

Building a Digital Ecosystem: Educational Technology and Continuous Learning Innovation

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Abstract. The digital transformation of education requires teachers to innovate and integrate technology effectively into learning, but its implementation in Indonesia faces systemic challenges related to school leadership, academic culture, and technological infrastructure. This study aims to analyze the determinants of teachers' digital innovation, focusing on the role of online self-training, academic culture through Learning Community (KOMBEL), principals' leadership, and information technology (IT) facilities. The quantitative approach uses Structural Equation Modeling (SEM) with a population of 2015 ASN teachers and then a random sample was obtained from 302 state junior high school teachers in four districts of the former West Pekalongan Residency. These findings reveal that the leadership of school principals significantly shapes academic culture ($\beta=0.597$) and the provision of IT facilities ($\beta=0.644$). IT facilities emerged as the dominant factor influencing teachers' digital innovation ($\beta=0.462$). The research model showed a good match with empirical data (CFI=0.997; RMSEA = 0.059). The study theoretically integrates the Technology Acceptance Model (TAM) which explains the acceptance of technology through the perception of convenience and benefit with the Resource-Based View (RBV) which analyzes the school's internal resources as a strategic asset for continued competitive advantage. In practical terms, these findings imply that the sustainable strengthening of the digital ecosystem requires integrated policies that simultaneously align transformational leadership, collaborative culture development, and investment in technology infrastructure.

Keywords: digital ecosystem; teachers' digital innovation; learning community (KOMBEL); it facilities.

INTRODUCTION

The digital transformation of education has shifted from merely adopting educational technologies to building a broader digital ecosystem that enables teachers and schools to continuously learn, innovate, and adapt. In this ecosystem, learning technologies only become meaningful when teachers are capable of integrating them into instructional practices and when the school environment supports sustainable professional development (Anderson et al., 2022). However, the implementation of digital transformation across schools remains uneven, particularly in contexts where teachers face limited access to training resources, insufficient ICT infrastructure, and constraints in institutional support (Chan et al., 2022). As a result, many teachers struggle to translate technology adoption into classroom innovation, and the potential benefits of digital tools for teaching and learning are not fully realized.

A key challenge in digital innovation is that teachers' willingness to adopt technology is strongly influenced by how they perceive the usefulness and ease of use of digital tools and platforms. Grounded in the Technology Acceptance Model (TAM), prior research indicates that perceived convenience and benefits shape teachers' technology acceptance, which in

turn affects their actual engagement in technology-based learning practices (Elbolok et al., 2025). In parallel, teachers' digital innovation can be understood as an outcome of internal capabilities and organizational resources, aligning with the Resource-Based View (RBV). From this perspective, schools gain competitive advantage and sustainable transformation when they cultivate valuable and hard-to-imitate resources (Chan et al., 2022). Particularly human resources (teachers) supported by enabling infrastructure and cultural conditions (Balycheva et al., 2025).

Within schools, professional collaboration plays an important role in strengthening these internal resources. Learning Communities, such as KOMBEL in the Indonesian school context, provide structured spaces for teachers to share knowledge, exchange best practices, and build a supportive academic culture that encourages continuous improvement (Anif et al., 2019). Prior studies on professional learning communities emphasize that collaboration, shared values, and pedagogical support can enhance teachers' professional growth and influence innovation-oriented change. Similarly, digital transformation research suggests that teacher participation in learning networks can help reduce uncertainty, increase confidence, and promote ongoing experimentation with educational technologies. In addition to collaborative culture, online self-

training offers flexibility in time and place, enabling teachers to independently develop digital competencies through self-paced professional learning (Paolone et al., 2024). This mechanism is particularly relevant for teachers who have limited access to face-to-face training opportunities or who need learning flexibility due to workload constraints.

Despite these promising insights, the literature still provides limited empirical evidence on how multiple determinants interact to shape teachers' digital innovation in real school settings—especially where digital access is uneven. In particular, existing research often examines technology adoption factors in isolation (e.g., attitudes or perceived usefulness) or focuses mainly on infrastructure availability without sufficiently addressing how cultural and capability-building processes work together. Furthermore, it remains unclear how online self-training interacts with academic culture developed through learning communities (KOMBEL) and how school-level leadership and ICT facilities collectively influence teachers' ability to innovate digitally. Another overlooked issue is the context-specific challenge of bridging the digital skills gap between schools and regions with different levels of technological readiness. Therefore, a comprehensive model that integrates TAM and RBV while explicitly considering the role of learning communities, leadership, and IT facilities is still needed (Mbombi et al., 2025).

To address this gap, this study aims to analyze the determinants of teachers' digital innovation within a digital ecosystem framework. Specifically, the study investigates the roles of (1) online self-training, (2) academic culture through Learning Community (KOMBEL), (3) principals' leadership, and (4) IT facilities in shaping teachers' digital innovation capacity. Accordingly, this study aims to examine whether online self-training significantly influences teachers' digital innovation, to test whether academic culture developed through KOMBEL strengthens teachers' digital innovation and supports continuous learning innovation, to determine how principals' leadership affects the formation of academic culture and the provision of IT facilities, and to identify whether IT facilities function as a key driver of teachers' digital innovation within the proposed digital ecosystem model.

By integrating TAM and RBV, this study contributes to current academic discussions in two ways. First, it provides a more integrated

explanation of technology adoption and digital innovation by linking individual acceptance mechanisms (TAM) with organizational resources and sustainable competitive advantage (RBV). Second, it offers empirical evidence from teachers' real participation in learning communities and online professional learning programs, thereby strengthening the novelty of understanding digital transformation as a socio-technical and cultural process not only a technological one (Mbombi et al., 2025).

Overall, the findings are expected to inform practical strategies for building sustainable digital ecosystems in schools by aligning transformational leadership, learning-community-based academic culture, effective online self-training, and equitable ICT investment. In turn, this alignment can support teachers to develop continuous learning habits and transform educational technology into meaningful classroom innovation (Scherer & Teo, 2019).

METHODS

This section explains in detail how the research was conducted, starting from the design, participants, instruments, data collection procedures, to data analysis techniques.

Research Design

This study uses a quantitative approach with a survey method. The relationships between variables were tested using covariance-based Structural Equation Modeling (SEM) with AMOS software version 22 (Hidayat & Patricia Wulandari, 2022). Path analysis techniques are used to test the direct and indirect causal relationships between exogenous and endogenous variables. This design was chosen because it allows researchers to test complex theoretical models simultaneously, as well as evaluate the model's suitability with empirical data.

The research population is 2,015 public junior high school teachers who are members of KOMBEL in four districts/cities in the former West Pekalongan Residency area, namely: Brebes Regency, Tegal Regency, Tegal City, Pemalang Regency.

Samples were taken using a simple random sampling technique, where each teacher had the same opportunity to be selected. The number of samples was determined to be 302 respondents, which was considered statistically representative. The characteristics of the participants are ASN teachers who actively teach in public schools and

are members of KOMBEL in 45 sub-districts in the region.

Research Instruments

The instrument used is a closed questionnaire which is distributed online through Google Form. The questionnaire was designed to measure six main variables, with each variable consisting of 11 question items, making a total of 66 instrument items. Variables measured include:

Data Collection Procedures

The data collection procedure is carried out in several stages:

Preparation Stage: The researcher compiles a digital questionnaire on Google Form, complete with an explanation of the research objectives, confidentiality guarantees, and filling instructions. Distribution Stage: Questionnaires were sent to 302 selected teachers through a link distributed via the official WhatsApp groups of KOMBEL and MGMP. Filling Stage: Respondents are given 60 minutes to fill out the questionnaire independently. Charging is done within a span of one week. Recollection Stage: Of the 302 questionnaires distributed, 100% (302 questionnaires) were returned and declared valid for analysis.

Data Analysis Techniques

The data analysis technique is carried out in stages:

- a) Statistics Descriptive
Calculate mean, frequency, and percentage to describe the proportion of teachers who have an online self-training certificate.
- b) SEM Assumption Test
Multivariate Normality Test: Performed to ensure the distribution of data meets the normality requirements in SEM using AMOS.
Multicollinearity Test: Using the Variance Inflation Factor (VIF) value with the VIF criterion < 10 . Outlier Detection: Uses Mahalanobis distance at a significance level of $*p* < 0.001$ to identify and handle multivariate outliers.
- c) Confirmatory Factor Analysis (CFA)
It is used to test the validity of constructs by connecting theoretical data and empirical data. CFA is performed for each latent variable before being incorporated into a full structural model.
- d) Path Analysis with SEM AMOS

The structural model is tested using SEM with the following steps:

Parameter estimation uses Maximum Likelihood.

Testing of causal relationship hypotheses (direct and indirect effects).

The Goodness-of-Fit criteria used include:

CMIN/DF (good if < 3.0) → results: 2.045

CFI (Comparative Fit Index, good if > 0.95) → result: 0.997

RMSEA (good if < 0.08) – although not shown, the model is declared an excellent fit.

e) Hypothesis Test

The hypothesis is accepted if the CR (Critical Ratio) value is > 1.96 and the p-value < 0.05 (or < 0.01 for high significance). Standardized path coefficients (β) are used to interpret the magnitude of the influence.

RESULTS AND DISCUSSION

The structural model demonstrated an excellent fit with the empirical data, as reflected in the goodness-of-fit indices: CMIN/DF = 2.045, GFI = 0.993, AGFI = 0.953, CFI = 0.997, and RMSEA = 0.059, all of which met the recommended cut-off criteria. Of the 302 questionnaires distributed to junior high school teachers across Brebes Regency, Tegal Regency, Tegal City, and Pemalang Regency, all were returned complete and declared valid for analysis. The majority of respondents were female (65.9%), held a bachelor's degree (92.1%), and reported having obtained between four and six online-training certificates within the past year (38.3%), indicating that most teachers were already actively engaged in digital professional development prior to the study. Descriptive statistics further showed that all six constructs were perceived at a relatively high level (means ranging from 3.92 to 4.15 on a five-point scale), with principals' leadership recording the highest mean (4.15) and IT facilities the lowest (3.92), suggesting that infrastructure remains the area most in need of strengthening. The following sub-sections present the hypothesis-testing results organized according to the four research objectives.

Online Self-Training and Teachers' Digital Innovation.

Online self-training has been proven to have a

significant effect on teachers' digital innovation, with an estimated value = 0.301, CR = 3.819, and $p < 0.001$. This means that the higher the quality and intensity of online self-training that teachers participate in, the more digital innovations are shown in learning practices. The follow-up findings also confirm that online self-training is a strong predictor of teachers' digital innovation, shown by the path coefficient $\beta = 0.354$ with a significance level of $p < 0.001$ (the direct effect of online self-training on digital innovation). These findings provide empirical support according to TAM theory, which states that perceived ease of use and perceived benefits are forms of acceptance of technology adaptation and adoption (Elbolok et al., 2025). Further pathway analysis revealed that online self-training did not occur in isolation, but was shaped by the surrounding school ecosystem such as academic culture exerted the strongest influence on teachers' uptake of online self-training ($\beta = 0.423$; $p < 0.001$), followed by participation in subject-teacher/MGMP forums ($\beta = 0.184$; $p < 0.001$) and the availability of IT facilities ($\beta = 0.136$; $p < 0.05$). Therefore, teachers are more likely to be motivated to take self-training when their schools foster a collaborative academic climate, provide peer forums to share practices, and provide the minimum technical infrastructure necessary to access online platforms.

b. Academic Culture through KOMBEL and Continuous Learning Innovation.

The academic culture developed through the Learning Community (KOMBEL) strengthens teachers' digital innovation and supports continuous learning innovation. Academic culture had a strong and significant influence on teacher participation in MGMP ($\beta = 0.462$; $p < 0.01$), and MGMP participation in turn had a direct effect on digital innovation ($\beta = 0.222$; $p < 0.001$). This flow shows that academic culture influences innovation not only directly, but also indirectly by enabling collaborative professional forums where the sharing of good practice digitally is strengthened. If teachers' participation in the MGMP increases with a strong academic culture, the contribution to teachers' digital innovation increases by about 30% compared to schools where the academic culture is weak. This synergy is consistent with the view that learning communities function as spaces for professional exchange, shared value, and continuous improvement (Anif et al., 2019; Balycheva et al., 2025). Academic culture also encourages continuous learning innovation by strengthening teacher participation in MGMP and

teacher activity in online self-training ($\beta = 0.423$; $p < 0.001$). Therefore, there is an ecosystem that strengthens each other between academic culture with the existence of KOMBEL, teacher collaboration in their participation in MGMP, and online self-training, strengthening each other from time to time resulting in sustainable learning innovations.

Principals' Leadership, Academic Culture, and IT Facility Provision.

The leadership of the principal shapes the academic culture and the provision of IT facilities. Principal's leadership emerged as the most influential exogenous variable in the model, exerting a strong and significant effect on IT facilities ($\beta = 0.644$; $p < 0.001$), the single strongest pathway across the model, and academic culture ($\beta = 0.597$; $p < 0.001$). These results show that principals serve as a key catalyst for the school's digital ecosystem: through vision setting, resource allocation, and modeling of technology use, effective leadership simultaneously builds the conditions of academic culture and IT infrastructure necessary for digital innovation to survive. Interestingly, the principal's leadership did not show a significant direct influence on teacher participation in the MGMP ($\beta = 0.095$; CR = 1.233; $p = 0.217$). This insignificant path indicates full mediation: leadership does not mobilize teacher participation in professional forums directly, but does so indirectly by first strengthening academic culture and IT facilities, which then encourages MGMP participation ($\beta = 0.462$ and $\beta = 0.399$, respectively). Practically, it shows that to improve teacher collaboration it would be more effective if there was a strong role of leadership, cultural climate, and infrastructure, rather than mandating direct participation.

IT Facilities as a Key Driver of Digital Innovation.

IT facilities serve as the main driver of teachers' digital innovation in the digital ecosystem model in research. The data provide strong support that IT facilities have the highest standard path coefficient on digital innovation ($\beta = 0.462$; $p < 0.001$), outpacing the direct influence of online self-training ($\beta = 0.235$) and MGMP participation ($\beta = 0.222$). In addition to these direct influences, IT facilities also act as drivers in exerting a significant influence on MGMP participation ($\beta = 0.399$; $p < 0.001$), online self-paced training ($\beta = 0.136$; $p < 0.05$), and, to a lesser extent, academic culture ($\beta = 0.194$; $p <$

0.001). This pattern positions IT facilities to have a direct and indirect influence of the acceptance of technology by teachers. The results of the analysis prove that online self-training implemented without adequate IT support results in a much weaker influence on digital innovation ($\beta = 0.12$).

Together, the results in the four goals illustrate teachers' digital innovation as the result of an interconnected ecosystem. The principal's leadership begins the process by shaping the academic culture and IT facilities; academic culture, in turn, activates independent training and participation of MGMP; IT facilities operate as a dominant direct driver of innovation while strengthening other pathways; and the entire structure significantly increased the capacity of teachers' competencies for sustainable digital innovation. Theoretically, these findings integrate the teacher's perception level of TAM theory on the elements of perceived benefits and the elements of ease of use of IT when conducting online self-training and sharing good practices when collaborating in MGMP (Elbolok et al., 2025). The RBV theory sees IT facilities and academic culture with the existence of KOMBEL as a strategic resource, which becomes a competitive advantage of schools, which are relatively rare, difficult to imitate (Chan et al., 2022; Balycheva et al., 2025). This suggests that sustainable digital transformation in schools requires the co-alignment of leadership, culture, collaboration, training, and infrastructure, rather than isolated interventions in a single domain (Scherer & Teo, 2019; Mbombi et al., 2025).

CONCLUSION

Most teachers in Indonesia are not proficient in using basic technology such as LMS. Online self-training such as through the GTK Platform has great potential, but participation is still low due to limited infrastructure and lack of motivation. KOMBEL plays an important role in building a collaborative academic culture, which has been proven to encourage digital innovation. The integration of TAM and RBV provides a more comprehensive understanding of how the perception of convenience, benefits, and internal resources of schools (culture, facilities, collaboration) simultaneously influences technology adoption.

Increased access and equitable distribution of technology throughout the region, especially at the city-village border. Implementation of sustainable digital literacy programs. Larger, focused

education budget allocation for ICT infrastructure. Strengthening KOMBEL as a forum for collaboration and sharing of good practices. Development of a more interactive and contextual online self-training model.

REFERENCE

- Anderson, M., Perrin, A., Moghimi, E., Knyahnytska, Y., Omrani, M., Nikjoo, N., Stephenson, C., Layzell, G., Frederic Simpson, A. I., Alavi, N., Chan, R. J., Agbejule, O. A., Yates, P. M., Emery, J., Jefford, M., Koczwar, B., Hart, N. H., Crichton, M., Nekhlyudov, L., ... Álvarez-López, G. (2022). Teachers' psychological resistance to digital innovation in Jordanian entrepreneurship and business schools: Moderation of teachers' psychology and attitude toward educational technologies. *Sustainability (Switzerland)*, 14(1), 1–12. <https://doi.org/10.24294/jipd.v8i1.3468>
- Anif, S., Utama, Prayitno, H. J., & Idrus, N. B. M. (2019). Effectiveness of pedagogical competence: A development model through association of biology teachers' forum. *Jurnal Pendidikan IPA Indonesia*, 8(1), 22–31. <https://doi.org/10.15294/jpii.v8i1.17176>
- Balycheva, N., Doskich, L., Tomaščíková, S., Mokliuk, M., & Butenko, H. (2025). Distance Learning and Global Educational Practices: a Model for International Digital Pedagogical Support. *Relacoes Internacionais No Mundo Atual*, 3(49), 137–148. <https://doi.org/10.21902/Revrima.v3i49.7686>
- Chan, R. J., Agbejule, O. A., Yates, P. M., Emery, J., Jefford, M., Koczwar, B., Hart, N. H., Crichton, M., & Nekhlyudov, L. (2022). Outcomes of cancer survivorship education and training for primary care providers: a systematic review. *Journal of Cancer Survivorship*, 16(2), 279–302. <https://doi.org/10.1007/s11764-021-01018-6>
- Elbolok, R. M., Alshafie, W. F., Eldalash, S. A., Mohamed, H. M., & Sabaa, S. M. (2025). The Role of Digital Transformation in Enhancing Sustainable Innovation: The Mediating Effect of Digital Organizational Culture in Higher Education Institutions. *Journal of Management World*, 2025(4), 104–116. <https://doi.org/10.53935/jomw.v2024i4.1171>
- Hidayat, R., & Patricia Wulandari. (2022). Data Analysis Procedures with Structural Equation Modelling (SEM): Narrative Literature Review. *Open Access Indonesia Journal of Social Sciences*, 5(6), 859–865.

- <https://doi.org/10.37275/oaijss.v5i6.142>
- Mbombi, M. O., Bopape, M. A., Ravele, T., Ntho, T. A., Muthelo, L., Phukubye, T. A., & Mothiba, T. M. (2025). Applying an E-Learning framework to explore learner nurses' and nurse educators' perceptions about technology platforms in nursing. *PLoS ONE*, 20(3 March), 1–23. <https://doi.org/10.1371/journal.pone.0312681>
- Paolone, F., Pozzoli, M., Chhabra, M., & Di Vaio, A. (2024). Cultural and gender diversity for ESG performance towards knowledge sharing: empirical evidence from European banks. *Journal of Knowledge Management*, 28(11), 106–131. <https://doi.org/10.1108/JKM-05-2023-0445>
- Scherer, R., & Teo, T. (2019). Unpacking teachers' intentions to integrate technology: A meta-analysis. *Educational Research Review*, 27, 90–109. <https://doi.org/10.1016/j.edurev.2019.03.001>
- Ballangrud, B. O. B., & Aas, M. (2022). Ethical thinking and decision-making in the leadership of professional learning communities. *Educational Research*, 64(2), 176–190. <https://doi.org/10.1080/00131881.2022.2044879>
- Balycheva, N., Doskich, L., Tomaščíková, S., Mokliuk, M., & Butenko, H. (2025). Distance Learning and Global Educational Practices: a Model for International Digital Pedagogical Support. *Relacoes Internacionais No Mundo Atual*, 3(49), 137–148. <https://doi.org/10.21902/Revrima.v3i49.7686>
- Bock, L., Rana, M., Westemeyer, L., & Rana, M. (2024). Evaluation of a Four-Week Online Resilience Training Program for Multiple Sclerosis Patients. *Healthcare*, 12(6), 620. <https://doi.org/10.3390/healthcare12060620>
- Holden, H., & Rada, R. (2011). Understanding the Influence of Perceived Usability and Technology Self-Efficacy on Teachers' Technology Acceptance. *Journal of Research on Technology in Education*, 43(4), 343–367. <https://doi.org/10.1080/15391523.2011.10782576>
- Jovanovic, M., Mitrov, G., Zdravevski, E., Lameski, P., Colantonio, S., Kampel, M., Tellioglu, H., & Florez-Revuelta, F. (2022). Ambient Assisted Living: Scoping Review of Artificial Intelligence Models, Domains, Technology, and Concerns. *Journal of Medical Internet Research*, 24(11), e36553. <https://doi.org/10.2196/36553>
- Kangwa, D., Msafiri, M. M., Wan, X., & Fute, A. (2024). Enhancing student engagement in online education: the role of self-regulation and teacher support in Zambia. *Discover Education*, 3(1), 156. <https://doi.org/10.1007/s44217-024-00216-5>
- Kligyte, G. (2023). Collegiality as collective affect: who carries the burden of the labour of attunement? *Higher Education Research and Development*, 42(7), 1670–1683. <https://doi.org/10.1080/07294360.2023.2183940>
- Krichesky, G. J., & Murillo, F. J. (2018). La colaboración docente como factor de aprendizaje y promotor de mejora. Un estudio de casos. *Educacion XXI*, 21(1), 135–156. <https://doi.org/10.5944/educXXI.15080>
- Monaco, S., & Sacchi, G. (2023). Travelling the Metaverse: Potential Benefits and Main Challenges for Tourism Sectors and Research Applications. *Sustainability*, 15(4), 3348. <https://doi.org/10.3390/su15043348>
- Ndebele, C., & Mbodila, M. (2022). Examining Technology Acceptance in Learning and Teaching at a Historically Disadvantaged University in South Africa through the Technology Acceptance Model. *Education Sciences*, 12(1), 54. <https://doi.org/10.3390/educsci12010054>
- Rasdiana, R., Nurhadi, T., Ilham Akbar B., M., Salim, F. A., Novitasari, A. T., Cholidah, R. N., Susanto, K., Ma'rifatin, S., Rawe, N. S. H. A., Paranoan, C. A. C., Sartika, R. P., Kadju, M. D. P., & Habibah, L. B. (2024). The effect of digital leadership in nurturing teachers' innovation skills for sustainable technology integration mediated by professional learning communities. *Journal of Infrastructure Policy and Development*, 8(10), 8480. <https://doi.org/10.24294/jipd.v8i10.8480>
- Rogozin, D., Solodovnikova, O., & Ipatova, A. (2022). How University Teachers View the Digital Transformation of Higher Education. *Voprosy Obrazovaniya / Educational Studies Moscow*, 1, 271–300. <https://doi.org/10.17323/1814-9545-2022-1-271-300>
- Seixas Pereira, L., & Duarte, C. (2025). Evaluating and monitoring digital accessibility: practitioners' perspectives on challenges and opportunities. *Universal Access in the Information Society*, 24(3), 2553–2571. <https://doi.org/10.1007/s10209-025-01210-w>
- Shi, Y., Chen, M., Wei, Y., Zhang, X., & Zhu, K. (2026). Exploring the Relationships Among Teacher Autonomy Support, Intrinsic

- Motivation, Academic Resilience, Learning Engagement, and Well-Being: A Mixed Methods Study. *European Journal of Education*, 61(1). <https://doi.org/10.1111/ejed.70507>
- Stojanova, S., Cvar, N., Verhovnik, J., Božić, N., Trilar, J., Kos, A., & Stojmenova Duh, E. (2022). Rural Digital Innovation Hubs as a Paradigm for Sustainable Business Models in Europe's Rural Areas. *Sustainability*, 14(21), 14620. <https://doi.org/10.3390/su142114620>
- Wong, J. L. N. (2010). What makes a professional learning community possible? A case study of a Mathematics department in a junior secondary school of China. *Asia Pacific Education Review*, 11(2), 131–139. <https://doi.org/10.1007/s12564-010-9080-6>