacy (LT) with a path coefficient of 0.673 (t-statistic = 7.632, $p < 0.001$). Meanwhile, the relationship between Creative and Innovative Thinking (BKI) and Technology Literacy (LT) shows a weaker and marginally significant influence with a path coefficient of 0.181 (t-statistic = 1.922, $p = 0.055$). Overall, the Path Coefficient analysis confirms strong and significant relationships among variables in the model, with almost all paths showing t-statistic values above 1.96 and p-values below 0.05, except for the BKI → LT relationship, which shows marginal significance. These findings support the research hypothesis about the interconnectedness of various aspects of teachers' abilities in integrating 21st-century skills at Sarolangun Vocational High School. Furthermore, based on the Indirect Effects analysis shown in Table 8, it can be explained that there are significant indirect effects among variables in this research model.

Table 8. Indirect Effects Result

Variable	*Original Sample* (O)	*Sample Mean* (M)	*Standard Deviation* (STDEV)	*T statistics* (|O/STDEV|)	P Values
BKI → BKPM	0.440	0.459	0.072	6.138	0.000
BKI → LI	0.559	0.576	0.071	7.885	0.000
BKI → LM	0.344	0.363	0.068	5.047	0.000
BKI → LT	0.232	0.246	0.055	4.236	0.000
BKPM → LT	0.526	0.534	0.078	6.780	0.000
KK → BKPM	0.589	0.603	0.060	9.862	0.000

Variable	*Original Sample* (O)	*Sample Mean* (M)	*Standard Deviation* (STDEV)	*T statistics* (|O/STDEV|)	P Values
KK → LM	0.461	0.477	0.065	7.085	0.000
KK → LT	0.310	0.323	0.059	5.257	0.000
LI → LM	0.616	0.628	0.061	10.020	0.000
LI → LT	0.415	0.425	0.067	6.146	0.000

The analysis shows that all indirect paths have t-statistic values above 1.96 and p-values below 0.05, indicating statistical significance of all mediation effects. The strongest indirect effect was found between Information Literacy (LI) and Media Literacy (LM) with a coefficient of 0.616 (t-statistic = 10.020, $p < 0.001$), followed by the relationship between Creativity and Collaboration (KK) and Critical Thinking and Problem Solving (BKPM) with a coefficient of 0.589 (t-statistic = 9.862, $p < 0.001$). This indicates a strong mediation role in the relationships between these variables. Creative and Innovative Thinking (BKI) showed substantial indirect effects on Information Literacy (LI) with a coefficient of 0.559 (t-statistic = 7.885, $p < 0.001$), and Critical Thinking and Problem Solving (BKPM) had significant indirect effects on Technology Literacy (LT) with a coefficient of 0.526 (t-statistic = 6.780, $p < 0.001$). Moderate mediation effects were found on the paths from Information Literacy (LI) to Technology Literacy (LT) with a coefficient of 0.415 (t-statistic = 6.146, $p < 0.001$), and from Creative and Innovative Thinking (BKI) to Critical Thinking and Problem Solving (BKPM) with a coefficient of 0.440 (t-statistic = 6.138, $p < 0.001$). Smaller but still significant indirect effects were found on the BKI → LT path (0.232, t-statistic = 4.236, $p < 0.001$).

Overall, the Indirect Effects analysis confirms the existence of complex mediation mechanisms in the model, where the influence of one variable on another is often mediated through one or more intermediary variables. These findings enrich the understanding of how various aspects of teachers' abilities in integrating 21st-century skills are interconnected and influence each other through direct and indirect effects. Furthermore, based on the Total Effects analysis shown in Table 9, it can be explained that there are significant total effects among variables in the model, which are a combination of direct and indirect effects. All relationships show t-statistic values above 1.96 and p-values below 0.05, indicating the statistical significance of all total effects.

Table 9. Total Effects Result

Variable	*Original Sample* (O)	*Sample Mean* (M)	*Standard Deviation* (STDEV)	*T statistics* (|O/STDEV|)	P Values
BKI → BKPM	0.440	0.459	0.072	6.138	0.000
BKI → KK	0.747	0.757	0.048	15.711	0.000
BKI → LI	0.559	0.576	0.071	7.885	0.000
BKI → LM	0.344	0.363	0.068	5.047	0.000
BKI → LT	0.412	0.428	0.085	4.848	0.000
BKPM → LM	0.782	0.789	0.046	16.906	0.000
BKPM → LT	0.526	0.534	0.078	6.780	0.000
KK → BKPM	0.589	0.603	0.060	9.862	0.000
KK → LI	0.748	0.758	0.047	16.049	0.000
KK → LM	0.461	0.477	0.065	7.085	0.000
KK → LT	0.310	0.323	0.059	5.257	0.000
LI → BKPM	0.788	0.794	0.041	19.049	0.000
LI → LM	0.616	0.628	0.061	10.020	0.000
LI → LT	0.415	0.425	0.067	6.146	0.000
LM → LT	0.673	0.677	0.088	7.632	0.000

The strongest total effects were found in the relationship between Information Literacy (LI) and Critical Thinking and Problem Solving (BKPM) with a coefficient of 0.788 (t-statistic = 19.049, $p < 0.001$), followed by Critical Thinking and Problem Solving (BKPM) towards Media Literacy (LM) with a coefficient of 0.782 (t-statistic = 16.906, $p < 0.001$). This highlights the crucial role of information literacy in developing teachers' critical thinking and problem-solving abilities. Creative and Innovative Thinking (BKI) showed strong total effects on Creativity and Collaboration (KK) with a coefficient of 0.747 (t-statistic = 15.711, $p < 0.001$), and Creativity and Collaboration (KK) had significant total effects on Information Literacy (LI) with a coefficient of 0.748 (t-statistic = 16.049, $p < 0.001$). Media Literacy (LM) also demonstrated substantial total effects on Technology Literacy (LT) with a coefficient of 0.673 (t-statistic = 7.632, $p < 0.001$).

Moderate total effects were found on several paths, such as BKPM → LT (0.526, t-statistic = 6.780), BKI → LI (0.559, t-statistic = 7.885), and LI → LM (0.616, t-statistic = 10.020). Meanwhile, smaller but still significant total

effects were discovered on paths like KK → LT (0.310, t-statistic = 5.257) and BKI → LM (0.344, t-statistic = 5.047). Overall, the Total Effects analysis provides a comprehensive overview of variable interconnections in the model, demonstrating that developing teachers' abilities to integrate 21st-century skills is an interconnected and complex process where improvements in one ability aspect can positively impact other aspects, both directly and indirectly.

Based on the research analysis of vocational high school teachers' ability to integrate 21st-century skills in Sarolangun, several key findings can be connected to previous research. The study shows that information literacy significantly influences teachers' critical thinking and problem-solving abilities, with a path coefficient of 0.788. This aligns with Makhrus et al. (2018), who emphasized the importance of teachers' ability to design learning to develop students' skills. Another interesting finding is the strong relationship between creativity and collaboration with information literacy (path coefficient 0.748), supporting Wijanarko et al. (2024) research on 4C skill development (Communication, Collaboration, Critical Thinking, and Creativity). Structural analysis revealed that media and technology literacy are closely interconnected, with Media Literacy significantly influencing Technology Literacy (path coefficient 0.673), consistent with Virijai and Asrizal (2023) research on technology integration in learning.

This research provides a unique contribution to understanding the complexity of 21st-century skill development among vocational teachers. The highest R-Square value for Technology Literacy (0.672) indicates that variables in the model can explain 67.2% of teachers' technology literacy ability variation. This is consistent with Pertiwi et al. (2021) study on teacher technological capabilities but offers deeper insights into inter-competency interconnections. Indirect effects analysis revealed complex mediation mechanisms, where improving one skill can impact others. For instance, Information Literacy has a strong indirect effect on Media Literacy (0.616), supporting Sari et al. (2023) research on innovative approaches to developing 21st-century skills. Overall, the research reinforces the argument that 21st-century skill development for teachers is a holistic and interconnected process. Findings underscore the need for a comprehensive approach to teacher training and professional development, focusing on integrating critical thinking, creativity, information, media, and technology literacy skills.

Conclusion

This research examining vocational high school teachers' abilities to integrate 21st-century skills in Sarolangun through school leadership perceptions reveals a complex, interconnected relationship between key competencies. Analysis of 105 respondents from 24 vocational schools found strong critical thinking and innovation capabilities (82.64), alongside substantial information literacy (82.64), media literacy (76.27), and technology literacy (75.35) skills. The structural model demonstrates significant relationships between variables, with information literacy strongly influencing critical thinking and problem-solving (path coefficient 0.788), critical thinking affecting media literacy (0.782), creative thinking impacting collaboration (0.747), and media literacy influencing technology literacy (0.673). Model validation confirms substantial predictive capabilities with R^2 values ranging from 0.558 to 0.672, robust F^2 metrics (0.041-1.637), acceptable VIF values (1.000-2.429), and significant Q^2 indicators (0.280-0.441), collectively indicating that enhancing one competency area positively affects others through both direct and indirect pathways, suggesting the need for holistic professional development approaches that integrate critical thinking, creativity, information literacy, media literacy and technology skills among vocational teachers.

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Author Contributions

Dessy Marlyna contributed to conceptualization, methodology, and initial manuscript drafting. Jonni Mardizal and M. Giatman contributed to data validation, formal analysis, manuscript review, and editing. Waskito was responsible for investigation, resources, and data curation. All authors have read and approved the final published manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest in this research. No personal circumstances or interests could be perceived as influencing the representation or interpretation of the reported research results.

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