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DETERMINANTS OF VOCATIONAL STUDENTS' LEARNING OUTCOMES IN THE ERA OF CONSTRUCTION DIGITALIZATION: THE ROLE OF DIGITAL LITERACY, LEARNING MOTIVATION, AND SCHOOL SUPPORT

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ABSTRACT

The rapid digitalization of the modern construction industry necessitates vocational students in the Building Information Modeling and Design (DPIB) program to possess robust digital literacy, intrinsic learning motivation, and comprehensive school support. This study systematically investigates the partial and simultaneous effects of these three determinants on student learning outcomes. Employing a quantitative ex-post facto correlational design, empirical data were gathered from a proportionally randomized sample of 132 tenth-grade DPIB students across four Vocational High Schools in Malang Raya. Data analysis utilizing multiple linear regression revealed that digital literacy, learning motivation, and school support exert a significant and positive impact on learning outcomes, both individually and collectively ($p < 0.05$). *Notably, digital literacy emerged as the most dominant partial predictor. However, the simultaneous contribution of these predictors accounted for only 11.0% of the total variance in academic achievement. This critical finding indicates that while foundational cognitive literacies and physical institutional backing are statistically essential, they remain insufficient to holistically capture vocational competence. The study concludes that future research must investigate the remaining unmeasured variance by directly examining the acquisition of tacit knowledge through work-based learning and industry-school alignments.*

Keywords: *Digital Literacy, Learning Motivation, School Support, Learning Outcomes, Vocational Education*

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INTRODUCTION

Vocational High Schools (SMK) constitute a fundamental educational framework explicitly designed to equip students with applied technological competencies and independence required for direct entry into the modern workforce. Within the architectural and infrastructure sectors, the Building Information Modeling and Design (DPIB) program is currently undergoing a structural transformation driven by rapid industrial digitalization. As articulated by Spöttl & Windelband (2021), the contemporary state of the art in construction education indicates a definitive shift from traditional manual drafting techniques to the utilization of advanced digital technologies, such as Computer-Aided Design (CAD) and Building Information Modeling (BIM). Building modeling currently transcends basic visual representation; it encompasses complex spatial, material, and functional analyses that necessitate a multidisciplinary systemic thinking regarding a building's entire life cycle. Consequently, mastering these complex tools requires students to possess adequate digital literacy, which enables them to critically access, evaluate, and operate digital information in a learner-centered educational paradigm (Zhao & Watterston, 2021).

The attainment of optimal learning outcomes in digital-based vocational education is heavily contingent upon the synergy between intrinsic psychological factors and extrinsic institutional facilitation. Chiu (2022) posits that learning motivation serves as a crucial internal driving force that initiates, directs, and sustains student persistence and creativity during complex pedagogical activities. In the context of digital laring, this motivation is determined by the relevance of the instructional material, active student involvement, and the perceived competence in executing technical tasks. Students exhibiting high learning motivation consistently demonstrate greater enthusiasm and resilience in overcoming academic challenges, directly elevating their academic achievements (Mubarroq et al., 2026). Concurrently, school support acts as a mandatory external determinant designed to reinforce the learning environment. Avis et al. (2021) emphasize that institutional backing must go beyond administrative policies to include tangible pedagogical support. The provision of comprehensive physical and digital infrastructure such as stable internet access, professional software licenses, and standardized computer laboratories is indispensable to ensure that vocational students develop practical skills and professional attitudes evenly (Prasetya et al., 2024).

Despite the established theoretical importance of these independent variables, a distinct research gap persists concerning their concurrent impact on specific technical competencies within VET institutions. Current empirical evidence indicates a persistent issue where internal student capacities and external environmental factors remain sub-optimal in effectively elevating student learning outcomes during the digital instructional transition. Previous literature has primarily assessed digital literacy, learning motivation, and institutional infrastructure in isolation, lacking a holistic quantitative evaluation of their simultaneous interplay within specialized programs like DPIB. Furthermore, the critical mechanism of how school support mitigates technical barriers

while interacting with students' intrinsic motivation requires robust statistical validation. Therefore, this study aims to systematically analyze the partial and simultaneous effects of digital literacy, learning motivation, and school support on the learning outcomes of DPIB students across Vocational High Schools in Malang Raya. Addressing this gap will provide strategic empirical foundations for educators and policymakers to synchronize VET curricula with modern construction industry standards.

METHOD

This study employed a quantitative approach utilizing an ex-post facto correlational research design. This specific framework was selected to systematically investigate the direction and significance of causal relationships among the variables without introducing experimental manipulation. The independent variables investigated comprised Digital Literacy (X1), Learning Motivation (X2), and School Support (X3), while the dependent variable was measured as Learning Outcomes (Y). The conceptual framework illustrating the interaction among these variables is presented in Figure 1.

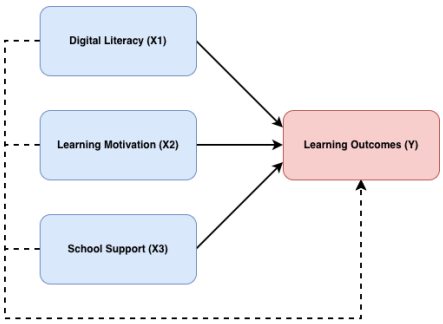


Figure 1. Conceptual Framework of the Relationship Between Independent and Dependent Variables

The target population for this study encompassed all tenth-grade students enrolled in the Building Information Modeling and Design (DPIB) program across the Malang Raya region. The population was distributed across four vocational institutions: SMKN 11 Malang, SMK Nasional, SMKN 6 Malang, and SMKN 1 Singosari, yielding a total population of 196 students. To ensure representativeness, the sample size and distribution were determined utilizing a proportional simple random sampling technique, which guaranteed that every student within each respective institution and classroom possessed an equal probability of selection. Based on standard sampling calculations, a final sample of 132 students was established. The detailed distribution of the sample allocation is outlined in Table 1.

Table 1. Population and Sample Distribution of DPIB Students

No	Vocational High School (SMK)	Class	Population (N)	Sample (n)
1	SMKN 11 Malang	X DPIB 1	33	22
2	SMK Nasional	X DPIB 1	29	20
3	SMKN 6 Malang	X DPIB 1	32	21
		X DPIB 2	34	23
4	SMKN 1 Singosari	X DPIB 1	34	23
		X DPIB 2	34	23
Total			196	132

Empirical data for the independent variables Digital Literacy, Learning

Motivation, and School Support were gathered through validated closed-ended questionnaires structured on a Likert scale. Conversely, data pertaining to the dependent variable, Learning Outcomes, were extracted directly from the students' official academic records. Prior to administration, all instruments were rigorously subjected to construct validity and reliability testing to ensure measurement accuracy.

The primary analytical procedure employed to test the formulated hypotheses was Multiple Linear Regression, executed via IBM SPSS software (version 25). This statistical technique facilitated the evaluation of both the partial and simultaneous effects of the predictors on the criterion variable. Furthermore, rigorous prerequisite diagnostic testing specifically assessing normality, linearity, multicollinearity, and heteroscedasticity was conducted prior to the regression analysis to verify that the generated model adhered strictly to the assumptions of a Best Linear Unbiased Estimator (BLUE).

RESULTS AND DISCUSSION

1. The Effect of Digital Literacy (X_1) on Learning Outcomes (Y)

Simple linear regression was employed to analyze the partial impact of Digital Literacy on the learning outcomes of DPIB students. The statistical parameters derived from the estimation are summarized in Table 2.

Table 2. Simple Linear Regression of X_1 on Y

Variable	Constant	Coefficient	R2	Sig.	Remarks
Digital Literacy (X_1)	57.458	0.732	0.087	0.001	Significant

The analysis presented in Table 2 reveals a significance value of 0.001, which falls below the 0.05 alpha threshold ($0.001 < 0.05$). The generated regression equation is: $Y = 57.458 + 0.732X_1$. Skulmowski & Xu (2022) confirm that digital literacy transcends basic operational skills; it serves as a fundamental cognitive catalyst in vocational architecture programs. Sweller (2024) apply Cognitive Load Theory within multimedia learning to demonstrate that robust digital literacy significantly minimizes the extraneous cognitive load associated with navigating complex user interfaces. Jian & Abu Bakar (2024) point out that when students are not cognitively overwhelmed by the mechanics of CAD and Building Information Modeling (BIM) platforms, their mental resources are effectively redirected toward intrinsic architectural problem-solving. Falloon (2020) observes that digitally competent students can autonomously evaluate construction standards, decode complex spatial geometries, and execute precise drafting protocols. Mengmeng et al. (2025) emphasize that this technical fluency enables students to transition from passive software operators to analytical designers, thereby elevating the quality of both their theoretical assessments and psychomotor drafting outputs.

2. The Effect of Learning Motivation (X_2) on Learning Outcomes (Y)

The partial impact of internal learning motivation on academic achievement was evaluated using the statistical parameters outlined in Table 3.

Table 3. Simple Linear Regression of (X_2) on (Y)

Variable	Constant	Coeff-icient	R2	Sig.	Remarks
Learning Motivation (X_2)	65.896	0.492	0.044	0.016	Significant

The statistical indicators show a significance value of 0.016 $(0.016 < 0.05)$, yielding the mathematical model: $Y = 65.896 + 0.492X_2$. Chiu (2022) utilizes Self-Determination Theory (SDT) to explain the profound impact of this internal drive on sustained academic engagement. Howard et al. (2021) underscore the necessity of fulfilling students' basic psychological needs autonomy, competence, and relatedness in rigorous vocational settings that demand high frustration tolerance. Reeve & Cheon (2021) find that highly motivated students perceive the complexities of structural engineering logic and 3D modeling not as insurmountable barriers, but as intellectual challenges. Pickal et al. (2026) conceptualize that intrinsically driven students do not view drafting errors as failures; rather, they process them as iterative steps in the design optimization process. Zervas & Stiakakis (2024) corroborate that the fulfillment of perceived competence during these digital tasks acts as the primary psychological mechanism that sustains long-term achievement in technical and vocational education and training (TVET).

3. The Effect of School Support (X_3) on Learning Outcomes (Y)

The contribution of external factors, specifically institutional facilities and policies, is presented through the regression results in Table 4.

Table 4. Simple Linear Regression of X_3 on Y

Variable	Constant	Coeff-icient	R2	Sig.	Remarks
School Support (X_3)	71.168	0.295	0.034	0.034	Significant

The data in Table 4 demonstrate that School Support has a significant partial effect on learning outcomes $(0.034 < 0.05)$, with the equation formulated as $Y = 71.168 + 0.295X_3$. Barcelos et al. (2021) highlight that providing physical infrastructure, such as high-end workstations and industry-standard software licenses, must be coupled with strategic pedagogical orchestration. Rapanta et al. (2021) draw upon the Technological Pedagogical Content Knowledge (TPACK) framework to warn that physical computing assets remain inert without an institutional climate that encourages technical exploration. Garavan & McGuire (2001) argue that school support in TVET extends beyond administrative backing to encompass the active implementation of an industrial work culture within the laboratory. Isnandar et al. (2023) demonstrate that simulating real-world architectural firm environments often materialized through the Teaching Factory (TeFa) paradigm provides students with a crucial psychological safety net. Norabuena-Figueroa et al. (2025) conclude that this supportive institutional climate effectively lowers students' technical anxiety, streamlines the transfer of tacit knowledge, and ensures the equitable development of psychomotor competencies.

4. The Simultaneous Effect of Digital Literacy ($\boldsymbol{X_1}$), Learning Motivation ($\boldsymbol{X_2}$) and School Support ($\boldsymbol{X_3}$) on Learning Outcomes ($\boldsymbol{Y}$)

A simultaneous test was conducted to measure the collective effect of all independent variables on the dependent variable. The multiple linear regression results are summarized in Table 5 and Table 6.

Table 5. Simultaneous Regression Test (X_1, X_2, X_3 *on* Y)

Model	Sig.	Remarks	Adjusted R^2
Multiple Regression	0.000	Significant	0.110

Table 6. Constants and Coefficients of the Multiple Regression Model

Model	Constant	Coefficient X_1	Coefficient X_2	Coefficient X_3
Multiple Regression	38.645	0.617	0.334	0.233

The analysis of variance yielded a simultaneous significance value of 0.000, establishing the model: $Y = 38.645 + 0.617X_1 + 0.334X_2 + 0.233X_3$. Spöttl & Windelband (2021) assert that the collective efficacy of individual digital readiness, psychological drive, and institutional facilitation creates a holistic ecosystem that equips vocational students for the disruptive demands of modern construction industry digitalization. Hiim (2022) provides a critical theoretical revelation regarding the low Adjusted R^2 value (11.0%), stating that TVET learning outcomes are fundamentally characterized by a high degree of tacit knowledge. Virtanen et al. (2021) explain that tacit skills acquired through repetitive psychomotor practice, experiential learning, and kinesthetic memory are notoriously difficult to capture through standardized diagnostic metrics like questionnaires. Nahardani et al. (2021) hypothesize that the remaining 89.0% of unaccounted variance likely resides in the "hidden curriculum" of vocational training, encompassing the quality of cognitive apprenticeship between master (teacher) and novice (student), peer-assisted learning dynamics, and innate spatial intelligence. Nkunya & Mwila (2024) signal a theoretical pivot, suggesting that comprehensively bridging the skills gap in programs like DPIB requires future research to directly measure the quality of industry-school alignments and real-world apprenticeship programs.

CONCLUSION

This study establishes that digital literacy, learning motivation, and school support exert a significant and positive impact on the learning outcomes of vocational students in the DPIB program, both partially and simultaneously. Despite their statistical significance, these determinants collectively account for only 11.0% of the total variance in academic achievement. This reveals that foundational technical literacies and physical institutional facilities, while fundamentally essential, remain insufficient to fully capture the multidimensional epistemology of vocational competence. Consequently, future research must pivot toward investigating the unmeasured 89.0% of variance by directly examining the acquisition of tacit knowledge through work-based learning, the quality of cognitive apprenticeship, and the specific pedagogical

effectiveness of industry-school alignments within real-world teaching factory environments.

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