

EVALUASI KESIAPAN DAN KOMPETENSI MAHASISWA TEKNIK SIPIL UNTUK MENGIMPLEMENTASIKAN BUILDING INFORMATION MODELLING (BIM) DI DUNIA KERJA

EVALUATION OF CIVIL ENGINEERING STUDENTS' READINESS AND COMPETENCY FOR BUILDING INFORMATION MODELING (BIM) IMPLEMENTATION IN THE WORKPLACE

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Abstrak

Meningkatnya penerapan Building Information Modelling (BIM) di industri konstruksi mendorong integrasi BIM dalam pembelajaran di perguruan tinggi. Namun, evaluasi mengenai kesiapan dan kompetensi mahasiswa untuk mengimplementasikan BIM di dunia kerja masih terbatas. Penelitian ini bertujuan mengevaluasi faktor-faktor yang memengaruhi kesiapan mahasiswa serta kompetensinya dalam mengimplementasikan BIM di dunia kerja. Penelitian menggunakan pendekatan kuantitatif terhadap mahasiswa Program Studi S1 Teknik Sipil Universitas Jenderal Soedirman yang telah menempuh mata kuliah Tugas Gambar Struktur Bangunan. Analisis kesiapan dilakukan menggunakan *Structural Equation Modeling-Partial Least Squares*, sedangkan kompetensi dievaluasi melalui simulasi *Autodesk Certified User* (ACU) Revit non-resmi. Hasil penelitian menunjukkan bahwa ekosistem belajar dan kepercayaan diri akademik berpengaruh signifikan terhadap kesiapan mahasiswa, sedangkan fasilitas BIM serta kelengkapan materi dan penugasan dosen tidak berpengaruh signifikan. Ketidaksignifikanan fasilitas menunjukkan bahwa akses dasar terhadap sumber daya belum menjadi pembeda utama kesiapan, sedangkan kesenjangan antara kesiapan yang dipersepsikan dan hasil ACU mengindikasikan bahwa kepercayaan diri yang terbentuk dari tugas pemodelan yang familiar belum sepenuhnya ditransfer ke fitur konseptual dan lanjutan yang diuji ACU. Sebagian besar mahasiswa belum memenuhi standar kompetensi entry level ACU Revit, terutama pada aspek elements and families serta stair dan site modelling. Oleh karena itu, pembelajaran BIM perlu diarahkan pada penguatan kompetensi praktis melalui evaluasi yang mengacu pada standar industri.

Kata kunci: Autodesk revit, building information modelling, kesiapan kerja, kompetensi BIM, pendidikan teknik sipil

Abstract

The increasing adoption of Building Information Modeling (BIM) in the construction industry has driven the integration of BIM into higher education curricula. However, evaluations of students' readiness and competence to implement BIM in the workplace remain limited. This study aims to evaluate the factors that influence students' readiness and competence in implementing BIM in the workplace. The study employed a quantitative approach targeting undergraduate students in the Civil Engineering program at Jenderal Soedirman University who had completed the "Building Structural Drawing" course. Readiness was analyzed using SEM-PLS, while competency was evaluated through an unofficial Autodesk Certified User (ACU) Revit simulation. The results indicate that the learning ecosystem and academic self-confidence significantly influence students' readiness, whereas BIM facilities and the comprehensiveness of course materials and assignments provided by instructors do not have a significant effect. The non-significance of facilities suggests that basic access to learning resources is not the main differentiating factor for readiness, while the gap between perceived readiness and ACU performance indicates that confidence developed through familiar modeling tasks may not transfer fully to the less-practiced conceptual and advanced features assessed by ACU. Most students do not yet meet the ACU Revit entry-level competency standards, particularly in the areas of elements and families, as well as stair and site modeling. Therefore, BIM instruction should be directed toward strengthening practical competencies through evaluations based on industry standards.

Keywords: Autodesk revit, building information modeling, job readiness, BIM competencies, civil engineering education

I. INTRODUCTION

The digital transformation in the construction industry has propelled Building Information Modeling (BIM) to become one of the key competencies required in the execution of construction projects today [1]. By integrating information throughout the project lifecycle, BIM enhances coordination, efficiency, and the quality of decision-making, leading to its widespread adoption by the construction industry in various countries [2].

In Indonesia, the urgency to implement BIM has grown since the Ministry of Public Works and Public Housing (PUPR) issued regulations mandating the use of BIM for certain projects, such as integrated construction projects (design-and-build), projects valued at over Rp100 billion, National Strategic Projects, and government buildings with special classifications [3], [4]. A consequence of this policy is the growing demand for workers with BIM competencies [5].

In response to industry needs, various universities have integrated BIM into their civil engineering curricula by incorporating the subject matter into existing courses, creating specialized courses, providing laboratories, offering training, and collaborating with industry [6]. Nevertheless, various studies indicate that graduates' readiness to implement BIM in the workplace remains inconsistent [2], [7], [8]. This suggests that the implementation of BIM education has not yet fully ensured the attainment of competencies aligned with industry needs [9].

Most previous studies have focused on the integration of BIM into the curriculum [8], [9], [10], [11], the development of e-modules or training programs [12], [13], or the identification of barriers to BIM implementation in higher education institutions [9]. However, research that comprehensively evaluates BIM learning outcomes by measuring student readiness while verifying technical competencies using instruments based on industry standards remains relatively limited. Unlike previous studies, this research combines an analysis of factors influencing student readiness using SEM-PLS with an evaluation of technical competencies through an unofficial Autodesk Certified User (ACU) Revit simulation. This approach provides a more comprehensive picture of the effectiveness of BIM learning, not only in terms of perceived readiness but also in terms of students' achievement of technical competencies. Therefore, this study aims to evaluate the factors influencing the readiness of students in the

Bachelor of Civil Engineering program at Jenderal Soedirman University (Unsoed) to implement BIM in the workplace, as well as to evaluate students' technical competencies through the ACU Revit simulation.

II. LITERATURE REVIEW

A. BIM in Higher Education

The development of BIM has shifted the construction industry's paradigm toward integrated project information management throughout a building's life cycle. As BIM adoption in the construction industry increases, proficiency in BIM has become one of the competencies expected of civil engineering graduates. This trend has prompted universities to integrate BIM into their curricula through various approaches, such as incorporating BIM content into existing courses, developing specialized courses, implementing project-based learning, providing software training, and collaborating with industry practitioners [1], [2], [6], [14]. This integration aims not only to enhance students' ability to operate BIM software but also to develop the professional competencies, collaboration skills, and problem-solving abilities required in modern construction practice [15], [16], [17]. The learning process involves various facilitators, such as lecturers, lab technicians, student assistants, industry practitioners, and software developers, with learning outcomes covering 3D, 4D, and 5D modeling competencies, as well as clash detection using various BIM applications, such as Revit, Tekla, Cubicost, and Allplan [2], [6], [10], [14], [18], [19].

Although the implementation of BIM education in higher education institutions continues to grow, its success cannot be measured solely by the availability of curricula, software, or learning facilities. The effectiveness of learning must also be evaluated based on the university's ability to produce graduates who possess the technical competencies and readiness to implement BIM in the workplace [4], [8], [11]. Therefore, evaluating learning outcomes is crucial to assessing the extent to which the BIM learning process has equipped students with competencies aligned with the needs of an increasingly digitized construction industry.

B. Student Competencies and Readiness

BIM competency refers to students' ability to apply knowledge and skills to utilize BIM in the planning, modeling, documentation, and coordination of construction projects. This competency

encompasses not only the ability to operate software but also an understanding of modeling concepts, information management, and problem-solving in accordance with professional practice requirements [8], [15], [17]. In the context of higher education, the attainment of BIM competencies is generally evaluated through practice-based assessments, projects, or certifications that refer to industry standards, such as ACU, thereby providing an indication of students' level of technical competency [20], [21].

In addition to technical competencies, students' readiness to implement BIM in the workplace is also an important indicator in evaluating learning outcomes. Readiness reflects students' confidence in their ability to apply the competencies they have acquired to meet job demands, which is influenced by learning experiences, the academic environment, and individual factors [7], [11], [22]. Students with a high level of competency do not necessarily have a high level of readiness to implement BIM, and vice versa. Therefore, evaluating both competencies and readiness simultaneously is necessary to provide a more comprehensive picture of the effectiveness of BIM learning in preparing graduates to meet the needs of the construction industry. This approach allows for the identification of gaps between students' technical competencies and their readiness to implement BIM in a professional work environment.

C. Factors Affecting Students' Readiness to Implement BIM

Students' readiness to implement BIM is influenced by various interrelated factors, including institutional aspects, the learning environment, and individual characteristics. Institutional factors include instructional design, the completeness of course materials, and the availability of facilities that support the BIM learning process [2], [8], [10], [11]. Meanwhile, a conducive learning environment and social support from instructors, teaching assistants, and peers play a role in fostering positive learning experiences [23], [24], [25]. From an individual perspective, academic self-confidence is a key factor that motivates students to apply the knowledge and skills they have acquired to solve real-world problems [22], [26].

Empirical studies provide support for the proposed structural paths: BIM curriculum and instructional design studies link course structure and task design with BIM learning outcomes [1], [6], [16], [17], while studies of BIM education identify access to software and learning facilities as relevant contextual factors

[6], [14]. Collaborative and peer-supported learning supports the role of the learning ecosystem in student outcomes [23], [24], [27], and social support is associated with students' academic experiences and self-confidence [23], [24], [28]. Studies of self-efficacy, assessment, and learning performance also support the relationships involving academic self-confidence and academic evaluation [22], [26], [29]. Accordingly, the proposed model specifies $Ds \rightarrow MA$, $Ds \rightarrow EB$, $SA \rightarrow PD$, $NA \rightarrow PD$, and direct paths $EB \rightarrow KM$, $Fas \rightarrow KM$, $MA \rightarrow KM$, and $PD \rightarrow KM$, as shown in Figure 1.

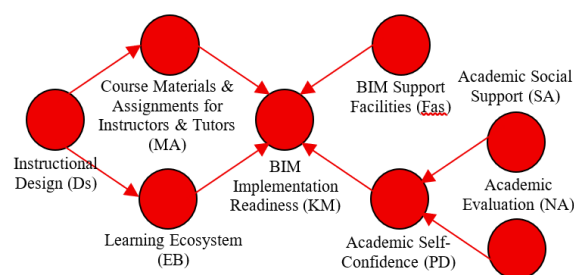


Figure 1. The relationship model among variables (constructs)

III. METHODS

A. Research Design

This study uses a quantitative approach to evaluate BIM learning outcomes among undergraduate students in the Civil Engineering program at Unsoed. The evaluation was conducted using two approaches: Structural Equation Modeling–Partial Least Squares (SEM-PLS) analysis to identify factors influencing students' readiness to implement BIM, and a competency assessment using an unofficial ACU Revit simulation to measure students' technical competencies. The research flowchart and instruments are shown in Figure 2 and Table 1.

B. Population and Data Collection

The study involved Civil Engineering undergraduates at Unsoed (2022–2024 cohorts) who had taken the Building Structural Drawing (TGSB) course. Participants were selected purposively, limited to those with BIM training experience.

Data collection was conducted using two complementary instruments. The first instrument was a questionnaire designed to measure students' perceptions of factors influencing their readiness to implement BIM, consisting of the constructs of instructional design, course materials, facilities, the

learning ecosystem, social support, academic self-confidence, academic evaluation, and readiness to implement BIM. All indicators were measured using a five-point Likert scale.

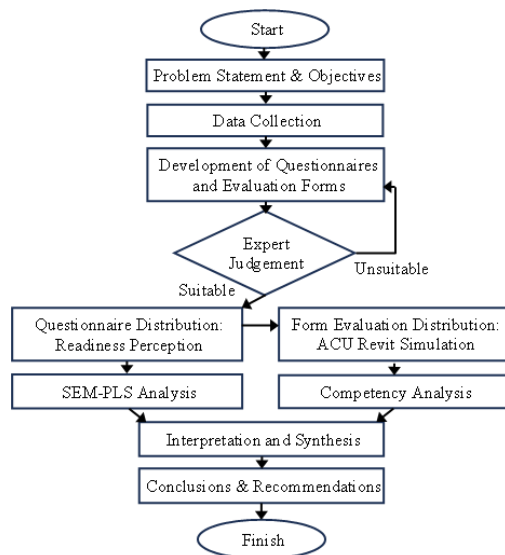


Figure 2. The Research Flowchart

The second instrument was an unofficial ACU Revit simulation designed to evaluate students' technical competencies in completing modeling tasks within the scope of basic-level competencies. The results from both instruments were analyzed

separately and subsequently interpreted in a complementary manner to provide an overview of BIM learning outcomes.

Table 1. Research instruments

Instruments	Purpose	Output
Questionnaire	To measure factors influencing BIM implementation readiness	SEM-PLS
Unofficial Revit ACU simulation	To measure students' technical BIM competencies	Descriptive analysis

C. Research Variables

This study consists of two groups of variables in accordance with the research objectives. The first group is used to analyze the factors influencing students' readiness to implement BIM using SEM-PLS, which include instructional design, course materials, facilities, the learning ecosystem, social support, academic self-confidence, academic evaluation, and readiness to implement BIM. The second group consists of students' technical BIM competencies, which are evaluated through an unofficial ACU Revit simulation. The operational definitions of each variable and the indicators used in the study are presented in Table 2.

Table 2. Variabel dan indikator model

Code	Variables	Indicators	Sourees
Ds	Instructional Design	Students understand the learning objectives of the BIM program	[2], [13]
		The syllabus/learning contract measures BIM competencies	[6], [7], [8]
		The syllabus contract supports the achievement of BIM competencies	[6], [8]
		The teaching methods used are effective	[5], [6], [7], [8]
		The assessment system can measure BIM competencies	[5], [6], [7], [8]
MA	Course Material & Assignments for Instructors	The required instructional materials are complete	[1], [10], [12]
		Assignments are designed for real-world application	[9], [10], [11]
		Instructional materials are designed for real-world application	[9], [10], [11]
		Assignments support students' readiness for the workplace	[9], [10], [11]
Fas	BIM Support Facilities	Hardware is available	[6], [9], [10], [11]
		Software is available	[6], [9], [10], [11]
		Other supporting facilities are available	[8], [15]
PD	Academic Self-Confidence	Students understand BIM material	[10], [11], [30]
		Students are competent in using BIM applications	[10], [11], [30]
		Students are competent in working independently	[10], [11], [30]
		Students are ready to implement their competencies in the workplace	[10], [11], [30]
EB	Learning Ecosystem	The campus environment supports learning	[1], [25]
		The classroom learning atmosphere is enjoyable	[8], [23]
		There are teaching assistants who provide support	[24], [31]
		There are supplementary programs that provide support	[10] [17], [32]
		There is a supportive culture of collaborative learning	[8], [30]
SA		There is a supportive atmosphere among students	[27], [28]

Code	Variables	Indicators	Soureces
	Academic Social Support	There are intensive discussion groups among students	[27], [33]
		An environment is created where students help one another understand BIM	[15], [28]
		An environment is created where students collaborate to finish assignments	[15], [28], [34]
NA	Academic Evaluation (Grades)	Students achieve high grades in courses that apply BIM	[16], [35], [36]
		Students are confident they can pass the entry-level BIM certification exam	[22], [26], [37]
		Students are satisfied with their BIM projects	[22], [26]
		Students are able to overcome technical obstacles in BIM learning	[17], [30]
KM	Readiness to Implement BIM (Dependent)	Students are ready to use BIM in the workplace after graduation	[1], [17]
		Students are confident in their ability to complete real-world projects	[22], [26], [37]
		Students can adapt to using BIM in a professional setting	[22], [26], [38]
		Students are interested in improving their BIM skills in the future	[26], [38]

D. Analysis Methods

1) Analysis of Student Readiness

The analysis of students' readiness to implement BIM was conducted using SEM-PLS with the assistance of SmartPLS 4 software. This method was chosen because it can simultaneously analyze relationships among latent constructs and is suitable for predictive research [39]. Model evaluation was performed through outer model testing, which included convergent validity, discriminant validity, and construct reliability, while the inner model was evaluated based on the coefficient of determination (R^2), path coefficients, and the significance of relationships between variables using the bootstrapping procedure at a 5% significance level.

2) Analysis of Student Competencies

Students' BIM competencies were evaluated through an unofficial ACU Revit simulation that adopted the scope of Autodesk Revit's foundational competency level. The simulation covered several competency domains, namely elements and families, views, documentation, modeling, stairs, and site modeling. The simulation results were analyzed descriptively to identify students' proficiency levels in each competency domain and compared with the ACU passing benchmark for entry-level competencies. The results of the SEM-PLS analysis and the ACU simulation were then interpreted in a complementary manner to gain insight into the relationship between students' readiness and BIM technical competencies as learning outcomes.

IV. RESULTS AND DISCUSSION

A. Respondent Characteristics

The Unsoed Civil Engineering students who served as respondents were from the 2022 to 2024 cohorts, as they had completed BIM training using Revit in the TGSB course (1 credit). Data collection yielded 233 questionnaire responses and 160 ACU simulation participants (Table 3). After the verification process, some data were eliminated for duplicate responses from the same respondent.

Table 3. Data Collection Results

Description	Questionnaire	ACU Simulation
Research Target	355	355
Responses Received	233	160
Rejected Data	15	4
Data Analyzed	218	156

B. Validity and Reliability Tests

1) Validity Test

An evaluation of the measurement model shows that all constructs meet the requirements for validity and reliability (Table 4 and Figure 3). Factor loadings range from 0.749 to 0.904, while AVE values range from 0.625 to 0.750, indicating that each construct explains more than 50% of the variance in its indicators. In addition, all constructs have Cronbach's Alpha values (0.700–0.889) and Composite Reliability values (0.833–0.923) above the recommended minimum thresholds. Thus, the measurement model is deemed to meet the requirements for convergent validity and reliability and is therefore suitable for use in structural equation modeling.

Table 4. Results of the Measurement Model Evaluation

Variable	Number of Indicators	Loading Factor >0,7	Average variance extracted >0,5	Cronbach's alpha >0,6	Composite reliability >0,7
Instructional Design	5	0.797 - 0.857	0.681	0.883	0.914

Course Material & Assignments for Instructors	4	0.795 - 0.858	0.693	0.851	0.900
BIM Support Facilities	3	0.778 - 0.825	0.625	0.700	0.833
Academic Self-Confidence	4	0.793 - 0.904	0.746	0.886	0.922
Learning Ecosystem	5	0.749 - 0.881	0.673	0.878	0.911
Academic Social Support	4	0.769 - 0.886	0.750	0.889	0.923
Academic Evaluation (Grades)	4	0.839 - 0.897	0.731	0.876	0.915
Readiness to Implement BIM	4	0.823 - 0.891	0.715	0.866	0.909

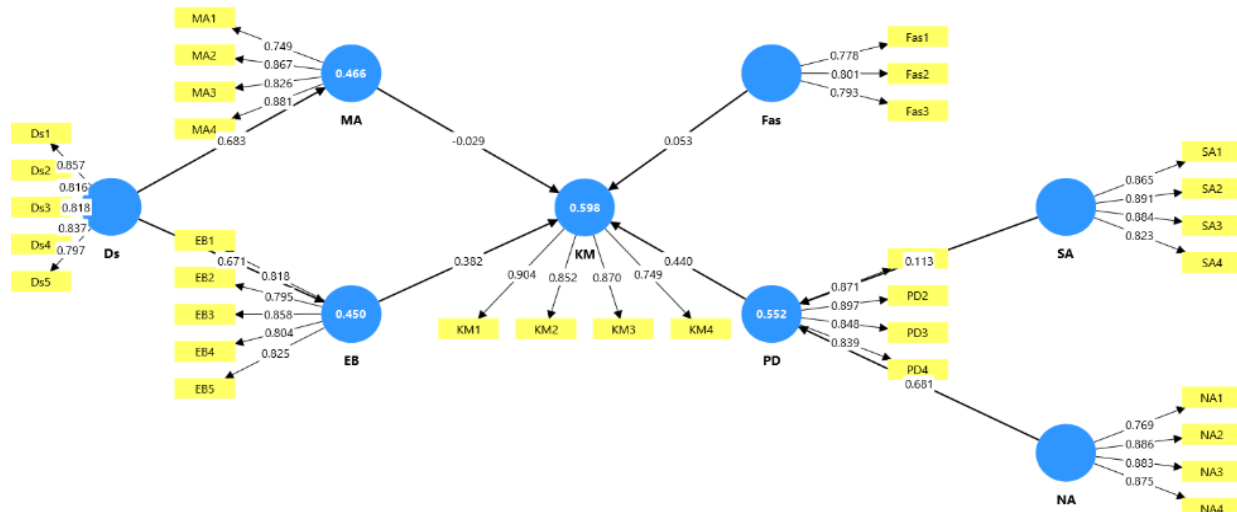


Figure 3. Structural model resulting from factor loading tests

Discriminant validity was evaluated using the Fornell–Larcker criterion. The square root of AVE for each construct was greater than its correlation coefficients with other constructs, indicating that all constructs met the criteria for discriminant validity. The complete results are presented in Table 5.

Table 5. Fornell-Larcker Test Results

	Ds	EB	Fas	KM	MA	NA	PD	SA
Ds	0.825							
EB	0.671	0.820						
Fas	0.608	0.574	0.791					
KM	0.634	0.707	0.498	0.846				
MA	0.683	0.650	0.616	0.547	0.832			
NA	0.649	0.682	0.487	0.810	0.515	0.855		
PD	0.750	0.714	0.554	0.722	0.672	0.736	0.864	
SA	0.467	0.710	0.499	0.475	0.519	0.487	0.445	0.866

2) Structural Model Evaluation (Inner Model)

The structural model explains relationships among latent variables. Evaluation used R-squared, path coefficients, T-statistics, and P-values. Table 7 reports the direct paths to the dependent variable, Readiness to Implement BIM.

The R-squared evaluation result shown in Table 6 indicates a value of 0.598. This suggests that the exogenous variables account for 59.8% of the

variance in the endogenous KM variable, while the remaining 40.2% is influenced by other factors. This value falls within the moderate category (0.50–0.75), and the model is considered capable of explaining variance at an adequate level [39].

Table 6. R-Square Test Results

Variabel	R-Square	Percentage
KM (Readiness to Implement BIM)	0.598	59.8%

Table 7. Path Coefficients, T-Statistic, & P-Value Test

Variable	Path Coefficients	T-Statistics > 1.95	P-Value < 0.05	Hypothesis H1
EB	0.382	4,168	<0.001	Accepted
Fas	0.053	0.797	0.425	Rejected
MA	-0.029	0.402	0.687	Rejected
PD	0.440	5,092	<0.001	Accepted

The results of hypothesis testing using bootstrapping on the SEM-PLS model are presented in Table 7. Of the four variables tested, only the learning ecosystem (EB) and academic self-confidence (PD) had a positive and significant effect on students' readiness to implement BIM. Conversely, BIM support facilities (Fas) as well as the completeness of materials, lecturer assignments, and

tutors (MA) did not show a significant effect. These findings indicate that students' readiness is more influenced by the quality of their learning experiences and their belief in their own abilities than by the availability of learning resources.

The learning ecosystem has a positive effect on student readiness ($\beta = 0.382$; $p < 0.001$). These results indicate that a collaborative learning environment—facilitated by group discussions, teaching assistant support, and peer interactions—plays a role in enhancing students' readiness to implement BIM. These findings are consistent with Versfeld [27], who states that collaboration and support from teaching assistants can improve the achievement of learning objectives, as well as Luckie [24], who emphasizes that the involvement of teaching assistants can enhance the effectiveness of learning.

Academic self-confidence was the factor with the greatest influence on students' readiness ($\beta = 0.440$; $p < 0.001$). This indicates that students who are confident in their ability to complete BIM modeling tasks tend to be better prepared to implement BIM in the workplace. Students felt prepared after completing the modeling of a two-story building using Revit in the TGSB course. This finding supports Papuraj [1], who states that a case/project-based learning approach is an effective pedagogical strategy for BIM education.

The result does not imply that resources are unimportant; rather, once basic access is available, active and collaborative learning may differentiate readiness more strongly. This interpretation is consistent with empirical BIM studies emphasizing team-based, problem-based, and experiential learning [6], [17], [29], although it differs from resource-centered views of BIM education [6], [14]. Personal laptop ownership and external tutorial use were not measured and therefore cannot be confirmed as explanations in the present study, but they remain relevant variables for future research.

C. Evaluation of Student Competencies through ACU Simulations

Revit ACU simulations were administered to assess students' technical competencies following BIM instruction in the TGSB course. Among 156 participants, only 44 students (28.2%) attained the minimum passing score of $\geq 70\%$, whereas 112 students (71.8%) fell short of this benchmark (Table 8). Overall mastery of Revit competencies therefore

remains below the entry-level competency benchmark represented by the ACU simulation.

Table 8. Respondent Value Interval

Value Interval	Number	Percentage	Description
70%-100%	44	28.2%	Passed
<70%	112	71.8%	Failed

Further analysis (Figure 4 and Table 9) shows good performance in Documentation, but lower competence in Elements & Families, especially system families and parameters, and in stair and site modeling. These results help explain the gap between perceived readiness and technical competence. Academic self-confidence reflects students' perceived ability to understand BIM, work independently, and complete the familiar two-story Revit task in TGSB, whereas ACU covers a broader entry-level scope with less-practiced conceptual and advanced functions [21]. Thus, confidence gained from familiar tasks may not transfer automatically to unfamiliar functions. Post-simulation discussions also identified English technical terminology as an additional challenge. BIM learning should therefore include broader Revit functions, unfamiliar tasks, certification-style assessment, and technical English.

Table 9. Respondents' strengths and weaknesses based on the ACU Revit simulation

Category	Strengths	Areas for Improvement
Elements & Families	Modifying basic elements & managing families	System families, parameters, advanced wall options
Modelling	Roof modeling	Stair dan site modeling
Views	Linking file	Cut planes, detail drawings, file formats
Document-ation	Sheets, text, dimensions	Dimensioning doors and windows

The ACU results therefore complement the SEM-PLS findings: perceived readiness was associated with learning ecosystem and academic self-confidence, but most students did not meet the technical benchmark. BIM learning outcomes should consequently combine perceptual and objective assessment, with greater emphasis on transfer to unfamiliar, industry-oriented tasks.

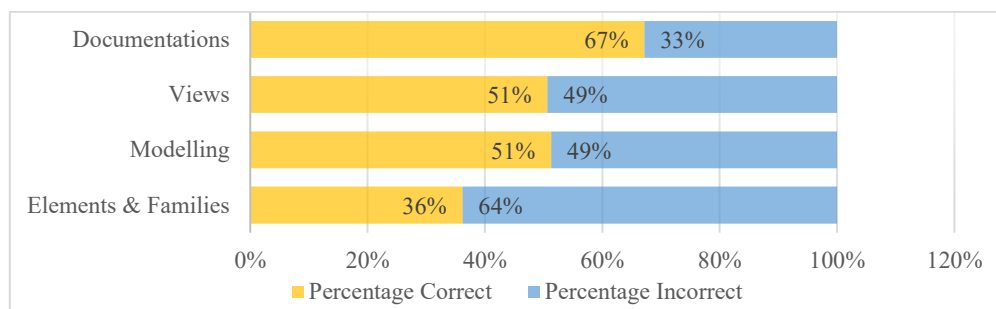


Figure 4. Distribution Chart of Correct and Incorrect Answers by Revit ACU Category

V. CONCLUSION

The evaluation indicates that BIM learning in the Civil Engineering Study Program at Unsoed supports students' readiness, but has not yet fully produced technical competencies that meet the ACU Revit entry-level benchmark. The SEM-PLS results show that the learning ecosystem and academic self-confidence have a positive and significant effect on student readiness, whereas BIM support facilities, as well as the completeness of materials, faculty assignments, and tutors, do not have a significant effect. These findings suggest that readiness is more strongly associated with collaborative learning experiences and self-efficacy than with the availability of learning resources.

ACU Revit simulations show only 28.2% of students met the passing standard, indicating readiness has not yet translated into entry-level technical skills represented by the ACU benchmark. Weaknesses remain in Elements & Families and Modeling, while post-simulation discussions highlighted challenges with English technical terminology. Thus, BIM education must reinforce project-based practice, industry-aligned exercises, and terminology familiarization to balance readiness and competence.

Overall, this study shows that the effectiveness of BIM learning cannot be measured solely by students' perceptions of their readiness but must be confirmed through an evaluation of technical competencies. The combination of SEM-PLS analysis and ACU simulation provides a more comprehensive approach to evaluating BIM learning outcomes in higher education.

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