EX POST FACTO ANALYSIS OF VOCATIONAL TEACHERS' CREATIVITY DEFICITS USING PAVLOVA'S TAXONOMY IN YOGYAKARTA

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Abstract
The transformation of vocational education necessitates that educators possess adaptive digital skills. The objective of this study is to delineate the digital technology competency profile of vocational high school teachers in Yogyakarta City, employing Pavlova's (2009) taxonomy as a framework. Additionally, the study seeks to examine the correlation between this profile and the teachers' years of experience in the field. The present study employed a quantitative ex post facto design, and the sample comprised 284 teachers from 25 public and private schools. These teachers were selected through proportional random sampling. The data were collected using a validated questionnaire and analyzed using descriptive statistics and Spearman's rank correlation. The results of the mapping process indicated a clear distinction in the degree of mastery of competencies. Technological Awareness demonstrated the highest level of achievement in the "very good" category, with a mean score of 21.13. In contrast, Technological Creativity exhibited the lowest level of achievement, remaining in the "fair" category with a mean score of 29.93. Inferential testing demonstrated a strong, significant positive correlation between length of service and overall digital competence ($r = 0.713$; $p < 0.001$). The prevailing tendency among teachers to adopt a passive stance toward technology use is evident, although teaching experience has been shown to positively influence the maturity of technological adaptation. These findings suggest a shift in training interventions toward project-based approaches, alongside the establishment of strategic peer-mentorship programs that empower senior teachers.
Keywords: *Vocational Teachers; Digital Technology Competencies; Vocational Education; Length of Service; Industrial Revolution 4.0*

INTRODUCTION

In the contemporary context of the Fourth Industrial Revolution, the field of vocational education must evolve to encompass more than mere access to physical infrastructure. Educators must be equipped with a comprehensive suite of digital technology competencies to address the demands of this transformative era effectively. Vocational high school (SMK) teachers serve as the primary agents in cultivating a workforce that is adaptable to market fluctuations (World Bank, 2018). To achieve this objective, it is imperative that teachers not only possess a foundation in fundamental pedagogical competencies but also the capacity to integrate technology into their instructional design seamlessly (Guttieres, 2019; Khademi-Vidra & Bakos, 2025). These digital competencies are imperative for educators to solve complex problems, drive innovation, and ensure that graduates align with the needs of an ever-evolving industry (Shenkoya & Kim, 2023; Tikhonova & Raitskaya, 2023).

Despite the evident urgency of this issue, empirical evidence indicates stagnation. Preliminary observations and interviews conducted at the Yogyakarta Special Region Office of Education, Youth, and Sports in 2024 indicated that vocational teacher training programs remain predominantly characterized by general pedagogy, with a conspicuous absence of specific interventions focused on advanced digital technology. This stagnation aligns with the findings of Astuti et al. (2022) and Mutohhari et al. (2021), which confirm the low digital maturity of vocational high school teachers. Nevertheless, the preponderance of extant literature continues to exhibit substantial methodological deficiencies. A review of the extant literature reveals a tendency among researchers to employ overly general indicators or to focus solely on post-training evaluations when measuring digital competencies (see Garzón Artacho et al., 2020; Sanchez-Prieto et al., 2020). A critical gap exists in the extant literature: a paucity of diagnostic mapping that uses a structured taxonomy to measure Industry 4.0-specific skills.

To address this measurement discrepancy, it is imperative to conduct a more comprehensive diagnostic analysis to ensure that professional interventions are effective (Sailer et al., 2021). This study employs a novel approach by implementing Pavlova (2009) taxonomy of digital technology, which meticulously categorizes technology proficiency into five sequential hierarchies: technology awareness, technology literacy, technology competence, technological creativity, and technology criticism. The use of this framework, in conjunction with an ex post facto design, facilitates a significantly more precise mapping of competencies than generic measurements. Additionally, it assesses the influence of demographic variables, such as years of service, on teachers' digital maturity levels.

In light of the aforementioned issues and lacunae in the extant literature, this study aims to provide a comprehensive overview of the digital technology competency profiles of vocational high school teachers in Yogyakarta City. The research questions in this study are meticulously crafted to address two fundamental inquiries. First, this study explores the digital technology competency profiles of vocational teachers in Yogyakarta City as viewed through the five levels of Pavlova's taxonomy. Secondly, this study investigates whether there is a significant relationship between years of teaching experience and levels of digital technology competency across these taxonomic levels.

METHOD

Research Design and Participants

This quantitative study uses an ex post facto design to evaluate teachers' competencies in the use of digital technology without experimental manipulation. While this design is effective in capturing existing realities, its primary limitation is the inability to establish absolute causal relationships between variables. The present study was conducted from September 2024 to March 2025 at 25 public and private vocational high schools in Yogyakarta.

The study population comprised 1,078 teachers. The sample size was determined using the Isaac and Michael formula with a 5% margin of error. The sampling method employed was proportional random sampling. The survey was disseminated precisely to 284 target respondents. To guarantee a 100% response rate and minimize attrition, data collection implemented a control system involving field coordinators at each of the 25 public and private vocational high schools in Yogyakarta. The present study focused specifically on the variable of teaching tenure, which served as the basis for hypothesis testing. This decision was made to maintain focus on the trajectory of educators' professional experience, without disaggregating other secondary demographic variables.

Research Instrument

The data collection process employed a closed-ended questionnaire that utilized a five-point Likert scale (Koo & Yang, 2025). The instrument under consideration was developed based on Pavlova (2009) taxonomy of digital technology, which encompasses five dimensions: technology awareness, technology literacy, technology competence, technological creativity, and technological critical thinking.

Before initiating data collection, the instrument underwent two rigorous validation stages. Initially, content validity was ascertained through expert judgment by three experts in vocational education and educational technology to ensure that the items aligned with Pavlova's taxonomy. Following a thorough evaluation process, the instrument, which comprises 60 initial items, was subjected to a pilot test with 30 vocational high school teachers who were not part of the primary sample. The pilot data were then analyzed using Pearson's Product-Moment correlation, a statistical method for assessing construct validity. The analysis results indicated that three items were invalid ($r < 0.361$) and had to be discarded. Consequently, 57 items were determined to be valid and suitable for analysis, with calculated r-value ranging from 0.363 to 0.823. The instrument's internal consistency was measured using the Alpha coefficient. The evaluation yielded satisfactory reliability across all measurement variables, with Alpha coefficient values ranging from 0.636 to 0.868, indicating high to very high reliability.

Data Analysis

The data analysis procedure was conducted in two stages using SPSS software. The initial stage of the study utilized descriptive statistics to map teachers' levels of digital technology competence. The raw scores obtained from the respondents were then transformed into five evaluative categories based on the Ideal Mean (Mi) and Ideal Standard Deviation (SBi) benchmarks, as outlined by Azwar (2021). The categorization interval criteria were strictly defined as follows: The quality of the subject is determined by the following scale: "Very Good" ($X > Mi + 1.8\ SBi$), "Good" ($Mi + 0.6\ SBi < X \leq Mi + 1.8\ SBi$), "Fair" ($Mi - 0.6\ SBi < X \leq Mi + 0.6\ SBi$), "Poor" ($Mi - 1.8\ SBi < X \leq Mi - 0.6\ SBi$), and "Very Poor" ($X \leq Mi - 1.8\ SBi$).

The second stage involves inferential testing to analyze the significance of the relationship between tenure and digital technology proficiency. Assumption testing is a process used to determine whether the data meet the requirements for nonparametric analysis. This is contingent upon the variables under examination being ordinal and exhibiting a monotonic relationship. Consequently, Spearman's rank correlation was used to test the hypothesis at the 0.05 significance level. To address the limitations of interpretation that rely solely on the significance value (p-value), this correlation test will also report the effect size and 95% confidence interval.

RESULTS

Digital Technology Competency Map of Vocational Teachers

This analysis delineates a five-tiered taxonomy of digital competencies, encompassing technology awareness, technology literacy, technology skills, technological creativity, and technological critical thinking. To ensure the interpretation is robust, descriptive statistics—including 95% confidence intervals (CI)—have been calculated (Table 1).

Table 1 Descriptive Statistics and 95% Confidence Interval for Digital Competence

Competency Level	Mean	*SD*	SE	95% CI	Cat.
Technological Awareness	21.13	2.30	0.14	20.85 – 21.41	Very Good
Technological Literacy	43.08	5.11	0.30	42.48 – 43.68	Good

Technological Capability	47.54	7.09	0.42	46.71 – 48.37	Good
Technological Creativity	29.93	5.70	0.33	29.97 – 30.59	Fair
Technological Criticism	33.07	4.58	0.27	32.54 – 33.60	Good

As illustrated in Table 1, there is considerable variation in the digital technology competencies of vocational high school teachers. The highest mean score was observed for technology awareness ($M = 21.13$), suggesting that teachers possess a robust fundamental understanding of the significance of technology in the classroom. Conversely, technological creativity was ranked lowest ($M = 29.39$) and was the only domain that did not reach the "excellent" level. A subsequent analysis of the instrument items identified 14 specific indicators that were the primary weaknesses, as outlined in Table 2.

Table 2 Competency Indicators Requiring Specific Interventions

Aspect	Specific Statement or Indicator	*M*	*SD*
Technological Literacy	Understanding developments in Internet of Things technology, including Arduino, Raspberry Pi, and other sensors.	3.40	0.948
	Monitoring advancements in big data and data analytics, such as advanced Microsoft Excel, Tableau, Power BI, or Google Data Studio.	3.31	0.929
	Tracking developments in Virtual Reality and Augmented Reality technologies, such as Oculus VR, Unity, or Unreal Engine.	3.16	0.929
Technological Capability	Utilizing Artificial Intelligence tools (e.g., ChatGPT, Gemini, Midjourney, Dall-E) to seek information and discover innovative instructional solutions.	3.32	1.026
	Employing IoT-based technologies to provide practical industrial application examples.	3.05	0.981
	Operating digital design and prototyping tools (e.g., Autodesk Fusion 360, SketchUp, Canva, Figma) to prepare creative teaching materials.	3.31	0.961
	Integrating VR and AR technologies to support practical learning activities. Utilizing video editing applications (e.g., Adobe Premiere, Filmora, CapCut) to create interactive instructional content.	3.34	1.086
	Instructing students regarding cybersecurity and data protection practices aligned with current industrial requirements.	3.13	0.990
Technological Creativity	Designing instructional methods utilizing new technologies (AR, VR, or mobile learning) to deliver interactive experiences and elevate student engagement.	2.79	0.976
	Creating digital learning content (video tutorials, interactive simulations) to support practical understanding of complex work processes.	3.38	0.961
	Utilizing industry-standard software (graphic design or IoT applications) to formulate interactive learning activities.	3.32	1.037
	Developing digital systems (e.g., Learning Management Systems) to manage and monitor student learning outcomes in real time.	2.98	1.016
	Guiding students in utilizing advanced technology to participate in national or international competitions (robotics, coding, graphic design).	2.92	1.123

The data presented in Table 2 indicate that the 14 critical indicators classified as "adequate" are not associated with fundamental computer operation skills. Instead, teachers' competencies are deficient in integrating advanced technologies, including artificial intelligence, the Internet of Things, virtual reality, and augmented reality, and in their inadequate understanding of cybersecurity. The low ranking of the technological creativity dimension is attributable to its failure to meet the established indicators. These empirical findings provide an evidence-based diagnostic foundation for education policymakers. The necessity for continuous professional development efforts to cease being generic has been identified. Training interventions must henceforth be exclusively focused on addressing deficits in the 14 specific indicators to ensure precise, efficient, and directly impactful improvements in educators' capacity, thereby enhancing the quality of vocational learning.

Analysis of Multicollinearity and Inter-Dimensional Correlation

To address potential overlaps among taxonomic levels and confirm the structural validity of the framework, a Spearman correlation matrix was constructed among dimensions (see Table 3).

Table 3 Interdimensional Correlation Matrix by Taxonomic Level

	Awareness	Literacy	Capability	Creativity	Criticism
Awareness	1.000				
Literacy	0.367**	1.000			
Capability	0.295**	0.812**	1.000		
Creativity	0.143*	0.606**	0.715**	1.000	
Criticism	0.253**	0.500**	0.527**	0.598**	1.000

The matrix reveals a positive, significant correlation among all subscales. A robust correlation (r_s = 0.812) was identified between Technology Literacy and Technology Competence. Instead of indicating problematic multicollinearity, this substantial overlap is theoretically consistent with Pavlova's taxonomy, in which practical operational skills are intrinsically built upon a foundation of digital literacy. These subscales are designed to assess distinct sequential cognitive stages; therefore, maintaining their separate utilization in the analysis constitutes a theoretically valid approach.

The Correlation Between Years of Service and Digital Technology Competence

Spearman's rank correlation was utilized to examine the relationship between teaching experience (years of service) and digital competence. The analysis findings suggest a substantial positive correlation between years of service and overall digital competence (r_s = 0.713, $p < 0.001$). With regard to effect size, the correlation coefficients indicate practical significance across all taxonomic levels. Years of work experience exhibited a substantial effect size when correlated with Technological Competence (r_s = 0.650), Technological Criticism (r_s = 0.631), and Technological Literacy (r_s = 0.588). A moderate effect size was observed for Technological Creativity (r_s = 0.545), whereas the relationship with Technological Awareness exhibited a smaller yet still significant effect size (r_s = 0.394).

In practical terms, the considerable magnitude of this effect suggests that teaching experience is not merely an administrative metric, but rather a pivotal driver of digital maturity. As educators accrue years of service, their capacity to operate, critically evaluate, and integrate technology into their teaching practices significantly improves. These findings challenge the assumption that senior teachers are inherently resistant to adopting technology.

DISCUSSION

An empirical mapping of vocational high school teachers' digital technology competencies in Yogyakarta City reveals a significant gap between mastery of basic aspects and stagnation in advanced productive skills. In accordance with Pavlova (2009) taxonomic framework, high scores on Awareness, Literacy, and Technology Competence indicate that teachers have moved beyond the technology-rejection phase and are capable of incorporating fundamental tools into their pedagogical practices (Skantz-Åberg et al., 2022). However, the precipitous decline in scores on the Technological Creativity dimension suggests the presence of structural barriers impeding the cognitive transition. The most plausible explanation for this discrepancy is the absence of exposure and opportunities for direct experimentation with complex Industry 4.0 technologies, such as artificial intelligence and the Internet of Things. Despite teachers' adequate intentions and literacy, constraints in advanced infrastructure at school facilities appear to compel them to function as technology consumers rather than as creators of innovative digital learning content (Bereczki & Kárpáti, 2021; Tanjung et al., 2021).

Regarding demographic variables, inferential testing revealed a significant positive correlation between years of service and all five dimensions of digital competence. These findings offer a novel perspective on the subject, one that contradicts the conclusions of previous studies (see Cattaneo et al., 2022; Mulyanti et al., 2024). These earlier studies often concluded that senior teachers exhibit greater resistance to technology. The convergence of these findings with others in the existing literature (ElSayary, 2023; Hinojo-Lucena et al., 2019) can be explained through the mechanism of accumulated experience. The mastery of Industry 4.0-specific technologies rarely occurs through brief, casual exposure. Teachers with longer tenure inherently have a higher cumulative probability of participating in various professional development interventions throughout their careers. This extensive institutional experience provides educators with the pedagogical maturity to filter, critique, and ultimately adopt new technologies more meaningfully than novice educators.

A synthesis of these findings indicates that concrete, actionable practical implications are essential to bridge the existing competency gap. First, policymakers must design training interventions that specifically target the dimension of technological creativity. These interventions should focus on projects that create digital prototypes using Augmented Reality or generative Artificial Intelligence tools, rather than merely on basic computer literacy training. Secondly, the empirical reality that senior teachers possess more mature digital competencies must be strategically leveraged. Educational institutions can develop peer-mentorship programs in which senior educators who exhibit high levels of creativity serve as pilot mentors for their junior colleagues. This initiative is designed to expedite the transfer of practical knowledge and facilitate the adept navigation of technology within the authentic school environment.

While the study provides a precise diagnostic mapping, several methodological limitations must be transparently acknowledged to prevent the findings from being overgeneralized. Firstly, the use of a cross-sectional ex post facto design limits the study's ability to establish an absolute causal relationship between tenure and enhanced competence. The execution of future longitudinal studies is imperative to substantiate this developmental trajectory. Secondly, the use of a self-report survey is susceptible to social desirability bias, in which respondents may overestimate their abilities. Given that the sample population is constrained to the urban vocational education ecosystem in Yogyakarta City, it is important to consider the external validity of the findings. It is possible that these findings may not fully reflect the reality of educators' competencies in rural areas facing far more severe infrastructure challenges.

A notable limitation of this study is the absence of comprehensive documentation of secondary sociodemographic data, including age and gender, due to technical limitations in archiving raw data. While this restriction limits the scope of a thorough examination of teachers' background profiles, it does not compromise the validity of the primary hypothesis testing, which focuses on the variable of years of service.

CONCLUSION

The study's findings indicate that the digital technology competency profile of vocational high school teachers in Yogyakarta City exhibits an uneven proficiency pattern. Educators exhibit a robust foundation in technological awareness; however, they face a significant impediment in technological creativity. This substantive finding suggests that the majority of teachers continue to function as passive technology consumers and have not yet undergone a full transformation into adaptive instructional creators aligned with the demands of Industry 4.0. In addition, empirical findings demonstrate a robust positive correlation between teaching experience and digital technology competencies. In the context of vocational education, the accumulation of institutional experience and long-term exposure to professional development are closely linked to digital adaptation maturity. These findings challenge conventional assumptions, demonstrating that seniority does not inherently impede technology adoption but is associated with a more comprehensive understanding of pedagogical integration.

In light of these findings, the present study proffers concrete recommendations for stakeholders. First, policymakers at the Department of Education and teacher-training institutions must consider the immediate restructuring of professional development programs for the upcoming academic year. It is imperative that the training paradigm shift from a focus on basic literacy to a more contemporary, project-based approach that fosters digital creativity by integrating artificial intelligence tools and the Internet of Things. The efficacy of this initiative is measured by an enhancement in the quantity and quality of interactive learning media prototypes produced by teachers. Secondly, for school leaders (i.e., vocational high school principals), the most rational intervention is to establish a peer-mentoring program within the school ecosystem. Senior teachers who have demonstrated high digital maturity must be empowered as model mentors for their peers, with the target indicator being the formation of active collaborative learning communities within each vocational program.

As a methodological implication, the diagnostic map from this study informs future research agendas. Given the cross-sectional design of the present study, longitudinal studies are highly recommended to track the developmental trajectories of teachers' digital competencies over time in order to confirm causal relationships. Furthermore, intervention trials using a quasi-experimental design are necessary to assess the efficacy of the digital creativity training module. Finally, cross-regional comparisons between educators in urban and rural areas will provide more comprehensive insights into how infrastructure disparities moderate technology adoption in vocational education.

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