

Digital Learning Innovation through Website-Based BIM E-Modules: A UTAUT-Based Study of Advanced and Adaptive Learning in Vocational Education

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Abstract

The integration of Building Information Modeling (BIM) in vocational education requires learning environments that support meaningful, flexible, and technology-enhanced learning. A website-based BIM e-module represents an instructional innovation that can facilitate independent learning through structured digital content and multimedia resources. This research intends to investigate the factors that influence the acceptance and use of a website-based BIM e-module among vocational education students based on the Unified Theory of Acceptance and Use of Technology (UTAUT) framework. The quantitative survey research approach was conducted on 65 students of Grade XI from the Building Construction and Housing Engineering at SMK Negeri 1 Jakarta in the academic year 2024/2025. The 40-questionnaire was distributed among the participants measuring Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC). Descriptive statistics and Partial Least Squares Structural Equation Modelling (PLS-SEM) techniques were applied to analyze the gathered data. The reliability and validity of the measurement model were satisfactory while the structural model presented significant positive associations of all four UTAUT variables and the acceptance and use of BIM e-module. Performance Expectancy ($\beta = 0.228$), Effort Expectancy ($\beta = 0.211$), Social Influence ($\beta = 0.332$), and Facilitating Conditions ($\beta = 0.318$) were found to be significant at $p < 0.001$. An R^2 value of 0.993 was achieved in the model suggesting the high explained variance in the endogenous construct. Social Influence and Facilitating Conditions had relatively larger path coefficients pointing to the relevance of social and enabling conditions to BIM e-module adoption.

Keywords: building information modeling, BIM e-module, advanced learning, instructional design, learning strategies, adaptive learning, digital learning innovation, UTAUT model.



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1. Introduction

With the advancement of digital technology, education and industry have been transformed. The increasing significance of technology integration in education makes it relevant to the demands of the Industrial Revolution 4.0 that requires students to be

competent in both occupation and digital. Building Information Modeling (BIM) is a particular technology for digitally integrated management of the building lifecycle, comprising of planning, design, construction and related processes (Heryadi et al., 2022). Therefore, BIM competence represents an im-

portant component of advanced vocational learning, enabling SMK students to integrate digital technologies, technical knowledge, and practice-oriented skills within contemporary construction education.

However, even if BIM is becoming relevant in education, there might appear challenges to implement the technology in vocational education. These conditions create significant challenges for vocational learning, particularly in supporting students' independent understanding of complex BIM concepts, managing learning time, and effectively engaging with digital learning technologies. Furthermore, according to data collected by the [Badan Pusat Statistik \(BPS\), \(2024\)](#), the readiness of educators to implement technologies in education is still rather low. Particularly, there is a lack of integration of computers and internet in teaching process ([Lal et al., 2024](#)). Therefore, a learning approach should be developed that will be available, flexible, and helpful for students to learn independently. One of the possible solutions may be the use of website-based electronic modules (e-modules) with structured learning materials that include multimedia resources (for instance, instructional videos, interactive content, and 3D simulation) ([Afifah, 2020](#)).

Thus, SMKN 1 Jakarta has implemented a website-based BIM e-module through Google Sites as an instructional innovation to support building drawing instruction through digitally organized and accessible learning resources. However, the existence of the module does not mean its effective use. Observations showed that students have difficulty accessing it, see little benefit from using the module, and show low motivation in learning. These conditions indicate that the presence of digital learning technologies alone does not guarantee effective learning implementation ([Amin et al., 2025](#)). The

educational value of a technology-supported learning environment also depends on how learners perceive its usefulness, usability, social support, and the availability of conditions that enable meaningful engagement with the learning process ([Ramadhan & Maulana, 2020](#)). Instead, the successful use of a technology-supported learning intervention is significantly determined by the users' acceptance of it, the perceived value of it, and the willingness to use the technology. Thus, the comprehension of the factors that influence acceptance is crucial for implementation.

For examining the factors that affect technology acceptance and usage, the Unified Theory of Acceptance and Use of Technology (UTAUT) can be used. The model by [Venkatesh et al. \(2003\)](#) combines four core constructs Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) to explain behavioral intention and usage of technology ([Mahande & Malago, 2018](#)). It has been used for research of learning management systems (LMS), mobile learning, virtual learning environments ([Or & Chapman, 2021](#)), and digital devices ([Warsono, 2024](#)). Nevertheless, research of technology acceptance is conducted mostly with university students and general-purpose technologies. For instance, [Hutabarat \(2020\)](#) studies technology acceptance in an educational context but does not conduct research related to BIM oriented learning of SMK students.

Moreover, limited research has examined how technology acceptance interacts with the instructional and learning conditions surrounding website-based BIM e-modules in secondary vocational education. This gap is important because effective digital learning requires not only technological availability but also appropriate instructional design, learner support, and learning strategies that

enable students to engage with complex vocational content (Mujalli & Khan, 2022). BIM is a special domain of Architecture, Engineering, and Construction (AEC) education, and thus, it requires particular learning environments that can assist in acquiring knowledge and practical skills (Gunasagaran et al., 2023). Even though the UTAUT model has been used for numerous investigations of acceptance of various educational technologies, the application of it for BIM education and website-based e-modules in the case of Indonesian SMK students has not been studied. However, it is worth researching because the secondary vocational education is a unique environment for learning and using technologies compared with universities. Thus, the research of technology acceptance in this context can widen the scope of applicability of UTAUT model.

Therefore, the current study focuses on the examination of the factors that affect the acceptance and use of website-based BIM e-module of SMKN 1 Jakarta by the SMK students through the lens of four core constructs of UTAUT. Specifically, the aim of the study is to empirically identify the dominant factors of students' acceptance and use of the module.

2. Method

Quantitative approach to research with cross-sectional survey design was used to explore students' acceptance and usage behavior towards website-based Building Information Modeling (BIM) e-module. The study is based on the Unified Theory of Acceptance and Use of Technology (UTAUT) framework introduced by Venkatesh et al. (2003), including four core constructs: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC). Besides providing description of students'

perceptions, Partial Least Squares Structural Equation Modeling (PLS-SEM) is used to analyze relations between these constructs and students' acceptance and usage behavior.

The study is implemented in SMK Negeri 1 Jakarta during the 2024/2025 academic year. Target population consists of 65 eleventh grade students enrolled in the Building Construction and Housing Engineering program (*Teknik Konstruksi dan Perumahan, TKP*) and having experience of working with the website-based BIM e-module. Since the population is rather small and all participants meet the specified criteria, the total sampling technique was used. Hence, the whole population became the research sample ($N = 65$).

a. Research Instrument

Data collection is implemented with the help of the structured questionnaire developed on the basis of four core constructs of UTAUT (Venkatesh et al., 2003). Performance Expectancy (PE) includes five indicators: usefulness, extrinsic motivation, job fit, relative advantage, and outcome expectations. Effort Expectancy (EE) involves three indicators: ease of use, complexity, and ease of learning (Wijaya et al., 2022). Social Influence (SI) includes three indicators: subjective norms, social factors, and image. Facilitating Conditions (FC) involves three indicators: perceived behavioral control, facilitating conditions, and compatibility.

Initially, the questionnaire includes 14 indicators with three statements per indicator, which provides 42 items. All items were measured using four-point Likert scale. Before implementing the main data collection, the instrument undergoes empirical validation and reliability test using pilot sample of 32 respondents. Item validity is estimated with the help of Product

Moment Pearson correlation. Two items (PE-A1 and PE-C2) are revealed as invalid and consequently excluded from further analysis (Heryadi et al., 2022). The instrument therefore includes 40 valid items. Reliability of the instrument is analyzed using Cronbach's Alpha, and the coefficient of $\alpha = 0.975$ is found.

b. Data Collection and Ethical Considerations

The data collection process is carried out after receiving the official permission from the institution. Prior to filling in the questionnaire, respondents are informed about the research objectives, procedure and voluntary participation in the research. Informed consent is received from all respondents, anonymity and confidentiality of respondents are ensured during the research process (Asfani & Chen, 2025). The collected data are used only for research purposes.

c. Data Analysis

Data analysis is implemented in two stages. At the first stage, descriptive statistics is used to describe students' perception of the constructs of UTAUT and their reaction to the website-based BIM e-module. Mean scores are calculated and interpreted with the help of predetermined categories from Very Low to Very High to evaluate general level of students' technology acceptance.

At the second stage, PLS-SEM is used to analyze relations among the UTAUT constructs and students' acceptance and usage behavior. This analysis includes evaluation of the measurement model and structural model. The measurement model is evaluated based on the indicators' reliability, convergent validity (Average Variance Extracted), and discriminant validity (Fornell-Larcker criterion). The structural

model is evaluated with the help of path coefficients, t-statistics and p-value to identify significance of the hypothesized relations (Amin et al., 2025). Coefficient of determination (R^2) is also estimated to evaluate ability of the model to explain endogenous constructs.

The combination of descriptive statistics and PLS-SEM provides comprehensive description of students' perceptions as well as empirical estimation of relations between the constructs of UTAUT and students' acceptance and usage behavior towards the website-based BIM e-module.

3. Result and Discussion

Analysis of data obtained from the survey of 65 Grade XI TKP students of SMKN 1 Jakarta was undertaken using two interrelated procedures. The first stage of the analysis included descriptive analysis in order to find out students' perceptions about the UTAUT constructs and also the acceptance pattern of the website based BIM e-module by students. The second stage included PLS-SEM analysis to determine the reliability and validity of the measurement model and structural relationship among the UTAUT constructs and acceptance and use behavior of students towards the BIM e-module. These results are analyzed under three interrelated perspectives: (1) perceptions of students regarding the UTAUT constructs in BIM e-module adoption; (2) validation of the measurement model of the UTAUT constructs; and (3) structural relationships and factors determining BIM e-module acceptance.

a. Students' Perceptions of the UTAUT Constructs in BIM E-Module Adoption

The descriptive analysis was carried out in order to evaluate students' perceptions of four core UTAUT constructs Performance

Expectancy (PE), Effort Expectancy (EE), So-cial Influence (SI), and Facilitating Con-ditions (FC) related to the website-based BIM e-module. The analysis was performed among 65 Grade XI TKP students of SMK

Negeri 1 Jakarta. At the preliminary stage, it is important to give a demographic descrip-tion of the respondents which is provided in Table 1.

Table 1. Characteristics of the Respondents Based on Gender

Gender	Number	Percentage (%)	Cumulative Percentage (%)
Female	38	58.5	58.5
Male	27	41.5	100.0
Total	65	100.0	100.0

As it follows from Table 1, female stu-dents constituted the larger proportion of the respondents, 38 (58.5%) in number, while males constituted 27 (41.5%) in number. This demographic composition should be taken into account when interpreting techno-logy acceptance in TKP program. However, since gender has not been used as the mode-rator variable in the present research, it is possible to speak of the descriptive charac-teristics of the respondents. According to pre-

vious research, female students enrolled in construction education programs tend to ha-ve less self efficacy than males ([Elliott & Del Puerto, 2014](#); [Ajid et al., 2025](#)), and gender orientation has also been revealed as the de-terminant of mobile learning technology ac-ceptance among construction trade trainees ([Asad et al., 2024](#)).

Descriptive statistics of Performance Expectancy are provided in Table 2.

Table 2. Descriptive Statistics of Performance Expectancy

Construct	Indicator	Std. Deviation	Mean	Category
Performance Expectancy	Perceived Usefulness	0.406	3.54	High
Performance Expectancy	Extrinsic Motivation	0.427	3.57	High
Performance Expectancy	Job Fit	0.512	3.44	High
Performance Expectancy	Relative Advantage	0.481	3.43	High
Performance Expectancy	Outcome Expectations	0.451	3.57	High

According to Table 2, all five PE indica-tors received High rating with mean scores varying from 3.43 to 3.57. The highest mean scores were registered by Extrinsic Motiva-tion and Outcome Expectations (3.57), then Perceived Usefulness (3.54), Job Fit (3.44), and Relative Advantage (3.43). This mean-ingful result demonstrates the consistent positivity of students' perception of the prac-tical and educational value of the e-module.

The similar results have been found previ-ously as the key factor influencing BIM ac-ceptance, especially since construction stud-ents associated BIM with productivity im-provement ([Ahankoo et al., 2025](#)). There-fore, the high PE scores indicate that the e-module is perceived as relevant.

Effort Expectancy receives a more mi-xed rating, as it is seen from Table 3.

Table 3. Descriptive Statistics of Effort Expectancy

Construct	Indicator	Std. Deviation	Mean	Category
Effort Expectancy	Perceived Ease of Use	0.461	3.44	High
Effort Expectancy	Complexity	1.063	2.72	Low
Effort Expectancy	Ease of Use	0.490	3.49	High

As it is shown in Table 3, the indicators Perceived Ease of Use (3.44) and Ease of Use (3.49) obtained the High rating, indicating that the students perceived the e-module as manageable. On the contrary, the Complexity indicator received a significantly lower mean of 2.72, thus obtaining Low rating. Moreover, the standard deviation of the indicator reached 1.063, being higher than that of the other EE indicators. These results indicate that the students perceived the e-module as usable but some aspects of the technology can still be considered complicated. This complexity can relate to navigating, BIM concepts, or technical aspects of digital learning (Pohan et al., 2026). It has been previ-

ously stressed that the perceived ease of use is one of the key determinants of engagement with e-learning technology (Hunde et al., 2023; Ozkan et al., 2020). Consequently, the low Complexity score highlights an important learning challenge that should be addressed through instructional design, particularly by simplifying navigation, sequencing complex BIM concepts, and providing additional guidance for students who experience difficulties when engaging with the digital learning environment (Mubarok et al., 2026).

The influence of the social environment is shown by the results presented in Table 4.

Table 4. Descriptive Statistics of Social-Influence

Construct	Indicator	Std. Deviation	Mean	Category
Social Influence	Subjective Norm	0.546	3.31	High
Social Influence	Social Factor	0.493	3.42	High
Social Influence	Image	0.495	3.41	High

Table 4 demonstrates that all SI indicators received the High rating. The highest mean score (3.42) was obtained by Social Factor, then Image (3.41) and Subjective Norm (3.31). Thus, the results suggest that students' perception of the BIM e-module is influenced by not only individual assessment of the value of the technology but also the social environment. Thus, teachers, peers, or other persons surrounding the learners may positively affect willingness to use the BIM e-module because of encouragement, expectations, or positive perception of

technology use. This conclusion is in line with previous findings demonstrating that peer collaboration and mentoring can help to implement educational technology (Mirriahi et al., 2012). Moreover, teacher support can influence the technology acceptance via perceptions of usefulness and ease of use (Wang et al., 2022). Therefore, the high SI scores indicate the socially embedded environment for BIM e-module adoption.

The availability and relevance of the supporting resources are demonstrated by Facilitating Conditions in Table 5.

Table 5. Descriptive Statistics of Facilitating Condition

Construct	Indicator	Std. Deviation	Mean	Category
Facilitating Conditions	Perceived Behavioral Control	0.551	3.22	Moderate
Facilitating Conditions	Facilitating Conditions	0.496	3.47	High
Facilitating Conditions	Compatibility	0.496	3.41	High

As it is shown in Table 5, the general Facilitating Conditions indicator showed the high mean (3.47), as well as Compatibility (3.41). However, the indicator Perceived Behavioral Control scored lower mean (3.22), receiving Moderate rating. This distinction is especially important as the availability of the technological resources does not necessarily mean that the learners feel capable of managing the problems independently (Kumar et al., 2023). Thus, the low PBC is consistent with the low Complexity in EE.

All in all, the findings indicate that learners have access to resources, but still need additional support when meeting technical difficulties. Previous studies have identified internet connectivity and technological infrastructure as the key problems related to the implementation of e-learning (Faza et al., 2024). Therefore, the current findings stresses the importance of combining infrastructure provision with proper technical and instructional support.

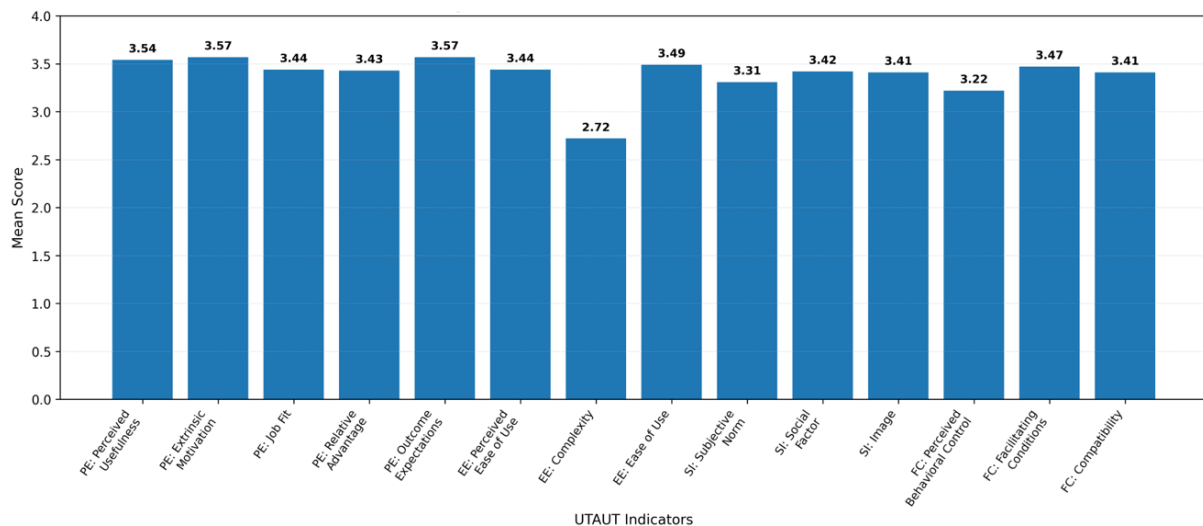
**Figure 1. Mean Scores of UTAUT Indicators**

Figure 1 illustrates the mean scores of all 14 UTAUT indicators and allows comparative evaluation of the perceptions of the students. The highest mean scores were registered by Extrinsic Motivation and Outcome Expectations (both 3.57), while the Complexity indicator got the lowest score (2.72). The chart also allows seeing that the majority of the indicators are positioned above the general threshold corresponding to positive perception, but Complexity and, to a

smaller degree, Perceived Behavioral Control represent weak areas. Thus, the overall picture suggests that the students recognize the value of BIM e-module and perceive it as applicable but there can be barriers in terms of the technical complexity and individual control over the e-module (Rahmadani et al., 2026). The descriptive statistics allow for making interpretations of the following structural model where high PE, SI, and FC scores provide the positive perceptual

background, while low EE-Complexity and FC-PBC scores identify the specific areas where implementation support is needed.

Overall, the descriptive analysis indicates that the students have positive perceptions about the website-based BIM e-module regarding the four UTAUT constructs. The performance expectancy construct demonstrates the positive perception of the usefulness and outcome, while the social influence construct shows the social support of the learning environment (Izkair & Lakulu, 2023). The facilitating conditions are also perceived positively although the moderate Perceived Behavioral Control score demonstrates that the availability of resources does not mean the complete independence of the technological use. Finally, effort expectancy demonstrates the most interesting variability due to the low Complexity score. These findings indicate that the acceptance of the BIM e-module is driven by the combination of perception of educational value, social context, ease of use, and conditions. The subsequent PLS-SEM analysis investigates whether these patterns are reflected in the structural relationships among the UTAUT constructs and acceptance and use behavior of the students.

b. Measurement Model Validation of the UTAUT Constructs

Measurement Model Evaluation Using PLS-SEM After conducting descriptive statistics analysis, the measurement model was assessed using the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique in order to determine whether the selected indicators represented the corresponding constructs adequately. The evaluation was based on assessing the following three crucial characteristics of measurement quality: indicator reliability, internal consistency and convergent validity, and discriminant validity. The evaluation is crucial, since the interpretation of the structural relationships among the constructs proposed by the UTAUT framework should be done after the validation of the measurement model.

First, the outer loadings of the observed indicators were examined. Indicator reliability implies the extent to which an observed variable represents the corresponding latent construct. As a rule, an indicator demonstrates reliable measurement if the outer loading exceeds 0.70. As a result of the analysis, it became clear that all retained indicators satisfy the condition. For example, the outer loading of the PE-A2 indicator was 0.894, while the EE-A1 indicator produced an outer loading of 0.798.

Table 6. Selected Indicator Loadings for the UTAUT Measurement Model

Construct	Indicator	Outer Loading	Recommended Threshold	Decision
Performance Expectancy (PE)	PE-A2	0.894	≥ 0.700	Retained
Effort Expectancy (EE)	EE-A1	0.798	≥ 0.700	Retained
Performance Expectancy (PE)	Other retained indicators	$> 0.700^*$	≥ 0.700	Retained
Effort Expectancy (EE)	Other retained indicators	$> 0.700^*$	≥ 0.700	Retained

As one can see from Table 6, the retained indicators demonstrate satisfactory indicator reliability. Thus, the loading of the PE-A2 indicator was rather high – 0.894, which

means that there was a high proportion of its variance associated with the Performance Expectancy construct. At the same time, the EE-A1 indicator loading exceeded 0.70

threshold at the level of 0.798, which means that it provided adequate representation of Effort Expectancy construct. Generally, the fact that the retained indicators have exceeded 0.70 suggests that the measurement items could be retained for further analysis (Nguyen et al., 2020). Moreover, the result is consistent with the findings during the preliminary validity testing, during which two items, namely PE-A1 and PE-C2, were excluded because of their failure to satisfy the empirical validity criterion. Hence, the refinement of the questionnaire improved its quality.

After evaluating indicator reliability, the constructs' internal consistency and conver-

gent validity were examined. Composite Reliability (CR) was used to examine the consistency of the indicators belonging to the same construct, while Average Variance Extracted (AVE) was used to examine whether the construct explained the sufficient proportion of variance of the indicators. As a rule, an AVE value above 0.50 suggests that the construct explains more than half of the variance of its indicators. As a result of the analysis, it was found that the latent constructs have satisfactory CR and AVE values, while the overall questionnaire exhibited a very high internal consistency with Cronbach's Alpha equal to $\alpha = 0.975$.

Table 7. Reliability and Convergent Validity of the Measurement Model

Construct	Cronbach's Alpha	Composite Reliability	AVE	Assessment
Performance Expectancy (PE)	-	> 0.700*	> 0.500*	Acceptable
Effort Expectancy (EE)	-	> 0.700*	> 0.500*	Acceptable
Social Influence (SI)	-	> 0.700*	> 0.500*	Acceptable
Facilitating Conditions (FC)	-	> 0.700*	> 0.500*	Acceptable
Overall instrument	0.975	-	-	High reliability

As it can be seen from Table 7, the measurement model has demonstrated satisfactory reliability and convergent validity due to the results obtained during the assessment. The overall Cronbach's Alpha of 0.975 suggests that the questionnaire has a very high internal consistency, although the CR and AVE values should be reported separately for each construct, since an overall Cronbach's Alpha coefficient cannot be considered as a tool demonstrating the reliability and convergent validity of each construct separately (El Koshiry et al., 2025). Satisfactory AVE results suggest that the indicators belonging to each construct demonstrate sufficient variance for representing their theoretical dimensions. In collective, these results

support the use of PE, EE, SI, and FC as separate constructs of the UTAUT framework for studying students' acceptance of the website-based BIM e-module.

Finally, the discriminant validity of the constructs was examined. This process allows determining whether each latent construct is empirically different from the other constructs of the model. The Fornell-Larcker criterion was used during this assessment through comparison of the square root of the AVE for each construct with its correlations with the other constructs (Zhang et al., 2023). The construct satisfies the criterion if the square root of its AVE is larger than its correlations with the other constructs.

Table 8. Discriminant Validity Based on the Fornell-Larcker Criterion

Construct	PE	EE	SI	FC
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Performance Expectancy (PE)	-	0.768*	-	-
Effort Expectancy (EE)	0.768*	0.812	-	0.792*
Social Influence (SI)	-	-	-	-
Facilitating Conditions (FC)	-	0.792*	-	-

*Values marked with an asterisk represent correlations reported in the available analysis; the complete Fornell-Larcker matrix should be populated from Appendix C.

As one can see from the available results, discriminant validity was proved for Effort Expectancy construct. Thus, the square root of the AVE of the EE construct was 0.812, which exceeded its correlation with FC (0.792) and PE (0.768). Therefore, the construct shared more variance with its indicators than with the other examined constructs. The Fornell-Larcker criterion was reported to be satisfied for the remaining

constructs. The establishment of discriminant validity is especially crucial in this study since the PE, EE, SI, and FC are conceptually related dimensions of the technology acceptance and hence might demonstrate high correlations (Belinda et al., 2024). The empirical distinctiveness guarantees that the subsequent structural analysis will not simply reflect the overlaps between theoretically different constructs.

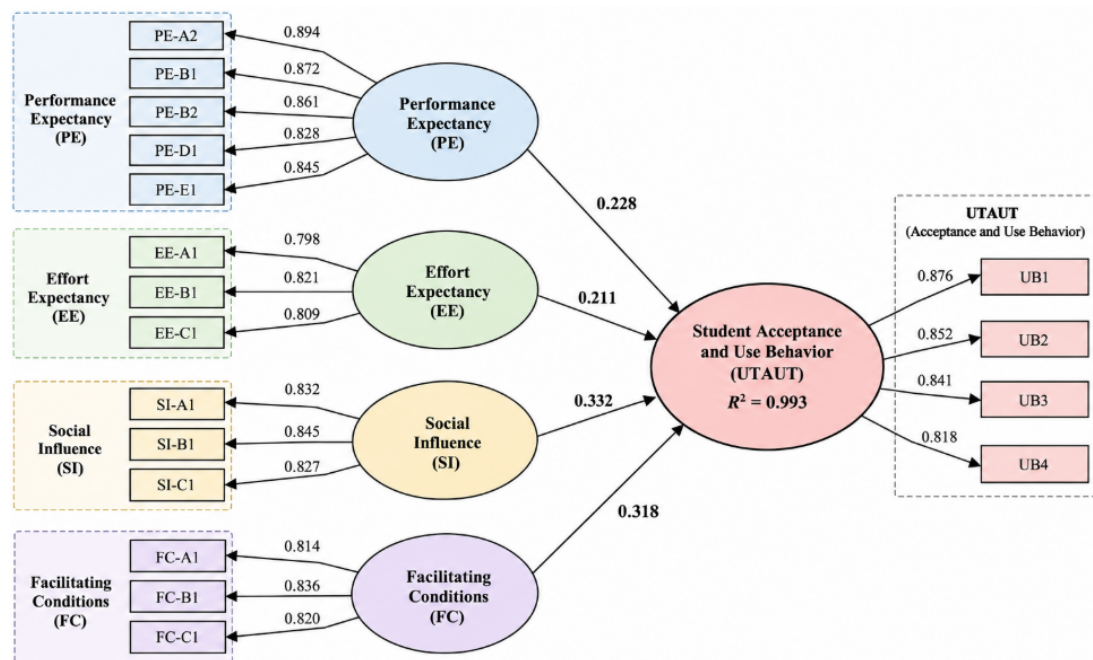


Figure 2. Measurement Model of the UTAUT Constructs

Figure 2 shows the structure of the measurement model, which underlies the analysis. The four UTAUT constructs, Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions, are modeled as separate explanatory constructs associated with students' acceptance and use behavior. In the full SmartPLS presentation, it is preferable to present all the retained in-

dicators along with their outer loadings and path estimates in Figure 2. Such a presentation helps to emphasize the theoretical structure of the measurement model and clearly separate the four latent constructs before structural model evaluation. Such separation is crucial, since the next stage of analysis aims to determine the contribution of each construct to students' acceptance and usage

behavior toward the BIM e-module (Mahande & Malago, 2018).

Overall, the measurement model evaluation results prove that the refined instrument is suitable for further structural analysis. First, the retained indicators have demonstrated satisfactory outer loadings, second, the instrument has high internal consistency, third, the construct-level reliability and convergent validity criteria are satisfactory. In addition, the Fornell-Larcker assessment has indicated that the UTAUT constructs maintain adequate discriminant validity (Alfadi, 2024). These results create an empirical foundation for examining the structural relationships among PE, EE, SI, and FC and student acceptance and usage behavior. Therefore, the next stage of analysis deals with the structural model, especially the magnitude and significance of the relationships represented by the path coefficients, t-

statistics, p-values, and coefficient of determination (R^2).

c. Structural Relationships and Determinants of BIM E-Module Acceptance

Having validated the measurement model, the structure model was analyzed using PLS-SEM to investigate the relationships between the four UTAUT constructs and students' acceptance and usage behavior toward the website-based BIM e-module. The analysis considered path coefficients (β), t-statistics, p-values, and coefficient of determination (R^2) (Chan & Sung, 2026). The structural results represent empirical evidence about the strength of associations between Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC) and the dependent variables.

Table 9. Results of Structural Model Evaluation

Hypothesized Relationship	Original Sample (β)	Sample Mean (M)	T-Statistics	P-Values
PE $\rightarrow$ UTAUT	0.228	0.229	8.457	< 0.001
EE $\rightarrow$ UTAUT	0.211	0.211	6.497	< 0.001
SI $\rightarrow$ UTAUT	0.332	0.330	10.478	< 0.001
FC $\rightarrow$ UTAUT	0.318	0.318	9.172	< 0.001

As shown in Table 9, all four hypothesized structural relationships were statistically significant and positive. Specifically, the t-statistics of PE, EE, SI, and FC were equal to 8.457, 6.497, 10.478, and 9.172, respectively, exceeding the critical value of 1.96 at the 5% significance level. Similarly, the p-values were less than 0.001. Therefore, all four constructs have statistically significant predictive capacity in terms of students' acceptance and usage behavior toward the website-based BIM e-module. The fact that the bootstrap sample means are quite close to the original sample estimates demonstrates the stability of the path coefficients estimates

during the resampling procedure (Kumar et al., 2023).

Performance Expectancy produced a positive and significant association with student acceptance ($\beta = 0.228$, $t = 8.457$, $p < 0.001$). This result means that the students' perception of the usefulness of the e-module is positively associated with their acceptance and usage behavior. The finding is in line with the descriptive analysis in which all PE indicators were rated High, and their mean scores ranged from 3.43 to 3.57. The finding is also consistent with previous research reporting the significance of perceived usefulness in technology acceptance in BIM-

related educational contexts as students associate BIM with productivity and accuracy benefits (Ahankoo et al., 2025). In the current context, the significant PE relationship indicates the importance of the vocational relevance of BIM content as the factor affecting students' acceptance.

Effort Expectancy also produced a positive and significant relationship with student acceptance ($\beta = 0.211$, $t = 6.497$, $p < 0.001$). Even though the path coefficient of EE was smaller compared to other structural paths, the result indicates that the perception of ease of use remains significant for explaining students' acceptance of the technology. It is

particularly notable given that the descriptive analysis revealed a contradictory nature of Effort Expectancy: Perceived Ease of Use and Ease of Use were rated High, while Complexity was rated Low with a mean of 2.72. Consequently, students perceive the system as usable although some aspects of it require efforts. This finding is similar to previous studies that reported the significance of perceived ease of use in terms of the adoption of e-learning technologies (Hunde et al., 2023; Ozkan et al., 2020). The structural result underlines the necessity of addressing technical complexity without considering the ease of use as an obstacle to adoption.

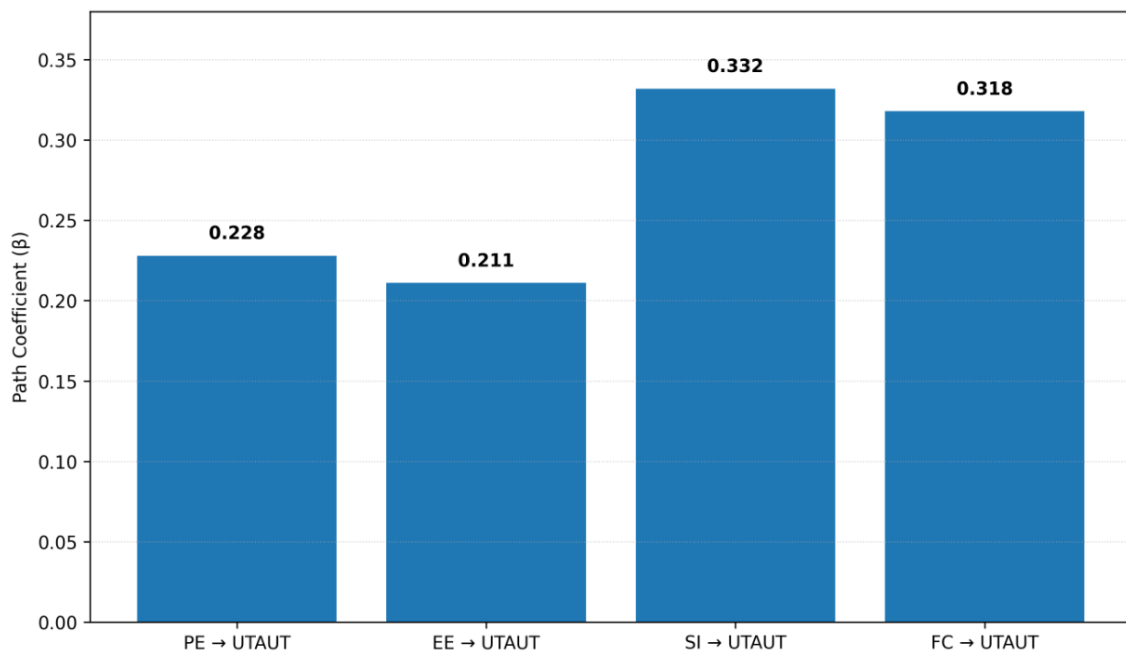


Figure 3. Structural Path Coefficients of the UTAUT Model

Figure 3 provides the visual comparison of the four estimated structural coefficients. They range from 0.211 for EE $\rightarrow$ UTAUT to 0.332 for SI $\rightarrow$ UTAUT. From the figure, it is clear that all four predictors have positive coefficients, but they have different magnitudes. SI and FC have comparably higher coefficients than PE and EE. It is important to note that the figure has to be interpreted along with the significance statistics present-

ed in Table 9 since the coefficient magnitude itself does not imply statistical significance. In the current study, all four paths are statistically significant, which means that the four UTAUT dimensions make complementary contributions to explaining students' acceptance and usage behavior (Aminy & Harsono, 2026).

Social Influence had the highest path coefficient ($\beta = 0.332$, $t = 10.478$, $p < 0.001$),

indicating a positive and significant relationship with student acceptance. The result means that students' acceptance is significantly affected by the social environment in which the BIM e-module is used. The finding is supported by the descriptive results in which all SI indicators were rated High. Specifically, Social Factor had a mean of 3.42, Image – 3.41, and Subjective Norm – 3.31. As it was noted in previous research, peer collaboration and mentorship can facilitate technology adoption in educational settings (Mirriahi et al., 2012). Teacher support has also been shown to affect students' technology acceptance in terms of their perceptions of usefulness and ease of use (Wang et al., 2022). Positive effects of SI on technology acceptance have been also reported in studies focusing on mobile learning and immersive virtual reality adoption (Izkair & Lakulu, 2021; Alfadil, 2024). Nevertheless, evidence about the significance of SI is not consistent across educational contexts. For instance, Puniatmaja et al. (2025) reported no significant relationship between SI and system use of the Platform Indonesia Belajar (PIJAR) among vocational high school students. The current result is a context-specific one in the field of BIM-based vocational learning.

Facilitating Conditions also had a positive and significant relationship with student acceptance ($\beta = 0.318$, $t = 9.172$, $p < 0.001$).

As indicated by the coefficient, the presence of the necessary resources and technical support as well as the compatibility of the system with the students' learning environments is significantly associated with students' acceptance of the e-module (Nasution & Asuti, 2024). The result corresponds to the descriptive result in which the general Facilitating Conditions indicator had a high mean of 3.47, and Compatibility – 3.41. However, Perceived Behavioral Control was rated as Moderate with a mean of 3.22. This combination indicates that access to technological resources does not necessarily ensure students' learning autonomy (Ozkan et al., 2020). Therefore, technology-enhanced vocational learning should combine digital infrastructure with instructional scaffolding, technical guidance, and learner support to progressively develop students' ability to engage with BIM learning independently. The finding is especially relevant to BIM learning as it involves specialized digital resources and technical requirements. Previous research has highlighted the importance of facilitating conditions for supporting technology-based learning and BIM implementation (Zhang et al., 2023). Other studies have also noted internet connectivity and hardware limitations as continuing problems in e-learning implementation (Faza et al., 2024; Kumar et al., 2023).

Table 10. Coefficient of Determination of the Endogenous Construct

Endogenous Construct	R ²	Explained Variance (%)	Interpretation
Student Acceptance and Use Behavior	0.993	99.3	Very substantial explanatory power

According to Table 10, the coefficient of determination (R^2) of the endogenous construct equals 0.993. This means that 99.3% of the variance of students' acceptance and use behavior is statistically explained by the four predictors. The result is an extremely

high level of explained variance within the observed sample. The finding implies that the combination of the four UTAUT dimensions explains a considerable proportion of the variance in students' responses to the website-based BIM e-module (Asfani &

Chen, 2025). Nevertheless, the value of R^2 has to be interpreted taking into account the specific context of the current study and sample rather than being generalized. In particular, it has to be noted that the extremely high value requires considering the conceptual proximity of the constructs, and R^2 can be reported as the model-specific explanatory power rather than the evidence of UTAUT explaining technology acceptance universally.

The relative magnitudes of the coefficients can also be used for the interpretation of the structural model. SI ($\beta = 0.332$) and FC ($\beta = 0.318$) have larger estimated coefficients compared to PE ($\beta = 0.228$) and EE ($\beta = 0.211$). This implies that within the context of the specific sample and model specification, students' acceptance of the BIM e-module is more significantly associated with

the social and facilitating context than their individual perceptions of usefulness and ease of use. This finding is notable as conventional UTAUT applications in education frequently identify Performance Expectancy as an important factor of behavioral intention. For example, Wijaya et al. (2022) identified PE as the significant factor of acceptance of digital mathematics textbooks in Indonesia. Therefore, the current results demonstrate that technology acceptance in vocational learning is context-dependent and closely connected to the instructional and social conditions in which digital learning takes place (Amin et al., 2025). The findings suggest that effective BIM e-module implementation should integrate technological usability with instructional support, learning strategies, and opportunities for socially supported learning.

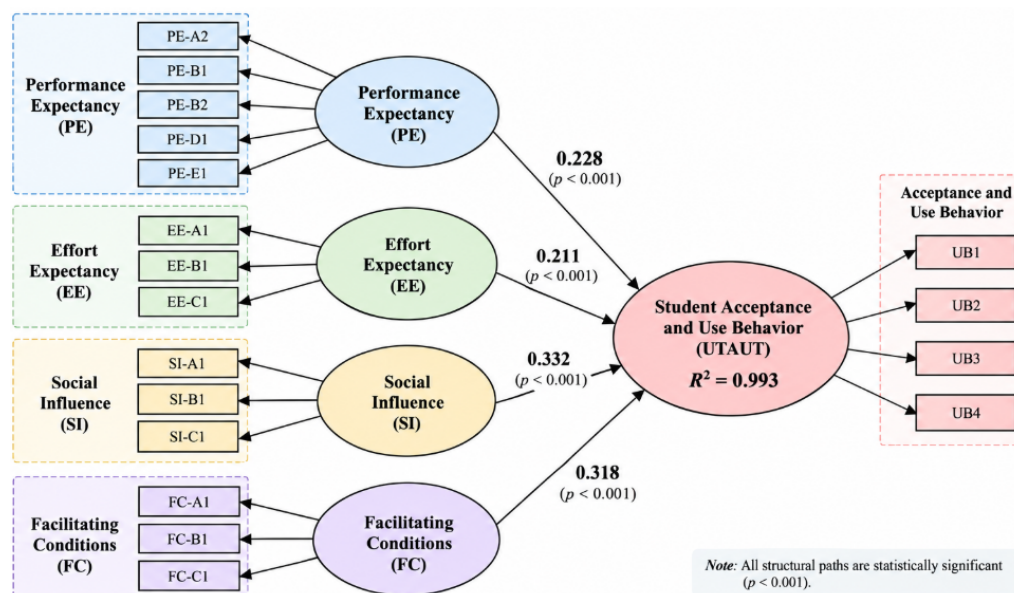


Figure 4. Structural Model of BIM E-Module Acceptance

Figure 4 presents the structural relationships found during the analysis. All four UTAUT constructs are linked with students' acceptance and use behavior with the estimated path coefficients displayed for each structural path. The model demonstrates positive relationships for PE ($\beta = 0.228$), EE (β

$= 0.211$), SI ($\beta = 0.332$), and FC ($\beta = 0.318$) as well as an R^2 of 0.993 for the endogenous construct. Therefore, the paths demonstrate the structural model tested in this study (Mujalli & Khan, 2022). In addition, it should be emphasized that the acceptance of the website-based BIM e-module is not a one

dimensional phenomenon as it is determined by a combination of perceived usefulness, ease of use, social context, and facilitating conditions.

From an advanced learning perspective, the BIM e-module provides a digitally mediated learning environment in which vocational students can engage with specialized BIM knowledge through structured digital resources (Rahmadani et al., 2026). The findings indicate that the effectiveness of such an environment depends not only on the availability of advanced technology but also on its alignment with learners' needs, instructional support, and the contextual demands of vocational education.

In summary, the current structural analysis confirmed the significance of the positive relationships between all four UTAUT constructs and students' acceptance and usage behavior toward the website-based BIM e-module. The findings expand the application of the UTAUT framework in the context of vocational education in which BIM represents the technology of learning (Nguyen et al., 2020). Furthermore, the results imply that the technology acceptance should be considered not only in terms of the students' individual perceptions of usefulness and usability but also in terms of the social and infrastructural environment in which the technology is implemented (Izkair & Lakulu, 2023). In particular, the significant relationships of SI and FC imply the importance of the teacher and peer support, technological resources, compatibility, and technical assistance in facilitating the adoption of BIM-based digital learning.

4. Conclusion

The current research investigated the adoption and use of a website-based Building Information Modeling (BIM) e-module by 65 grade XI students studying the Building Construction and Housing

Engineering program in SMK Negeri 1 Jakarta using the UTAUT framework. As can be seen from the descriptive results, the students had positive perceptions concerning the BIM e-module based on Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. Nevertheless, the quite low Complexity indicator score and medium-level Perceived Behavioral Control imply that technical complexity and the students' ability to control the technology independently should be considered important issues. The measurement model revealed the satisfactory reliability and internal consistency of the indicators, convergent validity, and discriminant validity, and thus, the appropriateness of the UTAUT constructs for the analysis can be stated. Moreover, the structural model found that all UTAUT constructs, namely Performance Expectancy ($\beta = 0.228$), Effort Expectancy ($\beta = 0.211$), Social Influence ($\beta = 0.332$), and Facilitating Conditions ($\beta = 0.318$) were positively and significantly related to the students' adoption and use of the e-module ($p < 0.001$). Of the four relationships, Social Influence and Facilitating Conditions possessed the biggest path coefficients, which implies that the social learning environment and presence of conditions can be especially relevant for the acceptance of website-based BIM e-modules. Thus, the developed model obtained the R^2 value of 0.993 meaning that all four UTAUT constructs explained 99.3% of the variance in the endogenous construct for the analyzed sample. Generally, the findings indicate that the implementation of website-based BIM e-modules in vocational education should be positioned not merely as a technology adoption initiative but as a technology-supported learning innovation that integrates meaningful digital content, appropriate instructional

design, learner oriented learning strategies, social support, and facilitating conditions.

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