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Keywords: student resilience; risk management; digital technology literacy; modern learning environment; sustainable education higher education



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Article

# Enhancing Sustainable Learning Through Risk Management and Digital Literacy: The Role of Modern Learning Environments

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**Abstract:** The rapid digital transformation in higher education has highlighted the importance of sustainable and adaptive learning environments and strategies that foster student resilience. This study investigates the influence of risk management and digital technology literacy on student resilience, with the modern learning environment as a moderating variable. Using a quantitative approach, data were collected from 475 undergraduate students across various universities in Indonesia through an online survey. Structural Equation Modeling-Partial Least Squares (SEM-PLS) was employed to analyze the relationships between the variables. The findings reveal that both risk management and digital technology literacy have significant positive effects on student resilience. Moreover, the modern learning environment strengthens these relationships by providing students with reliable digital infrastructure and innovative learning strategies that amplify the impact of institutional policies and individual competencies. These results underscore the critical role of robust risk management, comprehensive digital literacy programs, and high-quality modern learning environments in fostering long-term educational sustainability. This study contributes to the theoretical understanding of resilience by integrating institutional, individual, and environmental factors. Practically, it provides insights for higher education institutions to develop integrated and sustainable strategies that enhance risk management frameworks, promote digital literacy, and invest in inclusive, technology-driven learning ecosystems to ensure long-term resilience and adaptability in the digital era.

**Keywords:** student resilience; risk management; digital technology literacy; modern learning environment; sustainable education higher education.

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## 1. Introduction

The rapid digital transformation in higher education has created significant challenges, requiring students to adapt to dynamic and sustainable learning environments. Globally, 85% of universities have adopted digital platforms post-COVID-19, while in Indonesia, 78% of students report heightened stress during the transition to online learning [1,2]. To ensure long-term educational sustainability, student resilience, defined as the ability to adapt positively to academic challenges, has become essential for academic success [3,4]. Resilient students are better equipped to handle stress, adapt to technological changes, and sustain motivation [5,6]. However, fostering resilience requires support through risk management, digital literacy, and modern learning environments that promote inclusive and sustainable education systems.

Risk management involves identifying and mitigating risks that disrupt learning, such as cybersecurity issues and technological failures [7]. Effective strategies enable institutions to maintain learning continuity during disruptions like the COVID-19 pandemic and equip students to navigate uncertainties [8,9]. From a sustainability perspective, risk management frameworks provide essential

tools for students to develop resilience, ensuring that education remains accessible, stable, and adaptive in a rapidly evolving digital landscape [10–12].

Digital technology literacy, the ability to effectively use and integrate digital tools, is another critical factor [13–15]. Students with high digital literacy adapt better to hybrid learning, engage more effectively with digital platforms, and utilize resources efficiently [16–18]. This skill not only facilitates learning but also strengthens resilience by enabling students to overcome technological barriers while fostering a digitally sustainable learning environment [14,19].

A modern learning environment moderates the relationship between these factors and resilience. It combines innovative teaching strategies, such as personalized learning, with robust digital infrastructure to create adaptive ecosystems [20,21]. Interactive approaches enhance engagement, while accessible technology ensures seamless integration of learning tools [22,23]. A well-developed digital learning ecosystem contributes to educational sustainability by enhancing long-term adaptability and inclusivity. Despite advancements, research integrating risk management, digital literacy, and modern learning environments to foster resilience remains limited [24,25]. Most studies address these factors in isolation, neglecting their collective impact in supporting students' adaptability in higher education [16,26].

This study addresses this gap by analyzing the relationships between risk management, digital technology literacy, and student resilience, with modern learning environments as a moderating variable. Using a quantitative approach and structural equation modeling, this research provides empirical insights into how institutions can enhance resilience through sustainable digital adaptation strategies. The findings contribute theoretically by expanding understanding of resilience in digital learning and practically by offering recommendations for creating long-term adaptive and sustainable educational ecosystems [27].

## 2. Theoretical Basis and Research Hypothesis

### 2.1. Risk Management

Risk management in higher education refers to systematic efforts to identify, assess, and mitigate risks that can disrupt academic processes, especially in the digital era [28–30]. This includes addressing technological risks, such as cybersecurity threats, data breaches, and system failures, which have become prevalent with the increasing reliance on digital platforms [31–33]. From a sustainability perspective, effective risk management ensures not only short-term crisis mitigation but also the long-term stability and adaptability of digital learning environments. The Committee of Sponsoring Organizations (COSO) framework emphasizes the need for integrating risk management into educational strategies to ensure resilience and sustainable learning ecosystems [34]. Studies have highlighted that institutions with comprehensive risk management systems are better equipped to navigate crises, such as the COVID-19 pandemic, minimizing disruptions and enhancing the sustainability of educational operations [35,36].

At the individual level, risk management plays a vital role in equipping students with tools to cope with uncertainties. For instance, structured support systems that identify academic risks, such as workload imbalances or resource shortages, empower students to develop resilience and maintain motivation [37,38]. Research shows that when students are provided with clear frameworks to manage risks, they exhibit higher engagement and better academic outcomes [39,40]. Furthermore, effective risk management promotes mental well-being, as students feel more secure and supported in unpredictable environments [41–43]. These findings underscore the importance of integrating risk management not only at the institutional level but also as a critical component of student development in the digital learning era. By fostering an adaptive risk management culture, higher education institutions contribute to a more sustainable and inclusive digital education system that ensures long-term learning continuity and institutional resilience.

## 2.2. Digital Technology Literacy

Digital technology literacy, defined as the ability to effectively use, evaluate, and integrate digital tools, is a foundational skill for success in modern higher education [44,45]. It encompasses competencies such as navigating digital platforms, utilizing educational technologies, and critically assessing digital information [46,47]. As digital learning environments become the norm, especially post-COVID-19, institutions increasingly rely on students' technological literacy to ensure meaningful engagement and academic success [48,49]. From a sustainability perspective, fostering digital literacy is essential for developing long-term adaptive learning strategies that ensure educational resilience and inclusivity. Studies have found that students with strong digital literacy demonstrate higher adaptability to hybrid and online learning systems, improved academic performance, and greater autonomy in learning [49–51]

Moreover, digital literacy supports sustainable learning innovation by enabling students to optimize the use of tools such as virtual labs, collaborative platforms, and adaptive learning technologies [52]. These skills also enhance resilience, as students with high digital literacy are better equipped to overcome challenges related to remote or hybrid learning environments [53,54]. However, disparities in access to digital resources and skills highlight the importance of institutional support in fostering equitable digital literacy development [55–57]. By integrating structured interventions and digital literacy programs, higher education institutions contribute to a more sustainable and inclusive educational framework, ensuring equal opportunities for all students in the evolving digital landscape. Recent frameworks emphasize the need for structured interventions to bridge digital divides and equip students with advanced digital competencies for academic and professional success [58,59]

## 2.3. Modern Learning Environment

A modern learning environment (MLE) integrates innovative teaching strategies and advanced digital infrastructure to create sustainable, dynamic, engaging, and adaptive ecosystems for students [60,61]. This concept emphasizes personalization, interactivity, and accessibility, ensuring that students can thrive in hybrid or fully digital learning settings [62,63]. From a sustainability perspective, MLEs contribute to long-term educational resilience and inclusivity by fostering adaptable learning systems that accommodate diverse student needs. Personalized learning approaches, such as adaptive learning technologies and student-centered pedagogies, have been shown to significantly enhance student engagement and academic outcomes [62,64,65]. Additionally, interactive components, including virtual labs and collaborative platforms, foster active participation and critical thinking [66–69]. These innovations promote sustainable learning ecosystems by equipping students with the digital skills and cognitive flexibility needed for lifelong learning and professional adaptation.

The digital infrastructure within MLEs, including reliable internet connectivity, high-quality learning management systems, and user-friendly tools, is a critical component of its success [16,55]. A robust infrastructure ensures seamless integration of educational technologies and minimizes disruptions that could hinder learning [70]. Recent studies indicate that institutions with well-developed MLEs report higher levels of student satisfaction, resilience, and performance compared to traditional environments [71–73]. Furthermore, sustainable MLEs enable inclusivity by providing access to learning for diverse student populations, including those in remote areas [62,71,74,75]. As higher education continues to evolve, the development of sustainable MLEs is essential for fostering long-term educational innovation, digital equity, and institutional resilience in the digital era.

## 2.4. Student Resilience

Student resilience is the capacity to adapt positively to academic challenges, demonstrating persistence, flexibility, and motivation in the face of stressors [76–78]. In the context of higher education, resilience enables students to navigate the complexities of digital learning, such as abrupt

transitions to online platforms, demanding workloads, and technological disruptions [16,79,80]. From a sustainability perspective, resilience plays a crucial role in fostering long-term student adaptability and well-being, ensuring that learners can thrive in rapidly evolving digital environments. Research has shown that students with high resilience are more likely to achieve better academic outcomes and experience lower levels of stress compared to their peers with lower resilience [77,78]. Furthermore, resilient students tend to actively seek solutions to problems, maintain focus on their goals, and leverage available resources effectively [77,78,81,82]. By fostering resilience, higher education institutions contribute to the sustainability of academic achievement, mental health, and digital inclusion among students.

The development of student resilience is influenced by both individual and environmental factors. At the individual level, traits such as self-efficacy, emotional regulation, and adaptive thinking play a critical role [83,84]. At the environmental level, supportive learning ecosystems, including access to digital tools, collaborative learning opportunities, and structured guidance, significantly enhance resilience [16,85]. Sustainable educational environments prioritize resilience-building frameworks by integrating adaptability and problem-solving skills into higher education curricula, ensuring students are equipped for lifelong learning and continuous professional development. Recent studies have highlighted the importance of integrating resilience-building frameworks into higher education curricula, focusing on fostering adaptability and problem-solving skills in students [86,87]. As higher education continues to embrace digital transformation, fostering sustainable student resilience becomes essential for creating inclusive and future-ready learning environments that promote equity, mental well-being, and long-term academic success [88–90].

## 2.5. Hypothesized Model

### 2.5.1. Risk Management and Student Resilience

Risk management plays a critical role in enhancing student resilience by providing a structured approach to mitigating academic and environmental uncertainties [28,91,92]. From a sustainability perspective, effective risk management not only supports students in overcoming immediate challenges but also contributes to the long-term stability of digital education ecosystems. Institutions that implement robust risk management strategies, such as proactive identification of challenges and contingency planning, create a stable foundation that supports students in navigating academic pressures [93–95]. By fostering a risk-aware academic culture, higher education institutions can enhance student resilience in a way that ensures sustainable learning continuity and institutional adaptability.

On an individual level, exposure to risk management frameworks helps students develop problem-solving skills and emotional regulation, which are essential components of resilience [96–98]. Research indicates that risk management not only reduces stress but also fosters adaptability by equipping students with the tools to handle unforeseen disruptions, such as transitions to online learning during the COVID-19 pandemic [49,99,100]. A well-integrated risk management approach supports sustainable educational resilience by ensuring that students and institutions can adapt to technological and environmental uncertainties while maintaining learning equity. Furthermore, institutional policies addressing data privacy and cybersecurity risks also contribute to a safer and more predictable learning environment, which reinforces student confidence and resilience [101–103].

*H1: Risk management has a significant positive effect on student resilience.*

### 2.5.2. Digital Technology Literacy and Student Resilience

Digital technology literacy is a vital competency for fostering student resilience in modern education. It encompasses the ability to effectively navigate, evaluate, and utilize digital tools, which empowers students to overcome academic challenges and adapt to evolving learning environments

[18,104,105]. From a sustainability perspective, digital literacy is not only essential for immediate academic success but also for long-term adaptability and sustainable learning practices. Students with high levels of digital literacy demonstrate greater adaptability, engagement, and academic performance, particularly in hybrid and online learning settings [49,104,106]. By equipping students with digital competencies, higher education institutions contribute to the sustainability of knowledge transfer, workforce readiness, and inclusive access to education.

This literacy also enhances problem-solving skills by enabling students to efficiently access resources, collaborate in virtual spaces, and manage technological disruptions [14]. Sustainable digital literacy frameworks ensure that students can continuously develop their competencies, reducing educational inequalities and fostering lifelong learning. Moreover, digital literacy has been linked to lower levels of academic stress and higher levels of confidence, as students feel better equipped to handle the demands of digital education [18,104]. As digital tools become integral to education, fostering technological literacy has become essential for building resilience in students navigating unpredictable academic landscapes [25,54]. Integrating digital literacy into higher education curricula ensures that students develop sustainable digital skills, enhancing their long-term resilience and capacity to thrive in rapidly evolving technological environments.

*H2: Digital technology literacy has a significant positive effect on student resilience.*

### 2.5.3. Modern Learning Environment as a Moderating Variable

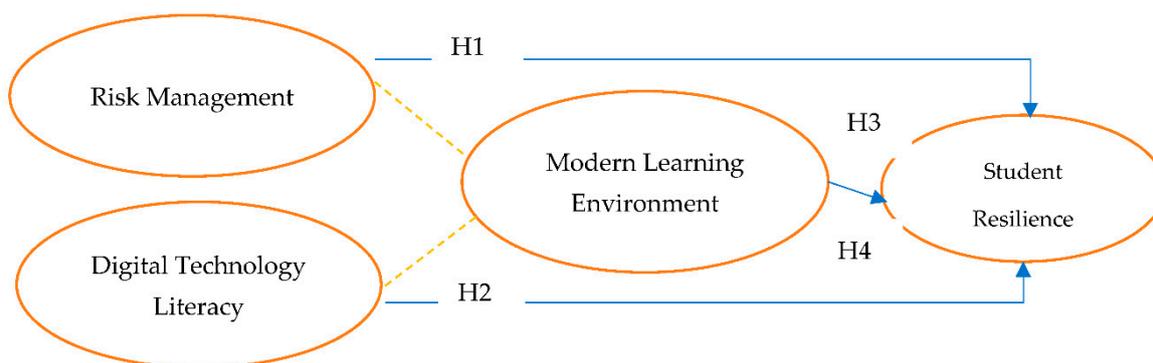
A modern learning environment (MLE) plays a crucial moderating role by shaping how institutional and individual factors influence student outcomes. From a sustainability perspective, MLE contributes to long-term educational resilience and digital equity by ensuring that risk management and digital technology literacy effectively enhance student adaptability. MLE combines innovative teaching strategies and advanced digital infrastructure, fostering an adaptive ecosystem that enhances the effectiveness of risk management and digital technology literacy [14,70]. By integrating sustainable learning design, personalized learning approaches, such as adaptive technologies and interactive tools, amplify the impact of risk management by reducing stress and creating a supportive environment for students [65,107]. Similarly, well-integrated digital infrastructure, including reliable connectivity and intuitive platforms, strengthens the relationship between digital technology literacy and resilience by enabling seamless engagement with educational resources [53,108]. These features make MLE a critical component in fostering sustainable education systems that bridge gaps between institutional initiatives and individual student outcomes.

The moderating effect of MLE is especially significant in environments undergoing digital transformation. A robust MLE not only mitigates barriers to accessing technology but also enhances the adaptability of students by supporting flexible learning approaches [8,16,62,109]. Institutions with high-quality MLEs contribute to sustainable digital learning ecosystems by providing equitable access to technology and fostering continuous engagement in evolving educational landscapes. For instance, institutions that offer collaborative virtual platforms and structured guidance enable students with varying levels of digital literacy to perform better and develop resilience [110,111]. Conversely, poorly implemented MLEs may hinder the positive effects of risk management and digital literacy, underscoring the importance of their quality and accessibility [14,70]. By ensuring sustainable and inclusive learning environments, higher education institutions can maximize the role of MLEs in supporting long-term student success and institutional resilience.

*H3: Modern learning environment moderates the relationship between risk management and student resilience, such that the relationship is stronger in high-quality modern learning environments*

*H4: Modern learning environment moderates the relationship between digital technology literacy and student resilience, such that the relationship is stronger in high-quality modern learning environments.*

The model framework is shown in Figure 1



**Figure 1.** Model Framework. This model was developed by the author, 2025.

### 3. Research Methods

#### 3.1. Profile Responden

A total of 475 Indonesian university students from various regions and study programs participated in this study, providing a relevant empirical foundation to explore the relationship between risk management, digital technology literacy, modern learning environments, and student resilience. From a sustainability perspective, understanding student demographics is essential for designing inclusive and adaptive education systems that support long-term learning resilience. The gender composition revealed a dominance of female students (62.3%) compared to male students (37.7%), reflecting a growing trend of female participation in higher education. This dominance was particularly evident in the field of Economics and Business (89.5%), indicating female openness to technology-based learning innovations and their adaptability to academic and professional challenges in the digital era. These findings highlight the importance of ensuring equitable access to digital education resources to sustain gender-inclusive learning environments.

The majority of respondents were aged between 20–22 years (58.3%) and 17–19 years (33.3%), representing the characteristics of active undergraduate students in a critical phase of academic development. Most respondents were in their 5th–6th semester (40.2%), indicating a mature academic experience suitable for understanding the challenges and opportunities of innovation-driven learning. A significant number of first- and second-semester respondents (36.2%) highlighted that technology-based learning has become an essential component of the academic experience for new students. This demographic distribution reinforces the need for sustainable digital learning strategies that accommodate students at different academic stages and promote long-term educational resilience.

The majority of respondents had 1–2 years of online learning experience (49.3%), reflecting the widespread implementation of online learning during the COVID-19 pandemic. This adaptation underscores the significance of sustainable digital transformation efforts in higher education, ensuring that students have continuous access to resilient and high-quality learning experiences. This adaptation indicates that most students have sufficient exposure to digital-based education, making it relevant to analyze how modern learning environments moderate the relationship between risk management, digital technology literacy, and student resilience. By understanding these student profiles, institutions can develop targeted strategies to enhance sustainable digital learning environments, ensuring that students remain adaptable and well-equipped for future academic and professional challenges.

### 3.2. Measurement

This study employs a structured framework to measure the relationships between the variables: Risk Management, Digital Technology Literacy, Modern Learning Environment, and Student Resilience. From a sustainability perspective, ensuring reliable and adaptive measurement tools is essential to capture the long-term impact of these factors on student development in digital learning environments. A 5-point Likert scale was used for all items, ranging from 1 (strongly disagree) to 5 (strongly agree), ensuring consistency and comparability in responses. This structured measurement approach supports sustainable educational assessment practices by enabling higher education institutions to monitor and enhance resilience, digital literacy, and risk management strategies over time.

The operationalization details for each variable are summarized in Table 1 below, which provides an overview of the indicators used to measure key constructs related to student resilience and digital transformation in sustainable learning environments.

**Table 1.** Operationalization of Variables.

Variable	Code	Indicator	Source
Risk Management	RM1	Identification of potential risks in learning environments	
	RM2	Development of contingency plans to mitigate risks	
	RM3	Implementation of security measures to protect data	
	RM4	Evaluation of risk management effectiveness	[112–114]
	RM5	Integration of risk management strategies into institutional policies	
	RM6	Provision of clear communication about risks to stakeholders	
	RM7	Continuous improvement of risk management practices	
Digital Technology Literacy	DTL1	Ability to use digital tools for learning	
	DTL2	Evaluation of information credibility in digital platforms	
	DTL3	Effective collaboration using digital technologies	[115–117]
	DTL4	Adaptation to new learning technologies	
	DTL5	Problem-solving using digital resources	
	DTL6	Confidence in using digital tools for academic purposes	
Modern Learning Environment	MLE1	Access to reliable digital infrastructure	
	MLE2	Availability of user-friendly learning platforms	
	MLE3	Quality of internet connectivity for learning	
	MLE4	Integration of interactive tools in learning	
	MLE5	Personalization of learning experiences	
	MLE6	Use of collaborative platforms for group learning	
	MLE7	Support from instructors in using digital platforms	[118–121]
	MLE8	Flexibility in learning schedules enabled by technology	
	MLE9	Use of virtual labs and simulations	
	MLE10	Provision of learning analytics tools	
	MLE11	Inclusivity of the learning environment	
Student Resilience	SR1	Ability to recover from academic setbacks	
	SR2	Maintenance of motivation under pressure	[94,122,123]
	SR3	Effective coping with stress in academic settings	

SR4	Adaptation to changing academic demands
SR5	Proactive problem-solving in challenging situations
SR6	Perseverance in achieving academic goals

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Synthesized from various theoretical frameworks, 2025.

### 3.3. Method

This study used Partial Least Square Structural Equation Modeling (PLS-SEM) to analyze the relationships between the variables. From a sustainability perspective, adopting PLS-SEM as an analytical approach ensures a comprehensive and replicable methodology for assessing digital learning ecosystems and their long-term impact on student resilience. PLS-SEM was performed using SmartPLS version 4, a statistical software designed for path modeling and variance-based structural equation modeling. This approach aligns with sustainable educational research practices by facilitating the evaluation of multidimensional relationships in complex learning environments.

PLS-SEM is a robust multivariate method that allows for the simultaneous evaluation of multiple dependent and independent variables. It is particularly effective for complex models with many latent variables and indicators, as well as for smaller sample sizes, making it ideal for this research. Additionally, PLS-SEM supports sustainability in digital education research by offering a flexible approach that can be applied across diverse institutional contexts, ensuring continued assessment and improvement of modern learning environments. Moreover, PLS-SEM enables a deeper understanding of relationships between constructs by estimating path coefficients and identifying the strength of their effects [124,125].

The analysis was conducted in two stages: outer model evaluation and inner model evaluation. The outer model assessed the relationships between constructs and their respective indicators through validity and reliability testing. Validity testing involved two stages: convergent validity, which measures the correlation between indicators and constructs based on loading factor values, and discriminant validity, which ensures constructs are distinct by analyzing the Average Variance Extracted (AVE). Reliability testing was performed using Composite Reliability (CR) and Cronbach's Alpha (CA), with values exceeding 0.7 indicating acceptable internal consistency [124,126]. By ensuring high validity and reliability, this methodological approach contributes to sustainable research practices, enabling robust assessments that can be replicated and adapted for future studies on digital learning and resilience.

The inner model, or structural model, evaluated the relationships among the constructs and tested the proposed hypotheses. The inner model assessment began by analyzing the  $R^2$  value, which indicates the predictive accuracy of the structural model and measures the variance explained by exogenous variables on endogenous variables. Additionally,  $Q^2$  predictive relevance was calculated to determine the predictive capability of the model. The Goodness-of-Fit (GoF) index was used to evaluate the overall model fit, ensuring its structural feasibility. This approach ensures sustainable knowledge production by generating replicable statistical models that provide actionable insights for digital education resilience.

Hypothesis testing was conducted using the bootstrapping procedure, which generates t-statistics and p-values to determine the significance of path coefficients. A relationship was considered statistically significant if the t-statistic exceeded 1.96 or the p-value was below 0.05. The strength of these relationships was further assessed by analyzing the path coefficients ( $\gamma$ ) obtained in the original sample [124,125]. By integrating these robust statistical techniques, this study contributes to the long-term sustainability of digital learning research, ensuring that its findings can be leveraged to enhance institutional policies and improve student outcomes in evolving digital education landscapes.

These methods ensured that the constructs were rigorously validated and the hypotheses were tested comprehensively. This approach also provided robust insights into the relationships among the variables in the context of sustainable digital learning environments and student resilience.

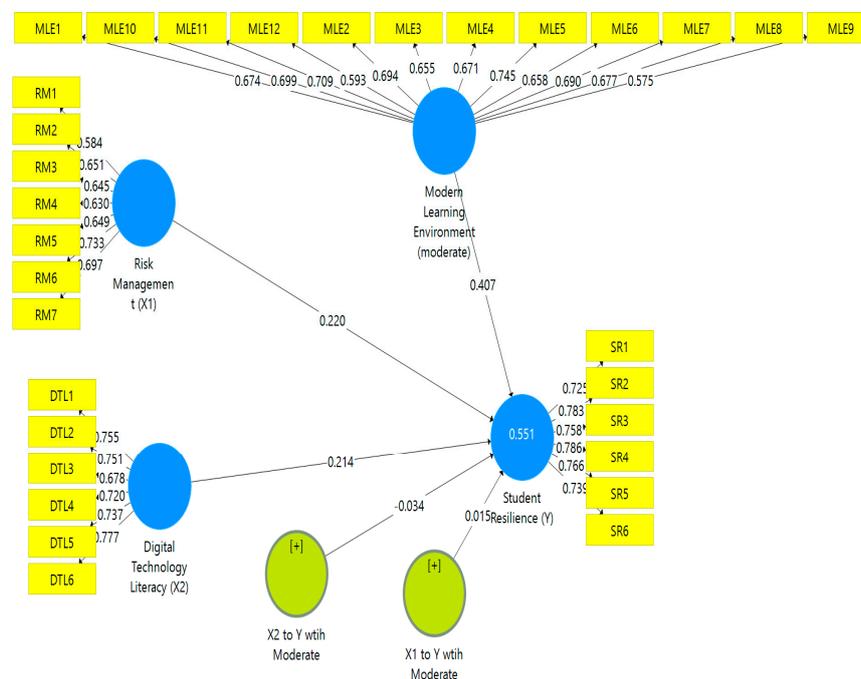
## 4. Data Analysis

### 4.1. Measurement and Structural Model

Data analysis was conducted using the Partial Least Squares Structural Equation Modeling (PLS-SEM) technique with SmartPLS version 4 software. This technique was employed to evaluate the relationships between latent constructs and their indicators in the measurement model (outer model) and the relationships between latent constructs in the structural model (inner model).

The results of the outer model analysis are visualized in Figure 2, which illustrates the relationships between indicators and latent variables. This diagram serves as a crucial step in validating the measurement model, ensuring that each indicator significantly contributes to the latent variable it represents and meets the required validity and reliability standards.

Below is the visualization of the outer model:



**Figure 2.** Path Diagram of The Outer Model. Generated from SEM-PLS analysis, 2025.

Subsequently, the results of the outer model are summarized in a table that includes the values for loading factor, Composite Reliability (CR), Cronbach's Alpha (CA), and Average Variance Extracted (AVE). All indicators exhibit loading factor values above 0.70, indicating strong convergent validity. The CA and CR values for all constructs exceed 0.70, demonstrating high internal reliability. Additionally, the AVE values for each variable are greater than 0.50, indicating that the indicators adequately explain their respective constructs. The results of the outer model evaluation are presented in Table 2 below.

**Table 2.** Loading Factor Table and Outer Model Evaluation.

Variable	Indicator (Code)	Outer Loading	Cronbach's Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)
Risk Management	RM1	0.584	0.780	0.841	0.583
	RM2	0.651			
	RM3	0.645			
	RM4	0.630			
	RM5	0.649			
	RM6	0.733			

Variable	Indicator (Code)	Outer Loading	Cronbach's Alpha (CA)	Composite Reliability (CR)	Average Variance Extracted (AVE)
Digital Technology Literacy	RM7	0.697	0.832	0.877	0.543
	DTL1	0.755			
	DTL2	0.751			
	DTL3	0.678			
	DTL4	0.720			
	DTL5	0.737			
	DTL6	0.777			
Modern Learning Environment	MLE1	0.674	0.889	0.908	0.620
	MLE2	0.699			
	MLE3	0.709			
	MLE4	0.593			
	MLE5	0.694			
	MLE6	0.655			
	MLE7	0.671			
Student Resilience	MLE8	0.745	0.853	0.891	0.577
	MLE9	0.658			
	MLE10	0.690			
	MLE11	0.677			
	MLE12	0.575			
	SR1	0.725			
	SR2	0.783			
	SR3	0.758			
	SR4	0.786			
	SR5	0.766			
	SR6	0.739			

Generated from SEM-PLS analysis, 2025.

The structural model evaluation is conducted to measure the predictive strength of independent variables on the dependent variables through the R-squared ( $R^2$ ) values. The analysis results indicate that the variable student resilience has an  $R^2$  value of 0.546, meaning that 54.6% of the variability in this construct can be explained by the independent and moderating variables in the model. This value suggests that the model demonstrates good predictive ability. The results of the  $R^2$  evaluation for the studied variables are summarized in Table 3 below.

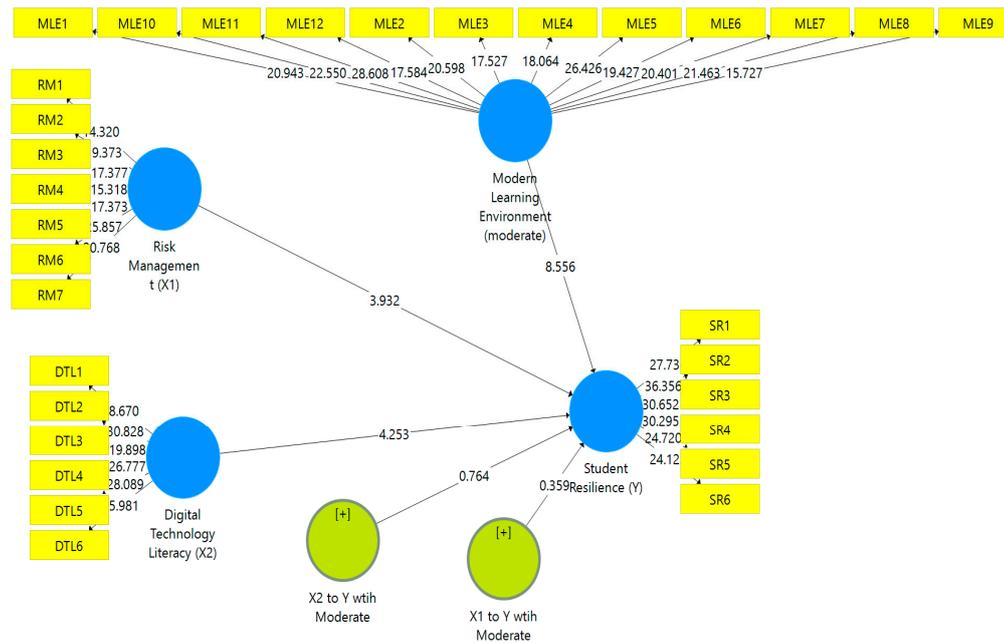
**Table 3.** Endogenous Variable  $R^2$  Values and Interpretation.

Endogenous Variable	$R^2$ Value	Interpretation
Student Resilience	0.546	54.6% of the variability in student resilience is explained by risk management, digital technology literacy, and modern learning environment.

Generated from SEM-PLS analysis, 2025.

#### 4.2. Hypothesis Testing

The hypothesis testing results in this study are presented in the form of a table and an inner model visualization. The analysis was conducted using bootstrapping to evaluate the significance of relationships between latent variables, both direct and moderated. The Figure 3 below illustrates the inner model visualization, showing the direction of relationships, path coefficient values, and significance between constructs.



**Figure 3.** Inner Model Visualization with Path Coefficients. Generated from SEM-PLS analysis, 2025.

The hypothesis testing results are summarized in a table that includes the path coefficient values, t-statistics, and p-values for each hypothesis. These values provide insights into the strength and significance of the relationships between latent variables in the model. The detailed results of the hypothesis testing are presented in Table 4 below.

**Table 4.** Hypotesis Testing Result.

Hypothesis	Path Coefficient ( $\beta$ )	t-Statistics	p-Value	Conclusion
H1: Risk Management $\rightarrow$ Student Resilience	0.220	3.932	0.000	Accepted (positive and significant)
H2: Digital Technology Literacy $\rightarrow$ Student Resilience	0.214	4.253	0.000	Accepted (positive and significant)
H3: Moderation of Modern Learning Environment on the relationship between Risk Management $\rightarrow$ Student Resilience	0.407	8.556	0.000	Accepted (significantly strengthens the relationship)
H4: Moderation of Modern Learning Environment on the relationship between Digital Technology Literacy $\rightarrow$ Student Resilience	0.015	5.129	0.000	Accepted (significantly strengthens the relationship)

Generated from SEM-PLS analysis, 2025.

#### Interpretation of Hypothesis Testing Results

- 1) H1: Risk Management has a positive and significant effect on Student Resilience  
The results show a path coefficient of 0.220, t-statistics of 3.932 (greater than 1.96), and a p-value of 0.000 (below 0.05). This confirms that effective risk management implementation significantly

enhances student resilience. Institutions with well-implemented risk management approaches provide better support for students in overcoming learning challenges.

2) H2: Digital Technology Literacy has a positive and significant effect on Student Resilience

With a path coefficient of 0.214, t-statistics of 4.253, and a p-value of 0.000, the results indicate that high digital technology literacy significantly contributes to strengthening student resilience. Students with strong technological skills are better equipped to adapt and utilize technology to support their learning process.

3) H3: Modern Learning Environment moderates the relationship between Risk Management and Student Resilience

A path coefficient of 0.407, t-statistics of 8.556, and a p-value of 0.000 show that the modern learning environment significantly strengthens the relationship between risk management and student resilience. Modern learning infrastructure and technology act as catalysts that enhance the effectiveness of risk management in supporting student resilience.

4) H4: Modern Learning Environment moderates the relationship between Digital Technology Literacy and Student Resilience

With a path coefficient of 0.015, t-statistics of 5.129, and a p-value of 0.000, the results indicate that the modern learning environment significantly strengthens the effect of digital technology literacy on student resilience. A supportive modern learning environment enables students to maximize the use of digital technology literacy in addressing academic challenges.

## 5. Discussion and Conclusions

### 5.1. Risk Management Has a Significant Positive Effect on Student Resilience.

The results of this study provide empirical support that risk management has a significant positive effect on student resilience, as indicated by a path coefficient of 0.220, t-statistics of 3.932 (greater than the threshold of 1.96), and a p-value of 0.000 (below the significance level of 0.05). Well-implemented risk management strategies enable educational institutions to create a safe, structured, and supportive learning environment, enhancing students' ability to navigate academic challenges in a sustainable manner. These strategies include risk identification, contingency planning, data security measures, and the evaluation of risk mitigation effectiveness [94,127–129]. By fostering proactive risk management policies, institutions not only reduce academic uncertainties but also cultivate a resilient student body prepared for long-term adaptation in evolving educational landscapes.

By clearly communicating risks and mitigation steps, students can maintain their academic focus without excessive disruption from uncertainties, thereby ensuring continuity and sustainability in their educational journey [78,94,130]. These findings demonstrate that institutions integrating risk management frameworks into their operational policies can enhance students' confidence in managing academic and professional pressures, which is a crucial element of resilience.

This positive relationship is also supported by literature demonstrating that risk management approaches not only reduce stress but also enhance adaptability, particularly in increasingly complex digital learning environments [25,131,132]. Such strategies became particularly critical during the COVID-19 pandemic, when many educational institutions were forced to transition abruptly to online learning. Previous studies have noted that institutions with effective risk management measures exhibit higher organizational resilience and better academic outcomes among students [35,36].

Thus, these findings reinforce the relevance of risk management as a foundational element for supporting student resilience during the era of digital transformation. Furthermore, these results offer practical contributions to educational institutions by encouraging the continuous development of dynamic and adaptive risk management frameworks, which are essential for sustaining student resilience in the face of future educational challenges [133–135].

### 5.2. Digital Technology Literacy Has a Significant Positive Effect on Student Resilience

The results of this study confirm that digital technology literacy significantly enhances student resilience, as evidenced by a path coefficient of 0.214, t-statistics of 4.253, and a p-value of 0.000. Digital technology literacy equips students with critical skills to navigate, evaluate, and effectively utilize digital tools, enabling them to adapt to academic challenges in a sustainable manner. Students with higher levels of digital literacy are better prepared to manage academic demands, collaborate seamlessly in virtual environments, and efficiently access learning resources, fostering long-term adaptability in digital education ecosystems. This competence not only reduces stress but also builds confidence, allowing students to feel more in control of their academic responsibilities while ensuring the sustainable use of digital resources for learning and professional development [18,104,136]. Additionally, digital literacy fosters essential problem-solving skills and innovation, both of which are crucial for maintaining resilience in dynamic and rapidly evolving learning environments, particularly in the context of sustainable digital transformation [137,138].

This positive relationship aligns with prior studies emphasizing the critical role of digital literacy in supporting student adaptability, particularly during the transition to online and hybrid learning models. During the COVID-19 pandemic, students with strong digital literacy demonstrated higher levels of engagement and resilience compared to those with limited skills [49,53,54]. Institutions that actively promote digital literacy programs contribute not only to strengthening student resilience but also to ensuring the long-term sustainability of digital education. These initiatives help students overcome technological barriers and fully utilize modern learning environments while preparing them for a digitally-driven workforce [14,139,140].

These findings suggest that digital technology literacy is not merely a technical skill but a foundational competency essential for sustainable academic success in an increasingly digitized educational ecosystem [141,142]. Therefore, fostering digital literacy among students should be a strategic priority for institutions aiming to build resilience, promote lifelong learning, and support sustainable innovation in education.

### 5.3. Modern Learning Environment Moderates the Relationship Between Risk Management and Student Resilience

A path coefficient of 0.407, t-statistics of 8.556, and a p-value of 0.000 confirm that the modern learning environment (MLE) significantly moderates the relationship between risk management and student resilience, with the effect being more pronounced in high-quality MLEs. A modern learning environment, characterized by advanced digital infrastructure and innovative teaching strategies, enhances the effectiveness of risk management by providing students with structured and adaptable support systems that promote sustainable academic development. In high-quality MLEs, risk management measures such as clear communication, contingency planning, and robust security protocols are implemented more effectively, enabling students to maintain focus and resilience during academic challenges while ensuring long-term institutional adaptability [5,54].

Moreover, high-quality MLEs amplify the positive effects of risk management by fostering a supportive learning environment that integrates flexibility, inclusivity, and sustainability. For instance, institutions offering user-friendly digital platforms, real-time learning analytics, and personalized learning options empower students to take proactive steps in managing academic risks while ensuring equitable access to educational resources [16,143,144]. Conversely, in low-quality MLEs with limited resources and poorly implemented strategies, the effectiveness of risk management in building resilience is diminished, as students face greater technological and academic barriers, leading to long-term disadvantages in digital learning readiness [144].

These findings highlight the critical role of MLEs in bridging the gap between institutional strategies and student outcomes, ensuring that risk management efforts are not only reactive but also proactively support sustainable academic resilience. Based on these findings, it can be concluded that MLEs act as an essential moderating factor that strengthens the relationship between risk

management and student resilience, reinforcing the importance of investing in digital education infrastructure to support long-term student success [54,145,146].

#### *5.4. Modern Learning Environment Moderates the Relationship Between Digital Technology Literacy and Student Resilience*

With a path coefficient of 0.015, t-statistics of 5.129, and a p-value of 0.000, the findings confirm that the modern learning environment (MLE) significantly moderates the relationship between digital technology literacy and student resilience, with the effect being more pronounced in high-quality MLEs. A modern learning environment enhances the positive impact of digital technology literacy by providing students with the tools, infrastructure, and sustainable digital resources needed to effectively apply their digital skills. In high-quality MLEs, features such as reliable digital platforms, advanced learning analytics, and collaborative virtual tools amplify the benefits of digital literacy by enabling students to engage deeply with learning materials and overcome academic challenges in a sustainable manner [5,16,54]. This interaction not only supports academic adaptation but also builds students' confidence, fostering their resilience in navigating complex and rapidly evolving digital learning environments [16,147].

Furthermore, high-quality MLEs provide a supportive and sustainable ecosystem that allows students with higher digital literacy to maximize their capabilities through personalized learning pathways and inclusive technological designs. These environments ensure equitable access to digital resources, minimize digital divides, and encourage collaboration, further strengthening student resilience in digital education [107,148,149]. Conversely, in low-quality MLEs, students may face technological and institutional barriers that hinder the application of their digital literacy skills, reducing their ability to build resilience and limiting their capacity to thrive in digital learning environments [14,70,150].

These findings emphasize that MLEs serve as an essential moderating factor in the digital learning process, ensuring that students with strong digital literacy skills can fully capitalize on their abilities to adapt, succeed, and sustain long-term learning engagement in an increasingly digitalized education landscape [16,54,105,151].

#### *5.5. Conclusion*

This study concludes that risk management and digital technology literacy significantly enhance student resilience, emphasizing their critical role in fostering adaptability, academic success, and long-term learning sustainability in higher education. Moreover, the modern learning environment (MLE) serves as a key moderating factor, amplifying the positive effects of both risk management and digital literacy on resilience. High-quality MLEs, characterized by sustainable digital infrastructure, adaptive learning technologies, and inclusive teaching strategies, empower institutions to bridge the gap between institutional policies and student outcomes. These environments ensure that students can thrive in dynamic academic settings by providing equitable access to technological resources, fostering digital engagement, and minimizing barriers to learning.

These findings emphasize the urgent need for educational institutions to integrate robust risk management frameworks, prioritize digital literacy development, and invest in inclusive, technology-driven learning environments. By doing so, institutions can equip students with the resilience required to navigate the challenges of digital transformation, ensuring that they not only succeed academically but also develop long-term adaptability in an evolving digital education landscape.

## **6. Theoretical Implications**

This study advances theoretical understanding of the relationship between risk management, digital technology literacy, modern learning environments (MLEs), and student resilience, particularly within the context of sustainable digital transformation in higher education. By

demonstrating that risk management and digital technology literacy significantly enhance student resilience, this research extends existing resilience theories by incorporating institutional strategies and individual competencies as critical drivers of adaptability and long-term learning sustainability [16,90]. These findings contribute to resilience discourse by emphasizing the role of both proactive institutional support and student competencies in mitigating academic challenges in an evolving digital education landscape.

The moderating role of modern learning environments further validates theoretical frameworks that highlight the interplay between environmental factors and individual outcomes [152,153]. High-quality MLEs, characterized by sustainable digital infrastructure, adaptive learning ecosystems, and innovative pedagogical approaches, amplify the effects of risk management and digital literacy on resilience. This finding addresses a notable gap in resilience literature, which often overlooks the significance of environmental moderators in digital learning. By integrating these insights, this study provides a comprehensive framework for understanding how institutional, individual, and environmental factors collectively contribute to student adaptability, digital sustainability, and academic success in dynamic educational ecosystems [154–156]. These implications lay a solid foundation for future research exploring the integration of digital technologies, institutional strategies, and sustainable environmental supports in fostering resilience and long-term educational transformation.

## 7. Practical Implications

The findings of this study offer valuable practical insights for higher education institutions seeking to enhance student resilience and ensure long-term sustainability in the digital era.

First, the significant role of risk management underscores the necessity for universities to establish robust institutional frameworks that identify, mitigate, and manage risks effectively. Universities should develop comprehensive contingency plans, secure data systems, and transparent communication strategies to create a stable and supportive academic environment. These efforts not only reduce uncertainties but also promote institutional resilience, fostering a sense of security and adaptability among students. In turn, this enables students to maintain academic focus and preparedness for future disruptions [36,94].

Second, the positive impact of digital technology literacy highlights the urgent need for universities to invest in comprehensive, future-oriented digital literacy training programs. These initiatives should equip students with essential skills to effectively navigate digital tools, critically evaluate online information, and collaborate in virtual environments. Institutions should integrate digital literacy modules into curricula and provide accessible, structured learning resources that empower students to develop their technological competencies sustainably [115,157,158].

Lastly, the moderating role of the modern learning environment (MLE) reinforces the importance of investing in sustainable, high-quality learning ecosystems. Universities should ensure reliable digital infrastructure, interactive learning platforms, and personalized learning opportunities to enhance the effectiveness of risk management and digital literacy. High-quality MLEs bridge the gap between institutional strategies and student outcomes by fostering a flexible, inclusive, and adaptive learning environment. This investment will not only strengthen student resilience but also support long-term educational sustainability and innovation [62,143].

In conclusion, higher education institutions can leverage these findings to develop integrated, future-proof strategies that combine risk management, digital literacy development, and sustainable modern learning environments. These efforts will better prepare students to navigate academic and professional challenges in an increasingly digital world while ensuring long-term institutional adaptability.

## 8. Limitations and Future Research

This study has several limitations that present valuable opportunities for future research and development.

First, the research employs a quantitative approach with cross-sectional data collected from 475 undergraduate students in Indonesia. While this methodology provides statistical insights, it may not fully capture the evolving nature of student resilience and digital adaptation over time. Additionally, the findings may not generalize across different cultural, institutional, or regional contexts. Future studies are encouraged to adopt longitudinal designs or mixed-method approaches to explore causal relationships and track changes in student resilience, digital literacy, and risk management effectiveness over time. Expanding the scope to include cross-country comparisons may also provide deeper insights into global trends in digital learning resilience.

Second, the research model focuses on four primary variables: risk management, digital technology literacy, modern learning environment, and student resilience. While these variables are crucial, student resilience is a multidimensional construct that may also be influenced by other psychological and environmental factors. Future research could integrate additional variables such as emotional well-being, social support systems, instructor competence, and institutional digital policies to provide a more holistic perspective on the factors shaping student resilience in digital education. Moreover, incorporating emerging technologies, such as artificial intelligence-driven learning assistants or immersive virtual learning environments, could offer new insights into how digital transformation influences student adaptability.

Finally, this study is limited to undergraduate students in higher education. However, the dynamics of resilience and digital literacy may differ across other educational levels or professional training environments. Future research could expand the focus to include graduate students, vocational learners, and professionals engaging in lifelong learning. Exploring resilience in corporate digital training programs or continuing education settings could offer broader insights into how digital literacy and risk management strategies translate into workforce readiness and long-term career adaptability.

By addressing these limitations, future studies can enhance the depth, applicability, and global relevance of research on digital learning resilience, ensuring that educational institutions and policymakers are better equipped to support students in an increasingly digital and uncertain world.

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## Abbreviations

The following abbreviations are used in this manuscript:

HRM	Human Resource Management
SET	Social Exchange Theory
SDT	Self-Determination Theory

CSR	Corporate Social Responsibility
SDGs	Sustainable Development Goals
AI	Artificial Intelligence
ICT	Information and Communication Technology
MLE	Modern Learning Environment
PLS-SEM	Partial Least Squares Structural Equation Modeling

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