JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Managing the Digital Competency of Educators and Students in the Age of Educational Transformation

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Received: May 24, 2025
Revised: July 22, 2025
Accepted: August 25, 2025
Published: August 31, 2025

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DOI: 10.29303/jppipa.v11i8.12266

Abstract: The education system is required to adapt to accommodate these developments and optimize students' digital competencies. Therefore, strengthening digital competencies is an urgent need in education to produce graduates who are ready to face global challenges.This study aims to analyze the relationship between students' digital competence and digital competence management towards digital education transformation at the Nias Regional Government Private Vocational School. The issues raised in this study are the low digital skills of students and the suboptimal management of digital competence by schools in supporting technology-based learning. This study uses a quantitative approach with a correlational method. The data collection technique was carried out by distributing questionnaires to grade XI students of the Nias Regional Government Private Vocational School, with a sample of 156 respondents taken using proportional random sampling technique. Data analysis was carried out using simple and multiple linear regression. The results of the study indicate a positive and significant relationship between students' digital competence towards digital education transformation, as well as between digital competence management towards digital education transformation. Simultaneously, these two variables contribute significantly to the acceleration of digital-based education transformation in the vocational school environment.

Keywords: Digital competency management; Digital education transformation; Student digital competency; Vocational education; Vocational school

Introduction

The digital era demands educational transformation to prepare "digital natives" with strong digital competencies, including ethics, information literacy, and technology adaptation. For Vocational High Schools (SMK), digital competency is crucial for competitiveness in the Industry 4.0 and Society 5.0 eras (Kholifah et al., 2025; Alayda et al., 2022). Effective digital competency management in vocational schools requires infrastructure, teacher capacity building, and learning that supports digital literacy. However, many vocational schools, particularly in rural areas, face challenges such as limited device access (Ahiaku et al., 2025; Liu et al., 2024; X. Wang et al., 2024), uneven internet access, and minimal teacher training. SMKS Pembda Nias in Gunungsitoli also faces these challenges, resulting in low student performance and a lack of a structured digital competency management system. Despite the existence of the Merdeka Belajar policy, its implementation is hampered by school readiness and resources (Tomasouw et al., 2024; Putri Lestari et al., 2023). Successful ICT integration depends on infrastructure, teacher capacity, a responsive

How to Cite:
Zai, D., Giatman, M., Ambiyar, & Irfan, D. (2025). Managing the Digital Competency of Educators and Students in the Age of Educational Transformation. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 989–997. https://doi.org/10.29303/jppipa.v11i8.12266

curriculum, and effective school management (Hennessy et al., 2022; Obied, 2025). SMKS Pembda Nias, a vocational education institution located in the Gunungsitoli region, also faces these challenges.

Based on initial observations and informal interviews with teachers, it was found that limited digital devices, unequal internet access, and minimal digital training for teachers are the main obstacles to implementing technology-based learning (Mustafa et al., 2024; Muhazir & Retnawati, 2020). This impacts students' ability to utilize technology optimally to support the learning process. Furthermore, the lack of a structured digital competency management system leads to disparities in digital proficiency among students (F. Wang et al., 2024). National policies such as the "Merdeka Belajar" (Freedom to Learn) initiative initiated by the Ministry of Education, Culture, Research, and Technology have opened up opportunities for schools to be more adaptive to technology. However, the implementation of this policy still faces challenges, particularly in terms of school readiness and available resources (Jahreie, 2023; Brown, 2024). Hunter et al. (2022) and Iachini et al. (2023), emphasized that the success of ICT integration in education is largely determined by three main factors: the availability of supporting infrastructure, increased capacity of teaching staff, and a curriculum that is responsive to technological developments. Furthermore, a study by Haleem et al. (2022) and Gkrimpizi et al. (2023), added that the success of school digitalization programs also depends heavily on the effectiveness of school management in facilitating the planning, monitoring, and evaluation of digital programs based on local needs (Schmid et al., 2023; Bitar & Davidovich, 2024; Witthöft et al., 2024).

Based on these issues, this study aims to analyze the management of students' digital competencies at SMKS Pembda Nias. The research focuses on aspects of school management strategies, the role of teachers in digital learning, and the readiness of existing infrastructure. The results are expected to contribute to strengthening internal school policies and serve as a reference for developing technology-based learning in vocational schools in island regions such as Nias.

Method

Research Schedule

The research will be conducted at the Nias Regional Government Private Vocational School (SMK) in Gunungsitoli, North Sumatra, from January to June 2025.

Research Type

This research uses a quantitative approach with a correlational and cross-sectional design. The goal is to measure and explain the relationships between the variables studied at a specific point in time, without manipulation.

Research Population and Sample

Population

The population of this study was all 11th-grade students of the Nias Regional Government Private Vocational School, totaling 256 students spread across 8 classes (TIK, DPIB, TAV, TKR, TSM).

Sample

The sample size for this study was 156 students, calculated using the Slovin formula with a 5% margin of error.

Sampling Technique

A non-probability sampling technique was used with a purposive sampling strategy, meaning that not all members of the population had an equal chance of being selected.

Operational Definition

This research transforms abstract concepts into measurable indicators: Digital Education Transformation (Y): The transformation of a conventional education system into a digitally adaptive one to improve learning quality, measured through the use of technology, curriculum adaptation, innovation, collaboration, and the role of technology; Student Digital Competence (X1): Students' ability to use digital technology effectively, safely, and responsibly, measured through technical skills, digital literacy, independence, collaboration, and the use of digital learning resources; Digital Competence Management (X2): The school's strategic process for planning, developing, and supporting the improvement of students' digital competencies, measured through digitalization policies, training, infrastructure, stakeholder engagement, and digital regulations.

Research Instrument

The main instrument was a closed-ended questionnaire using a 5-point Likert scale (Strongly Disagree to Strongly Agree). Each variable had 40 items (120 items in total). The instrument was structured based on a grid, validated by supervisors, and pilot-tested.

Validity Test

All 120 items were declared valid, meaning the correlation between the indicator scores and the total

variable scores was significant (calculated r ≥ table r at a significance level of 0.05).

Reliability Test

All variables (Y, X1, X2) showed Cronbach's Alpha values above 0.960, indicating the instrument has very high reliability and consistency.

Data Collection Techniques

Data were collected through written questionnaires completed by respondents themselves.

Data Analysis Techniques

Data were analyzed using SPSS version 30 software with multiple linear regression (OLS). The analysis included:

Descriptive Analysis

Describing data using tables, graphs, and basic statistical calculations (mean, minimum, maximum).

Classical Assumption Tests

Normality: Testing the distribution of residuals (coefficient of variance <30%); Linearity: Testing the linear relationship between variables (linearity significance <0.05); Multicollinearity: Tests the correlation between independent variables (tolerance value > 0.10 or VIF < 10).

Hypothesis Testing

Simultaneous Test (F Test): Tests the effect of independent variables simultaneously on the dependent variable; Individual Significance Test (t Test): Tests the effect of each independent variable on the dependent variable; Correlation Coefficient (R): Measures the strength and direction of the relationship between variables; Coefficient of Determination (R^2): Shows the percentage of variation in the dependent variable explained by the independent variables; Multiple Linear Regression: Predicts the simultaneous or individual effect of multiple independent variables on a single dependent variable.

Result and Discussion

The results of this study are as follows:

Data Description

The following description presents the research data, which includes Digital Education Transformation (Y) as the dependent variable and Student Digital Competence (X1) and Digital Competence Management (X2) as the independent variables. This data description is conducted to describe the condition of each variable, including the mean score, median, mode, standard deviation, minimum score, maximum score, and total score (sum). The statistical calculations of the collected data for the three variables can be seen in Table 1.

Table 1. Description of Research Data Y, X1 and X2

		Statistics		
		Digital Education Transformation (Y)	Students' Digital Competence (X1)	Digital Competence Management (X2)
N	Valid	156	156	156
	Missing	0	0	0
Mean		165.65	163.26	165.51
Std. Error of Mean		2.39	2.373	2.560
Median		165.50	161.00	166.50
Mode		160	160	160
Std. Deviation		29.86	29.641	31.973
Variance		892.034	878.582	1022.264
Range		160	160	160
Minimum		40	40	40
Maximum		200	200	200
Sum		25842	25469	25819

Based on Table 1, the data for these three variables are described as follows:

Digital Education Transformation (Y)

Based on the Career Planning variable data, the distribution of scores is spread from a minimum of 40 to a maximum of 200. From 156 respondents (N = 156), the mean score is 165.65, the median is 165.5, the most frequently occurring score (mode) is 160, the standard deviation is 29.86, and the variance is 892.03. To present the Digital Education Transformation (Y) data in the form of a frequency distribution and histogram, it is necessary to determine the number of classes and their class intervals as follows:

Many classes (k) = 1 + 3.3 Log N
= 1 + 3.30 Log 156
= 1 + 3.30 x 2.19
= 1 + 7.23 = 7.30 taken 7

$$Interval = \frac{Highest\ value - Lowest\ value}{Many\ classes} = \frac{200 - 40}{7} = 22.85\ taken\ 23 \quad (1)$$

Table 2. Frequency Distribution of Digital Education Transformation Variable Scores (Y)

Interval Class (Y)	Frequency	Percentage (%)
40-59	3	2
60-79	2	1
80-99	1	1
100-119	4	3
120-139	9	6
140-159	24	15
160-179	67	43
180-200	46	29
Total	156	100

By paying attention to Table 2 above, a histogram of Digital Education Transformation can be depicted as shown in Figure 2.

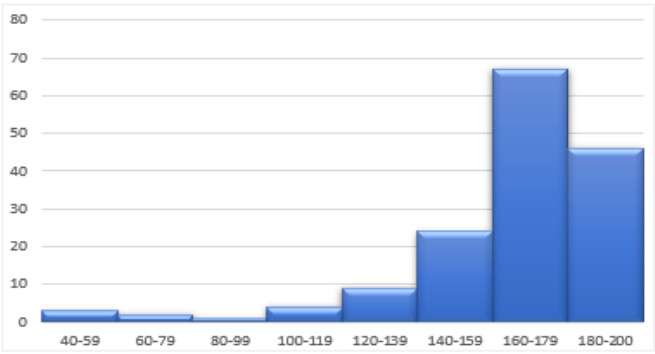

Figure 1. Histogram of digital education transformation

Based on Table 2, which displays the frequency distribution of scores for the Digital Education Transformation (Y) variable, it can be seen that the majority of respondents scored high in the digital education transformation aspect. Of the 156 respondents, only a small proportion scored at the lowest levels. Specifically, 3 respondents (2%) fell within the 40–59 range, 2 respondents (1%) fell within the 60–79 range, and 1 respondent (1%) fell within the 80–99 range. This indicates that only 4% of respondents fell within the very low digital transformation category. Furthermore, 4 respondents (3%) fell within the 100–119 range, and 9 respondents (6%) fell within the 120–139 range. Although still relatively small, this group reflects a small proportion of respondents who fall within the moderate category regarding the implementation of digital transformation in education.

Student Digital Competence (X1)

Based on the Student Digital Competence variable data, the distribution of scores is known to range from a minimum of 40 to a maximum of 200. From 156 respondents (N = 156), the mean score is 163.26, the median is 161, the most frequently occurring score (mode) is 160, the standard deviation is 29.461, and the variance is 878.582. To present Student Digital Competence data in the form of a frequency distribution and histogram, it is necessary to determine the number of classes and their class intervals as follows:

Many classes (k) = 1 + 3.30 Log N
= 1 + 3.30 Log 156
= 1 + 3.30 x 2.19
= 1 + 7.23 = 7.30 taken 7

$$Interval = \frac{Highest\ value - Lowest\ value}{Many\ classes} = \frac{200 - 40}{7} = 22.85\ taken\ 23 \quad (2)$$

Table 3. Frequency Distribution of Students' Digital Competence Variable Scores (X1)

Interval Class (Y)	Frequency	Percentage (%)
40-59	2	1
60-79	2	1
80-99	3	2
100-119	4	3
120-139	10	6
140-159	30	19
160-179	58	37
180-200	47	30
Total	156	100

By paying attention to Table 3 above, the Attitude histogram can be depicted as shown in Figure 2.

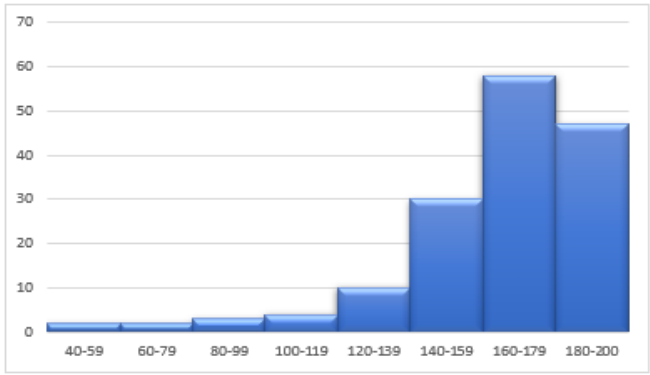

Figure 2. Histogram of student digital competence

Based on Table 3, the frequency distribution of scores for the Student Digital Competence variable (X1), it can be seen that the majority of students demonstrated a fairly high level of digital competence. Of the 156 respondents, only a small proportion had a low level of digital competence. Two respondents (1%) fell within the 40–59 range, and two other respondents (1%) fell within the 60–79 range. Furthermore, only three

respondents (2%) fell within the 80–99 range, and four respondents (3%) fell within the 100–119 range. These groups represent students who still have limitations in digital skills, both in terms of technological literacy, use of digital devices, and utilization of digital-based learning resources. Conversely, the number of respondents began to increase significantly in the 120–139 range, with 10 respondents (6%). Meanwhile, the largest distribution was found in the 140–159 interval (30 respondents) with 30 respondents, followed by 58 respondents (37%) in the 160–179 interval (160–179), and the highest interval (47 respondents) with 180–200. These three intervals indicate that more than 86% of respondents have high to very high levels of digital competence. This indicates that the majority of students have mastered basic and advanced skills in using digital technology to support their learning, such as accessing online information, using learning application software, and utilizing digital platforms for communication and collaborative work.

Digital Competency Management (X2)

Based on the Digital Competency Management variable data, the score distribution ranges from a minimum of 40 to a maximum of 200. From 156 respondents (N = 156), the mean score is 165.51, the median is 166.5, the most frequently occurring score (mode) is 160, the standard deviation is 31.973, and the variance is 1022.264. To present the Digital Competency Management data in the form of a frequency distribution and histogram, it is necessary to determine the number of classes and their class intervals as follows:

Many classes (k) = 1 + 3.30 Log N
= 1 + 3.30 Log 163
= 1 + 3.30 x 2.19
= 1 + 7.23 = 7.30 taken 7

$$Interval = \frac{Highest\ value - Lowest\ value}{Many\ classes} = \frac{200-40}{7} = 22.85\ taken\ 23 \quad (3)$$

Table 4. Frequency Distribution of Digital Competence Management Scores (X2)

Interval Class (X2)	Frequency	Percentage (%)
40-59	2	1
60-79	3	2
80-99	3	2
100-119	5	3
120-139	6	4
140-159	14	9
160-179	63	40
180-200	60	38
Total	156	100

By paying attention to Table 4. above, a histogram of Digital Competence Management can be depicted as shown in Figure 3.

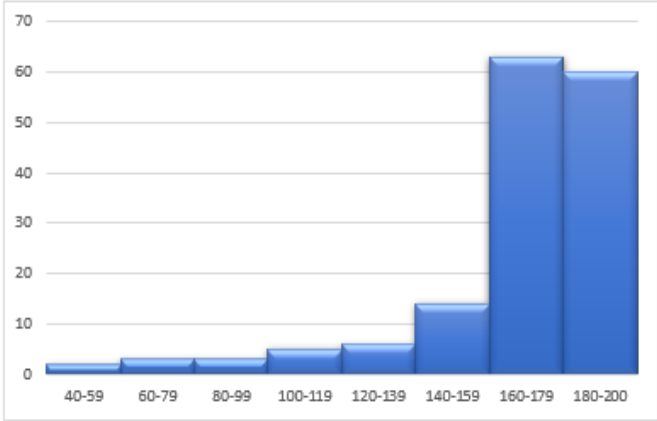

Figure 3. Histogram of digital competency management

Based on Table 4, which presents the frequency distribution of scores for the Digital Competency Management variable (X2), it can be seen that the majority of respondents have a high perception of the quality of digital competency management in the school environment. Of the 156 respondents, only a small proportion fell into the low category. Two respondents (1%) fell in the 40–59 score range, followed by three respondents (2%) in the 60–79 range, and three respondents (2%) in the 80–99 range. Furthermore, five respondents (3%) fell in the 100–119 range, and six respondents (4%) in the 120–139 range. These groups reflect that only 12% of respondents considered digital competency management in schools to be suboptimal. The number of respondents began to increase significantly in the 140–159 range, with 14 respondents (9%), indicating a group that began to perceive improved digital competency management efforts. The distribution peaks in the two highest intervals: 160–179 with 63 respondents (40%) and 180–200 with 60 respondents (38%). This means that 123 of the 156 respondents, or approximately 78%, assessed that digital competency management in their schools was at a high to very high level. This distribution indicates that the majority of schools have implemented effective management strategies to improve students' digital competency.

Discussion

This discussion interprets the research findings regarding the relationship between Student Digital Competence (X1) and Digital Competency Management (X2) and Digital Education Transformation (Y) at SMKS Pembda Nias.

Relationship of Student Digital Competence to Digital Education Transformation

The study found a very strong and significant relationship ($r = 0.811$, $p < 0.001$) between Student Digital Competence (X1) and Digital Education Transformation (Y). This indicates that students with strong digital competencies (technical, cognitive (Zhao et al., 2021; Spante et al., 2018), and ethical skills) tend to adapt more quickly to digital learning (Laufer et al., 2021; Hervás-Torres et al., 2024; Gerlich, 2025), become proactive, and play an active role in creativity and collaboration. Each one-unit increase in students' digital competency increases digital education transformation by 0.817 units. This finding is consistent with theory and previous research, confirming that students are the primary drivers of digital transformation. Consequently, SMKS Pembda Nias needs to continue strengthening students' digital competencies through training, adequate internet access, and technology integration in learning (Timotheou et al., 2023; Paul et al., 2024).

Relationship between Digital Competency Management and Digital Education Transformation

There is a strong and significant relationship ($r = 0.751$, $p < 0.001$) between Digital Competency Management (X2) and Digital Education Transformation (Y). This means that good digital management by the school (strategic planning, training, infrastructure, stakeholder engagement, regulations) contributes significantly to the success of the transformation (Toukola & Ahola, 2022; Prebanić & Vukomanović, 2023). Each one-unit increase in digital competency management increases digital education transformation by 0.702 units. All digital management indicators at SMKS Pembda Nias are in the high category, demonstrating the seriousness of the school's management. These findings align with the view that digital educational transformation requires a comprehensive management approach (Ben Youssef et al., 2022; Wei, 2023). Schools must continue to strengthen digital strategic planning, ongoing training, and collaboration to support relevant education in the digital age (Nikou et al., 2022; Imjai et al., 2024; Scheel et al., 2022).

The Joint Relationship between Student Digital Competence and Digital Competence Management to Digital Education Transformation

Student Digital Competence (X1) and Digital Competence Management (X2) simultaneously have a very strong and significant relationship to Digital Education Transformation (Y). These two variables explain 71.8% of the variation in digital education transformation ($R^2 = 0.718$), with a multiple correlation (R) value of 0.847. The F-test results (194.652, $p < 0.001$) confirm that this regression model is highly significant. This indicates that digital transformation requires synergy between individual (student) and institutional (school management) readiness (Müller & Wulf, 2020). Student competency influences the effectiveness of technology use, while school management determines direction and support (Dang et al., 2024). Consequently, SMKS Pembda Nias needs to develop both aspects simultaneously, through curriculum strengthening, teacher/student training, infrastructure, and adaptive digital management policies, to create relevant and inclusive technology-based education (Kayanja et al., 2025; Verhoef et al., 2021; Hwabamungu & Shepherd, 2024).

Research Limitations

This study has several limitations: Single location: Conducted only at SMKS Pembda Nias, limiting generalizability; Subjective instrument: Likert-scale questionnaires are susceptible to respondent perception bias; Solely quantitative approach: Does not capture the depth of experience or dynamics of digital implementation; Limited variables: Does not include other factors such as teacher competence, parental support, or the influence of the national curriculum; Short timeframe: Cross-sectional data does not capture long-term developments; Uncontrolled external factors: Network disruptions, socioeconomic conditions, and policy changes can influence the results. It is hoped that future research can address these limitations by expanding the scope, using mixed methods, adding relevant variables, and conducting longitudinal studies.

Conclusion

Based on the analysis, it was concluded that students' digital competence and the school's management of digital competence have a strong and significant relationship with the digital education transformation at the Nias Regional Government Private Vocational High School (SMK Pembda Nias). Students' digital competence (literacy, device mastery, creativity) strongly supports technology-based learning. Meanwhile, school digital management (policies, training, infrastructure, stakeholder engagement) plays a significant role in strengthening this transformation. These two factors together explain more than 70% of the variation in digital education transformation. Therefore, the success of technology integration in education depends on the synergy between student readiness and effective digital management strategies. Continuous improvement in both aspects is crucial for optimal and adaptive digital education transformation.

Acknowledgments
We would like to thank all parties who supported this research. We hope this research is useful.

Author Contributions
Conceptualization; methodology; validation; formal analysis; investigation; resources; data curation: writing—original draft preparation; writing—review and editing; visualization: D. T., M. G., A., D. I. All authors have read and approved the published version of the manuscript.

Funding
The researchers independently funded this research.

Conflicts of Interest
The researchers independently funded this research.

References

Ahiaku, P. K. A., Uleanya, C., & Muyambi, G. C. (2025). Rural schools and tech use for sustainability: The challenge of disconnection. *Education and Information Technologies*, *30*(9), 12557–12571. https://doi.org/10.1007/s10639-024-13311-9

Alayda, F. I., Sudira, P., & Mutohhari, F. (2022). Competency of Vocational Education Teachers in the Society Era 5.0. *Jurnal Pendidikan Dan Pengajaran*, *55*(3), 587–598. https://doi.org/10.23887/jpp.v55i3.46812

Ben Youssef, A., Dahmani, M., & Ragni, L. (2022). ICT Use, Digital Skills and Students' Academic Performance: Exploring the Digital Divide. *Information*, *13*(3), 129. https://doi.org/10.3390/info13030129

Bitar, N., & Davidovich, N. (2024). Transforming Pedagogy: The Digital Revolution in Higher Education. *Education Sciences*, *14*(8), 811. https://doi.org/10.3390/educsci14080811

Brown, C. P. (2024). Policy Justice Through Critical Qualitative Inquiry: Examining the Issue of School Readiness. *Qualitative Inquiry*, *30*(1), 59–70. https://doi.org/10.1177/10778004231163167

Dang, T. D., Phan, T. T., Vu, T. N. Q., La, T. D., & Pham, V. K. (2024). Digital competence of lecturers and its impact on student learning value in higher education. *Heliyon*, *10*(17), e37318. https://doi.org/10.1016/j.heliyon.2024.e37318

Gerlich, M. (2025). AI Tools in Society: Impacts on Cognitive Offloading and the Future of Critical Thinking. *Societies*, *15*(1), 6. https://doi.org/10.3390/soc15010006

Gkrimpizi, T., Peristeras, V., & Magnisalis, I. (2023). Classification of Barriers to Digital Transformation in Higher Education Institutions: Systematic Literature Review. *Education Sciences*, *13*(7), 746. https://doi.org/10.3390/educsci13070746

Haleem, A., Javaid, M., Qadri, M. A., & Suman, R. (2022). Understanding the role of digital technologies in education: A review. *Sustainable Operations and Computers*, *3*, 275–285. https://doi.org/10.1016/j.susoc.2022.05.004

Hennessy, S., D'Angelo, S., McIntyre, N., Koomar, S., Kreimeia, A., Cao, L., Brugha, M., & Zubairi, A. (2022). Technology Use for Teacher Professional Development in Low- and Middle-Income Countries: A systematic review. *Computers and Education Open*, *3*, 100080. https://doi.org/10.1016/j.caeo.2022.100080

Hervás-Torres, M., Bellido-González, M., & Soto-Solier, P. M. (2024). Digital competences of university students after face-to-face and remote teaching: Video-animations digital create content. *Heliyon*, *10*(11), e32589. https://doi.org/10.1016/j.heliyon.2024.e32589

Hunter, L. J., Bayly, B. L., Bierman, K. L., Welsh, J. A., & Gest, J. M. (2022). Predicting school readiness program implementation in community-based childcare centers. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.1023505

Hwabamungu, B., & Shepherd, P. (2024). The Influence of Stakeholder Involvement in the Adoption of Digital Technologies in the UK Construction Industry. *Informatics*, *11*(4), 97. https://doi.org/10.3390/informatics11040097

Iachini, A. L., Childs, T. M., Curcio, R., Ross, R. A., Ascetta, K. E., Ferguson, S. E., & Guest, J. D. (2023). Building schoolwide readiness for social emotional learning: A feasibility and acceptability study of the ReadySET intervention. *Social and Emotional Learning: Research, Practice, and Policy*, *2*, 100016. https://doi.org/10.1016/j.sel.2023.100016

Imjai, N., Aujirapongpan, S., & Yaacob, Z. (2024). Impact of logical thinking skills and digital literacy on Thailand's generation Z accounting students' internship effectiveness: Role of self-learning capability. *International Journal of Educational Research Open*, *6*, 100329. https://doi.org/10.1016/j.ijedro.2024.100329

Jahreie, J. (2023). Early childhood education and care teachers' perceptions of school readiness: A research review. *Teaching and Teacher Education*, *135*, 104353. https://doi.org/10.1016/j.tate.2023.104353

Kayanja, W., Kyambade, M., & Kiggundu, T. (2025). Exploring digital transformation in higher education setting: The shift to fully automated and paperless systems. *Cogent Education*, *12*(1). https://doi.org/10.1080/2331186x.2025.2489800

Kholifah, N., Nurtanto, M., Sutrisno, V. L. P., Majid, N. W. A., Subakti, H., Daryono, R. W., & Achmadi, A. (2025). Unlocking workforce readiness through

digital employability skills in vocational education Graduates: A PLS-SEM analysis based on human capital Theory. *Social Sciences & Humanities Open*, *11*, 101625. https://doi.org/10.1016/j.ssaho.2025.101625

Laufer, M., Leiser, A., Deacon, B., Perrin De Brichambaut, P., Fecher, B., Kobsda, C., & Hesse, F. (2021). Digital higher education: A divider or bridge builder? Leadership perspectives on edtech in a COVID-19 reality. *International Journal of Educational Technology in Higher Education*, *18*(1). https://doi.org/10.1186/s41239-021-00287-6

Liu, S.-M., Huang, Y.-C., & Wang, R.-J. (2024). Challenges and Professional Support for Principals at Rural Schools for Sustainable Development. *Sustainability*, *16*(21), 9251. https://doi.org/10.3390/su16219251

Muhazir, A., & Retnawati, H. (2020). The teachers' obstacles in implementing technology in mathematics learning classes in the digital era. *Journal of Physics: Conference Series*, *1511*(1), 012022. https://doi.org/10.1088/1742-6596/1511/1/012022

Müller, F. A., & Wulf, T. (2020). Technology-supported management education: A systematic review of antecedents of learning effectiveness. *International Journal of Educational Technology in Higher Education*, *17*(1). https://doi.org/10.1186/s41239-020-00226-x

Mustafa, F., Nguyen, H. T. M., & Gao, X. (2024). The challenges and solutions of technology integration in rural schools: A systematic literature review. *International Journal of Educational Research*, *126*, 102380. https://doi.org/10.1016/j.ijer.2024.102380

Nikou, S., De Reuver, M., & Mahboob Kanafi, M. (2022). Workplace literacy skills—How information and digital literacy affect adoption of digital technology. *Journal of Documentation*, *78*(7), 371–391. https://doi.org/10.1108/jd-12-2021-0241

Obied, A. S. (2025). Digital leadership in the academic environment: A systematic literature review. *Social Sciences & Humanities Open*, *11*, 101542. https://doi.org/10.1016/j.ssaho.2025.101542

Paul, J., Ueno, A., Dennis, C., Alamanos, E., Curtis, L., Foroudi, P., Kacprzak, A., Kunz, W. H., Liu, J., Marvi, R., Nair, S. L. S., Ozdemir, O., Pantano, E., Papadopoulos, T., Petit, O., Tyagi, S., & Wirtz, J. (2024). Digital transformation: A multidisciplinary perspective and future research agenda. *International Journal of Consumer Studies*, *48*(2). https://doi.org/10.1111/ijcs.13015

Prebanić, K. R., & Vukomanović, M. (2023). Exploring Stakeholder Engagement Process as the Success Factor for Infrastructure Projects. *Buildings*, *13*(7), 1785. https://doi.org/10.3390/buildings13071785

Putri Lestari, N. A., Selpi Wahyuni, L. T., Bagus Arnyana, I. P., & Dantes, N. (2023). Policy Analysis of the Implementation of Merdeka Curriculum in Elementary School. *International Journal of Elementary Education*, *7*(4), 567–575. https://doi.org/10.23887/ijee.v7i4.64103

Scheel, L., Vladova, G., & Ullrich, A. (2022). The influence of digital competences, self-organization, and independent learning abilities on students' acceptance of digital learning. *International Journal of Educational Technology in Higher Education*, *19*(1). https://doi.org/10.1186/s41239-022-00350-w

Schmid, R., Pauli, C., & Petko, D. (2023). Examining the use of digital technology in schools with a school-wide approach to personalized learning. *Educational Technology Research and Development*, *71*(2), 367–390. https://doi.org/10.1007/s11423-022-10167-z

Spante, M., Hashemi, S. S., Lundin, M., & Algers, A. (2018). Digital competence and digital literacy in higher education research: Systematic review of concept use. *Cogent Education*, *5*(1), 1519143. https://doi.org/10.1080/2331186x.2018.1519143

Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., Monés, A. M., & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies*, *28*(6), 6695–6726. https://doi.org/10.1007/s10639-022-11431-8

Tomasouw, J., Marantika, J. E. R., Wenno, E. C., & Van Delzen, J. C. N. (2024). The Challenges of the Kurikulum Merdeka Implementation in 3T Area. *KnE Social Sciences*. https://doi.org/10.18502/kss.v9i31.17598

Toukola, S., & Ahola, T. (2022). Digital tools for stakeholder participation in urban development projects. *Project Leadership and Society*, *3*, 100053. https://doi.org/10.1016/j.plas.2022.100053

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022

Wang, F., Ni, X., Zhang, M., & Zhang, J. (2024). Educational digital inequality: A meta-analysis of the relationship between digital device use and academic performance in adolescents. *Computers & Education*, *213*, 105003. https://doi.org/10.1016/j.compedu.2024.105003

Wang, X., Young, G. W., Iqbal, M. Z., & Guckin, C. M. (2024). The potential of extended reality in Rural Education's future – perspectives from rural

educators. *Education and Information Technologies*, *29*(7), 8987–9011. https://doi.org/10.1007/s10639-023-12169-7

Wei, Z. (2023). Navigating Digital Learning Landscapes: Unveiling the Interplay Between Learning Behaviors, Digital Literacy, and Educational Outcomes. *Journal of the Knowledge Economy*, *15*(3), 10516–10546. https://doi.org/10.1007/s13132-023-01522-3

Witthöft, J., Aydin, B., & Pietsch, M. (2024). Leading digital innovation in schools: The role of the open innovation mindset. *Journal of Research on Technology in Education*, 1–20. https://doi.org/10.1080/15391523.2024.2398528

Zhao, Y., Sánchez Gómez, M. C., Pinto Llorente, A. M., & Zhao, L. (2021). Digital Competence in Higher Education: Students' Perception and Personal Factors. *Sustainability*, *13*(21), 12184. https://doi.org/10.3390/su132112184