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Digital Transformation Factors Affecting Vocational Students' Learning Outcomes: Toward a Comfort-Centered Model

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ABSTRACT

The accelerated evolution of digital technology during the Fourth Industrial Revolution has revolutionized vocational education, requiring not just technical competence but also digital and emotional adaptability. This investigation aims to develop a comfort-based model that mediates technology comfort in mediating digital preparedness, infrastructure support, technical obstacles, and learning outcomes among vocational learners. An explanatory sequential mixed-methods design was adopted, incorporating quantitative correlation studies and qualitative interviews with 59 students and 7 participants for triangulation. Quantitative findings indicated significant positive correlations between digital preparedness ($r = 0.346$, $p < 0.05$) and infrastructure support ($r = 0.312$, $p < 0.05$) with technology comfort, while technical obstacles reflected a weak and non-significant negative association ($r = -0.251$, ns). In addition, technology comfort significantly correlated with learning outcomes ($r = 0.417$, $p < 0.01$), substantiating its mediating function. The qualitative findings identified students' emotional experience, usability experience, and adaptive confidence as key elements of comfort. The study broadens the scope of the Extended Educational Technology Acceptance Model (EETAM) by incorporating affective processes consistent with Self-Determination Theory. This investigation identifies that promoting emotional comfort with digital support-based pedagogy can encourage students' engagement and learning ability in vocational education.

Introduction

The Fourth Industrial Revolution has profoundly accelerated the integration of digital technologies into various spheres of education, particularly within vocational and technical learning contexts. Vocational schools are now expected to prepare graduates who possess not only

strong technical competencies but also digital adaptability to thrive in technology-driven workplaces (Setyowati, 2023; Yusuf, 2023). Digital transformation in education entails more than merely adopting new tools; it requires a systematic integration of digital platforms, online learning ecosystems, and technology-enhanced pedagogies to improve accessibility, engagement, and overall learning quality (Musa, 2022; Verhoef et al., 2021). Recent studies highlight that the effectiveness of digital transformation in vocational settings depends not only on technological infrastructure but also on human factors such as readiness, adaptability, and emotional comfort in using technology (Begantsova et al., 2020; Efremova, 2023).

Over the past years, digital transformation studies have mainly been preoccupied with infrastructure and illiteracy. More recently, the focus has been on revealing a deeper understanding of behavioral and affective aspects that motivate the adoption of technologies. Liang et al. (2024) reported that the implementation of technology-enhanced learning (TEL) significantly improves students' achievement and motivation. However, its effectiveness depends on institutional preparation and the ability to cope with technostress. Along a similar vein, Muyambi & Ramorola (2025) underscored inequalities in digital preparedness among teachers, indicating that institutional assistance and self-confidence influence teachers' participation in digital media-based instruction. They imply here that psychological preparation and emotional ease are key factors in the digital transformation outcomes.

In parallel with this, the Technology Acceptance Model (TAM) remains one of the most commonly used frameworks in the study of technology integration in education. Nonetheless, contemporary scholars have augmented TAM with affective constructs. Kemp et al. (2024) introduced an Extended Educational Technology Acceptance Model (EETAM) that augmented predictors with comfort and well-being as predictors of behavioral intention in the case of virtual classroom adoption. Jiang et al. (2025) conducted a comprehensive bibliometric analysis. They found an increasing trend in the incorporation of psychological factors, such as trust, perceived enjoyment, and comfort, in AI-based and online education settings. The studies highlight that comfort is not merely a result of readiness but also a mediator that shapes how users adopt and sustain digital learning practices.

In the domain of vocational education, contemporary scholarship also indicates the critical necessity to develop students' digital competence (DC). Pagaldai et al. (2025) illustrated that institutional and attitude predictors significantly forecast DC among vocational education and training (VET) learners, noting the role of contextual support and favorable technology perceptions. Xu et al. (2025)

also indicated that digital literacy for higher vocational learners is determined by computer self-efficacy, teacher digital competence, and organizational support, substantiating the interconnection between personal and environmental aspects of digital transformation. These empirical observations confirm that digital transformation is a multi-dimensional phenomenon involving technological, pedagogical, and psychological spaces.

Despite such advances, a significant amount remains unknown regarding the relationships between affective variables, specifically technology comfort, that mediate the effects of readiness, technical issues, and infrastructure on learning achievement in vocational training. Whereas prior work has found that readiness and infrastructure are predictors of engagement (Abid et al., 2024; Yuangga, 2023), studies have been sparse that empirically investigate the processes by which students' familiarity with technology is converted into scholars' achievements. Elucidating such interrelations is fundamental to ensuring that digital transformation in vocational training culminates in enhanced learning performance rather than causing cognitive and emotional distress. Founded on identified gaps, this study is keen to investigate the following research questions:

1. What digital transformation factors significantly affect vocational students' learning outcomes?
2. How does technology comfort mediate relationships between readiness, technological problems, and infrastructure informing learning outcomes?

An educator must always innovate to utilize technology in learning activities Gan et al., (2015). Currently, the use of technology-based media is very popular among young people. The results from To address these questions, the investigation adopted an explanatory sequential mixed-methods approach, pairing quantitative correlation analysis with qualitative interviews. This allows for a holistic investigation into how digital transformation factors work together and affect student achievement in vocational education settings. This study's findings will enhance the understanding of affective elements in digital transformation within vocational education contexts.

Method

This research utilized a quantitative descriptive–correlational design informed by qualitative data. Quantitative data were collected from 59 public vocational school students (SMK) in West Java, Indonesia, using purposive sampling because of their experience with digital-based learning. Furthermore, qualitative interviews with seven students reinforced the interpretation of the quantitative findings.

A four-point Likert scale was administered to assess five variables: digital preparedness, technological comfort, technical problems, infrastructural support, and learning achievement. The response scale was Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1), with no middle option. The items in the questionnaire were taken with permission from already validated digital transformation and technological acceptability studies (Kemp et al., 2024; Liang et al., 2024; Zubizarreta Pagaldai et al., 2025). Content validity was checked by an expert (supervisor of the study) to ensure clarity, relevancy, and linguistic precision. In contrast, construct validity was assessed by item–total correlation on pilot data retrieved from students not included in the main sample. Items with a correlation coefficient above 0.30 were kept. The reliability testing with Cronbach's Alpha returned values above 0.70 across all variables, suggesting good internal consistency. Composite measures were computed by averaging responses at the item level in each construct (range 1–4).

The investigation adhered to the principles of educational research ethics, including school consent and voluntary participation by pupils. The school head had permitted the investigation to be carried out, and information about the study goals, along with the right to withdraw at will, was given to all the participants. Informed consent was obtained from each student before data collection, and their responses were kept strictly confidential and used only for the study.

Data were also subjected to SPSS version 19. Descriptive statistics were used to report students' responses. Since the data were not normally distributed, non-parametric tests, such as the Chi-Square test and Spearman's rho correlation, were used to analyze relationships between digital transformation factors and learning outcomes with a $p < .05$ level of significance.

Data analysis was conducted on the qualitative interview data using a thematic analysis process, following Miles et al. (2014), which includes three stages: data reduction, data display, and conclusion drawing. The interview scripts were manually coded to extract repeated behaviors linking with students' digitization-readiness, comfort, and challenge. Extracted themes were cross-checked with quantitative outcomes and triangulated to achieve a credible and consistent interpretation.

Result and Discussion

After the instrument validation process, revisions were made based on expert feedback, followed by reliability and normality testing. The data were found to be not normally distributed, so non-parametric statistical techniques were used. Chi-Square tests were applied to examine

relationships between variables, and Spearman's rho correlations were used to analyze associations among the four digital transformation factors: digital readiness (Q1), technical challenges (Q2), technology comfort (Q3), and infrastructure support (Q4). Complementary qualitative data from interviews with seven students enriched the interpretation of these quantitative findings.

1. Quantitative Results

The results of the non-parametric analyses, including the Chi-Square and Spearman correlation tests, were used to identify relationships among digital transformation factors and students' learning outcomes. The results of the Descriptive Statistics of Digital Transformation Factors are shown in Table 1.

Table 1. Descriptive Statistics of Digital Transformation Factors

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Digital Readiness (Q1)	59	2.25	4.00	3.06	0.32
Technical Challenges (Q2)	59	1.75	4.00	2.77	0.46
Technology Comfort (Q3)	59	2.25	4.00	3.06	0.33
Infrastructure Support (Q4)	59	2.00	4.00	3.12	0.42

The descriptive results (Table 1) indicate that students demonstrated a high level of digital readiness (Mean = 3.06) and comfort in using technology (Mean = 3.06). Technical challenges had the lowest mean (Mean = 2.77), suggesting that while some students encountered difficulties, these did not dominate the learning experience. Infrastructure support also received a relatively optimistic assessment (Mean = 3.12), indicating adequate digital facilities within the school environment.

2. Chi-Square Tests

A significant relationship was found between digital readiness and learning outcomes (p = 0.005). This result (Table 2) suggests that students with higher readiness to engage in digital learning tend to achieve better academic outcomes. It reflects how readiness functions as a fundamental enabler for digital learning engagement.

Table 2. Relationship Between Digital Readiness (Q1) and Learning Outcomes

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	153.991	112	0.005
Likelihood Ratio	93.245	112	0.901
Linear-by-Linear Association	1.178	1	0.278
Valid N	59		

The analysis shows no significant relationship between technical challenges and learning

outcomes (p > 0.05). While students reported varying levels of technical difficulty, these challenges did not substantially hinder learning achievement, possibly due to the adaptive coping mechanisms developed during the pandemic-driven digital transition.

In Tabel 3 The analysis shows no significant relationship between technical challenges and learning outcomes (p > 0.05). While students reported varying levels of technical difficulty, these challenges did not substantially hinder learning achievement, possibly due to the adaptive coping mechanisms developed during the pandemic-driven digital transition.

Table 3. Relationship Between Technical Challenges (Q2) and Learning Outcomes

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	129.121	144	0.808
Likelihood Ratio	98.611	144	0.999
Linear-by-Linear Association	0.994	1	0.319
Valid N	59		

The results (Table 4) indicate a significant relationship between technology comfort and learning outcomes (p < 0.01). Students who feel emotionally and technically comfortable using digital platforms demonstrate higher engagement and better performance. This finding aligns with the Extended Educational Technology Acceptance Model (EETAM), which emphasizes emotional comfort as a mediator of technology adoption Kemp et al., (2024).

Table 4. Relationship Between Technology Comfort (Q3) and Learning Outcomes

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	186.642	112	0.000
Likelihood Ratio	91.582	112	0.921
Linear-by-Linear Association	6.391	1	0.011
Valid N	59		

No significant correlation on table 5 was observed between infrastructure support and learning outcomes (p > 0.05). Although students perceived adequate access to digital facilities, the quality of engagement and learning performance appeared to depend more on personal affective factors than infrastructural resources alone.

Table 5. Relationship Between Infrastructure Support (Q4) and Learning Outcomes

Test	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	106.478	96	0.218
Likelihood Ratio	81.289	96	0.858
Linear-by-Linear Association	0.315	1	0.575
Valid N	59		

3. Chi-Square Tests

In tabel 6 are The Spearman correlation results reinforce that technology comfort (Q3) has the strongest positive association with learning outcomes ($r = 0.417$, $p < 0.01$)... positively correlated with readiness ($r = 0.346$) and infrastructure support ($r = 0.312$), indicating that comfort serves as a mediating factor connecting cognitive and environmental aspects of digital transformation.

Table 6. Spearman Correlation among Digital Transformation Factors and Learning Outcomes

Variables	Q1	Q2	Q3	Q4	Learning Outcomes
Digital Readiness (Q1)	1.000	0.189	0.346*	−0.103	0.228
Technical Challenges (Q2)	0.189	1.000	−0.251 (ns)	0.217	0.249
Technology Comfort (Q3)	0.346*	−0.251 (ns)	1.000	0.312*	0.417**
Infrastructure Support (Q4)	−0.103	0.217	0.312*	1.000	0.215
Learning Outcomes	0.228	0.249	0.417**	0.215	1.000

$p < 0.05$, $p < 0.01$ (two-tailed)

Source: SPSS 19 Output

4. Qualitative Insights

To deepen the interpretation, semi-structured interviews were conducted with seven students. Thematic analysis Miles et al., (2014) produced three main themes: (1) emotional adaptation, (2) digital comfort and motivation, and (3) contextual barriers.

Theme 1: Emotional Adaptation

Students described an initial sense of anxiety when using new digital tools, which gradually transformed into confidence after repeated exposure. One participant reflected:

"At first, I was nervous during online exams, but over time I started enjoying them because I could access materials more easily."

This pattern supports the quantitative finding that technology comfort significantly affects learning outcomes, as emotional familiarity enhances cognitive engagement Liang et al., (2024).

Theme 2: Digital Comfort and Motivation

Students expressed that feeling comfortable with digital platforms boosted their motivation and autonomy. Another student shared:

"When I understand how to use the apps properly, learning feels easier and more interesting."

This aligns with the Technology Acceptance Model extension, indicating that perceived ease of use and emotional comfort increase behavioral intention and performance (Kemp et al., 2024).

Theme 3: Contextual Barriers

Despite overall readiness, several students reported intermittent internet problems and limited

device access at school, emphasizing that technical and infrastructural issues occasionally interrupted their learning. However, most participants viewed these as temporary constraints rather than major obstacles.

These insights corroborate the statistical results, indicating that technical challenges (Q2) and infrastructure (Q4) did not directly influence learning outcomes but were indirectly related to comfort and adaptability.

To provide a comprehensive synthesis between quantitative and qualitative phases, the following joint display integrates statistical findings with emergent interview themes.

5. Quantitative and Qualitative Findings

The integrated findings reveal that technology comfort consistently bridges cognitive and contextual factors, confirming its mediating role between readiness, infrastructure, and learning outcomes. This integration supports the comfort-centered model proposed in this study that shown on table 7 and the Comfort-Centered Model (Figure. 1) illustrates that technology comfort serves as a mediating affective variable linking digital readiness, infrastructure support, and technical challenge with students' learning outcomes..

Table 7. Joint Display of Quantitative and Qualitative Findings

Variable	Quantitative Result	Qualitative Theme	Integrated Interpretation
Readiness	Significant correlation with comfort (r = 0.346)	Emotional adaptation	Readiness enhances comfort via confidence.
Technical Challenges	No direct effect	Connectivity issues, coping strategies	Challenges influence comfort indirectly.
Comfort	Strong correlation with learning outcomes	Motivation, familiarity	Comfort mediates digital engagement.
Infrastructure	Significant correlation with comfort (r = 0.312, p < 0.05)	Access variability	Supportive but not decisive.

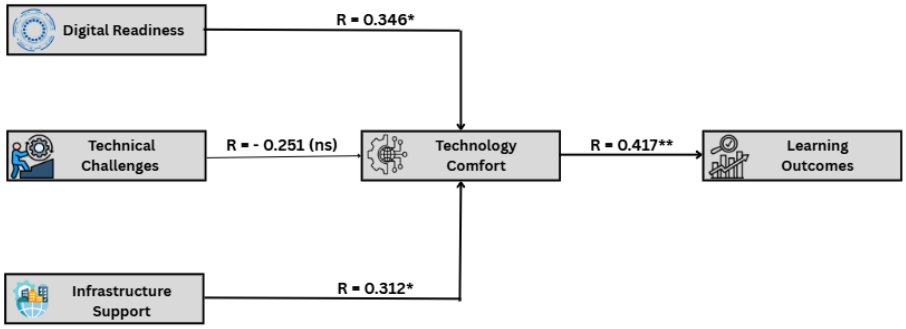

Fig 1: Comfort-Centered Model of Digital Transformation in Vocational Education

Empirical evidence indicates that digital readiness ($r = 0.346$, $p < 0.05$) and infrastructure support ($r = 0.312$, $p < 0.05$) are significantly positively correlated with technology comfort, suggesting that well-prepared students and favorable environments facilitate emotional ease in digital instruction practices. Conversely, technical challenge is found to show a weak and non-significant negative association ($r = -0.251$, ns), indicating that occasional technological problems do not significantly detract from students' comfort levels once confidence and adaptability have been built up. Furthermore, technology comfort is found to significantly correlate with learning outcomes ($r = 0.417$, $p < 0.01$), substantiating its mediating function in connecting readiness and infrastructure with performance enhancement.

Theoretically, this conceptual framework extends the Extended Educational Technology Acceptance Model (EETAM) Kemp et al., (2024) by incorporating affective processes such as confidence, pleasure, and digital well-being. It is consistent with Self-Determination Theory (Ryan & Deci, 2000) and Affective Engagement Theory Halverson and Graham (2019) in pointing out that digital transformation in vocational education is not just a function of cognitive preparedness and infrastructure but also a function of emotional and behavioral comfort experienced by the learners.

6. Discussion

The findings reveal that technology comfort plays a pivotal role in shaping learning outcomes in vocational education. Consistent with the Extended Educational Technology Acceptance Model (EETAM), affective readiness and perceived comfort serve as mediators that link digital preparedness with successful learning performance Kemp et al (2024).

While digital readiness contributed to improved learning outcomes, its influence was primarily indirect through enhanced comfort and motivation. Conversely, technical challenges and infrastructure support did not demonstrate significant direct effects, suggesting that cognitive and emotional factors outweigh technical availability in determining students' success (Xu et al., 2025).

The qualitative results strengthen these interpretations by illustrating how students' confidence, motivation, and familiarity with digital tools reduce anxiety and increase engagement. This resonates with findings by Zubizarreta Pagaldai et al. (2025), who emphasized that institutional support must be accompanied by attitudinal change to realize the benefits of digital transformation fully.

In the context of vocational education, this study highlights that the effectiveness of digital transformation depends not only on technology provision but also on cultivating emotional and

behavioral readiness among learners. Hence, pedagogical strategies should integrate emotional support, scaffolding, and continuous digital training, along with teacher professional development programs that strengthen educators' digital and affective competencies. Such initiatives would ensure that both students and teachers experience higher levels of technological confidence and comfort, fostering more sustainable digital transformation in vocational education.

Conclusion

This study concludes that technology comfort is the most influential factor affecting vocational students' learning outcomes, emphasizing the importance of affective readiness in digital transformation. Although digital readiness, technical challenges, and infrastructure support play roles, their effects are primarily indirect through comfort and emotional engagement. Students' confidence and motivation strengthen as they adapt to technology-supported learning. Therefore, schools and teachers should prioritize strategies that enhance digital comfort through emotional support, scaffolding, and continuous digital training. Future research should expand across multiple institutions to explore how affective and contextual factors shape sustainable digital transformation in vocational education. This study reaffirms that emotional comfort is the bridge between technological readiness and meaningful digital learning.

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