

## Advancing Sustainability Education through Narrative Digital Media: A Structural Model of Student Acceptance

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### Abstract

While teaching the 17 Sustainable Development Goals (SDGs) is important, many schools struggle to keep students interested, often leading to boredom or confusion. This research evaluates a 2D visual novel, Liora Island, for enhancing engagement and reducing cognitive complexity when teaching the SDGs. Using a quantitative associative design and the Technology Acceptance Model (TAM), five variables Perceived Ease of Use (PEOU), Perceived Usefulness (PU), Attitude Toward Using (ATU), Behavioral Intention (BI), and Actual Use (AU) were examined among 139 students at Mondial Senior High School, Batam. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Findings reveal high student acceptance across all TAM constructs. Perceived ease of use emerged as the primary driver of adoption, strongly influencing perceived usefulness and attitude. Attitude toward using significantly predicted behavioral intention, which in turn strongly determined actual use. Perceived usefulness showed smaller but significant effects on attitude and behavioral intention, indicating that usability outweighs instructional value during initial acceptance. This study contributes to sustainability pedagogy by identifying usability as key in reducing "sustainability fatigue." Practically, the results indicate that user friendly, narrative driven media are superior to traditional text heavy methods for communicating complex global challenges in secondary education.

**Keywords:** educational game; interactive learning; sustainable development goals; visual novel

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### INTRODUCTION

Education plays a fundamental role in preparing students to address global challenges and achieve the Sustainable Development Goals (SDGs). Beyond transmitting knowledge, educational institutions serve as critical spaces for cultivating sustainability values and responsible citizenship (Serafini et al., 2022). Although integrating sustainability into curricula enhances global responsibility (Angelaki et al., 2024), current implementation remains fragmented, resulting in uneven student awareness (Kusumaningrum et al., 2023; Sedovs et al., 2025). Even with national commitments, integrating SDG content into secondary education remains challenging, particularly in Asian countries where student awareness is low (Padilla et al., 2025; Papavasileiou et al., 2025). Concurrently, Indonesia's growing video game industry has spurred interest in leveraging gaming technologies for classroom learning (Christian, 2022).



The 17 SDGs comprise interconnected goals to end poverty and protect the environment by 2030. Effectively teaching these values requires a shift toward Constructivist Learning Theory, which posits that knowledge is best gained through active experience and decision making. While interactive and game like environments have been shown to improve motivation (Montenegro-Rueda et al., 2023; Suwarno et al., 2025), most existing SDG oriented tools focus only on isolated goals, such as climate action or poverty. This approach fails to demonstrate how the 17 goals function as an integrated system. Visual novels offer a promising alternative by supporting critical thinking through immersive narratives (Angraini et al., 2024).

Existing SDG focused educational tools predominantly address isolated goals and lack empirical validation in formal classroom settings (Adams et al., 2023). Furthermore, while visual novels have been proposed as pedagogical tools, studies to date have been largely descriptive, focusing on general appeal rather than systematically examining their capacity to convey the systemic nature of the SDGs (Ho et al., 2022). Researchers have noted that sustainability education suffers from fragmented implementation, resulting in uneven student awareness (Djirong et al., 2024). There is a notable gap of empirically tested interventions that leverage interactive storytelling to integrate all 17 goals within a single cohesive narrative, particularly within Asian educational contexts where student awareness remains low (Chen & Ho, 2022).

Evidence is currently lacking on whether interactive narrative tools can effectively foster understanding of the SDGs as an interconnected system. According to recent scholarship, while technology enhanced learning has gained traction in sustainability education, most interventions target isolated competencies rather than holistic systems thinking (Cocu et al., 2025). Exploring this gap is necessary because sustainability education requires learners to grasp complex relationships between social, economic, and environmental dimensions, a cognitive challenge that traditional fragmented approaches fail to address (André, 2024). The Technology Acceptance Model (TAM) provides a validated framework for examining user acceptance of new technologies by focusing on key determinants such as perceived usefulness and perceived ease of use, which shape users' attitudes and behavioral intentions (Liu et al., 2025). Without rigorous investigation employing validated theoretical frameworks such as the TAM, educators lack evidence-based guidance on designing and implementing technology mediated sustainability instruction (Rosli et al., 2022).

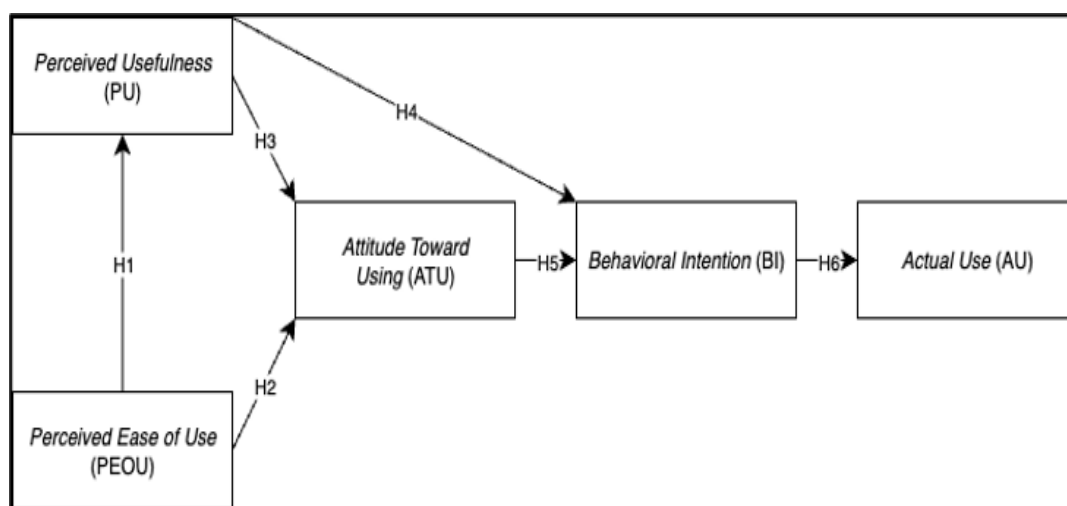
This study aims to empirically evaluate the effectiveness of a 2D visual novel designed to integrate all 17 SDGs into a single cohesive narrative, with a specific focus on student acceptance within a real-world classroom environment. The novelty lies in its systematic integration of all 17 goals into a single story, its empirical validation using TAM, and its real-world classroom setting, which distinguishes it from prior descriptive studies. This research contributes to sustainability education by providing evidence-based insights into interactive storytelling as a tool for technology mediated learning, an area significantly underexplored in the literature.

## METHOD

This study employs a quantitative design grounded in the TAM introduced by Fred D. Davis in 1989 to examine student acceptance of the developed 2D visual novel learning media. TAM explains technology adoption through several related perceptions and behavioral responses. In this study, perceived usefulness (PU) refers to the degree to which students believe that interacting with the visual novel helps them better understand Sustainable Development Goal (SDG) concepts. Perceived ease of use (PEOU) reflects students' perception that the narrative interface and interactions are clear and effortless to operate. Illustrated in Figure 1, these perceptions shape attitude toward using (ATU), defined as students' evaluative judgment regarding the experience of learning through the story based

medium. Attitude subsequently influences behavioral intention (BI), which represents students' willingness to continue using similar interactive learning tools in the future. Finally, actual use (AU) refers to students' direct engagement with the interactive features of the visual novel. (Or, 2024)

Although TAM has been widely applied in studies of educational technology adoption, its application in learning environments continues to be discussed in the literature. Some researchers argue that student acceptance of educational media may also involve pedagogical and motivational factors beyond those captured by the model. Even these debates, TAM remains a widely used analytical framework due to its consistent ability to explain technology adoption behavior. In this study, the model is not modified; rather, it is empirically validated within the context of interactive narrative learning media, specifically a visual novel designed to introduce SDG concepts.



**Figure 1.** Hypotheses model

Data were collected using a structured questionnaire measuring each TAM construct with a five point Likert scale. Students interacted with the visual novel for approximately 45 minutes in a supervised classroom setting before completing the questionnaire. Measurement quality was assessed through outer loading values, Average Variance Extracted (AVE), Cronbach's Alpha, and Composite Reliability. The hypothesized relationships were then examined using Partial Least Squares Structural Equation Modeling (PLS-SEM) implemented in SmartPLS 4. Structural evaluation included path coefficient analysis, coefficient of determination ( $R^2$ ), effect size ( $f^2$ ), predictive relevance using the  $Q^2$  blindfolding procedure, and multicollinearity assessment through the Variance Inflation Factor (VIF). These procedures were used to determine how well TAM explains students' acceptance of the visual novel learning media (Kyriazos & Poga, 2023).

## RESULTS AND DISCUSSION

### Results

This study involved Grade 10 students from Mondial Senior High School, Batam, to evaluate their acceptance of visual novel based learning using the TAM framework. Data were collected through questionnaires following direct interaction with the learning media and analysed using PLS-SEM in SmartPLS 4. The respondent profile in Table 1 shows a balanced gender distribution and a strong dominance of Grade 10 participants, ensuring alignment with the study focus. Most students reported frequent use of digital media and prior exposure to visual novels, indicating familiarity with interactive platforms. This context supports the

validity of assessing acceptance, as respondents possess adequate digital experience to evaluate the learning application meaningfully.

Validity and reliability assessments were performed to confirm that each indicator appropriately represents its underlying construct. As presented in Table 2, all variables satisfy established measurement benchmarks. Outer loading and composite reliability values surpass the 0.70 threshold, while AVE values exceed 0.50, demonstrating strong internal consistency and satisfactory convergent validity across the constructs. These results demonstrate that each construct adequately explains its indicators and that the instrument performs reliably. The findings establish a sound basis for further structural analysis, as the measurement model satisfies the required psychometric standards without indication of instability or inconsistency across variables.

**Table 1.** Demographic respondents

Criteria	Category	Total	Percentage
Gender	Male	71	51,1%
	Female	68	48,9%
Grade	High School (X)	137	98,6%
	High School (XI)	1	0,7%
	High School (XII)	1	0,7%
Frequency of Digital Media Use	Often	130	93,5%
	Sometimes	8	5,8%
	Rarely	1	0,7%
Previous Visual Novel Usage Frequency	Often	122	56,1%
	Sometimes	42	50,2%
	Never	20	14,2%

**Table 2.** Result of the validity and reliability test for the research variables

Variable	Indicator	Outer Loading	Cronbach's Alpha	Composite Reliability	AVE	Conclusion
Perceived Usefulness (PU)	PU1	0.813	0.854	0.856	0.632	Valid and Reliable
	PU2	0.761				
	PU3	0.801				
	PU4	0.807				
	PU5	0.790				
Perceived Ease of Use (PEOU)	PEOU1	0.736	0.887	0.888	0.639	Valid and Reliable
	PEOU2	0.765				
	PEOU3	0.821				
	PEOU4	0.862				
	PEOU5	0.812				
	PEOU6	0.796				
Attitude Toward Using (ATU)	ATU1	0.848	0.851	0.854	0.770	Valid and Reliable
	ATU2	0.895				
	ATU3	0.889				
Behavioral Intention (BI)	BI1	0.729	0.822	0.830	0.653	Valid and Reliable
	BI2	0.854				
	BI3	0.826				
	BI4	0.818				
Actual Use (AU)	AU1	0.879	0.787	0.815	0.701	Valid and Reliable
	AU2	0.748				
	AU3	0.879				

Discriminant validity testing further confirms that each construct represents a distinct concept within the model. The method used to assess discriminant validity is the Heterotrait-Monotrait (HTMT) ratio. HTMT values are used to evaluate the differences among variables in the research model. The criterion requires that HTMT values be below 0.90, indicating that each construct in the model represents a distinct concept. The results in Table 3 demonstrate that variables such as PEOU, PU, ATU, BI, and AU are empirically distinguishable from one another.

Although some constructs show relatively strong relationships, particularly between BI & AU, the values remain within acceptable limits, confirming that the constructs do not overlap conceptually. This is reinforced by the Fornell-Larcker results in Table 4, where the square root of AVE for each construct exceeds its inter-construct correlations. Together, these results indicate that the model achieves sufficient conceptual distinction, ensuring that each variable contributes uniquely to explaining student acceptance without overlap or redundancy.

**Table 3.** Results of the heterotrait-monotrait ratio test on variables

Variable	ATU	AU	BI	PEOU	PU
ATU					
AU	0.845				
BI	0.875	0.893			
PEOU	0.825	0.863	0.744		
PU	0.754	0.852	0.766	0.885	

**Table 4.** Results of the fornell-larcker criterion test on variables

Variable	ATU	AU	BI	PEOU	PU
ATU	0.878				
AU	0.699	0.838			
BI	0.734	0.734	0.808		
PEOU	0.720	0.731	0.638	0.800	
PU	0.644	0.710	0.646	0.771	0.795

Multicollinearity assessment using VIF values results presented in Table 5 shows that all predictors fall well below the threshold of 5, indicating no collinearity issues. This suggests that each independent variable contributes independently to the model without inflating estimation bias. The absence of multicollinearity supports the stability of the structural estimates and confirms that the model satisfies key statistical assumptions required for PLS-SEM analysis.

**Table 5.** Results of the variance inflation factor (vif) test on variables

Variable	VIF
ATU > BI	1.710
BI > AU	1.000
PEOU > ATU	2.469
PEOU > PU	1.000
PU > ATU	2.469
PU > BI	1.710

The structural model results in Table 6 indicate that all hypothesised relationships are significant. The strongest effect is observed for PEOU  $\rightarrow$  PU ( $\beta = 0.771$ ), followed by BI  $\rightarrow$

AU ( $\beta = 0.734$ ), highlighting ease of use and intention as critical drivers of acceptance. Moderate effects are found for PEOU  $\rightarrow$  ATU ( $\beta = 0.552$ ) and ATU  $\rightarrow$  BI ( $\beta = 0.543$ ), while PU  $\rightarrow$  BI ( $\beta = 0.296$ ) shows a smaller contribution. The weakest relationship is PU  $\rightarrow$  ATU ( $\beta = 0.219$ ), suggesting that perceived usefulness plays a less dominant role in shaping attitudes compared to usability. These findings position ease of use as the central factor influencing perception, attitude, and behavioural intention.

The explanatory power of the model shown in Table 7 indicates moderate strength across all endogenous constructs. The model explains 59.5% of the variance in PU, 53.8% in ATU, 59.0% in BI, and 53.8% in AU, reflecting stable predictive capacity within an educational context. Among these, behavioural intention shows the highest explained variance, indicating strong dependence on preceding attitudinal and perceptual factors. These values suggest that TAM provides a meaningful explanation of student acceptance while maintaining consistency with typical thresholds in technology acceptance research.

**Table 6.** Results of the direct effect test on variables

	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	Conclusion
H1:PEOU>PU	0.771	0.768	0.049	15.724	0.000	Significant
H2:PEOU>ATU	0.552	0.548	0.089	6.175	0.000	Significant
H3:PU>ATU	0.219	0.219	0.096	2.280	0.000	Significant
H4:PU>BI	0.296	0.298	0.084	3.506	0.000	Significant
H5:ATU>BI	0.543	0.542	0.075	7.233	0.000	Significant
H6:BI>AU	0.734	0.733	0.050	14.657	0.000	Significant

**Table 7.** Results of the r-square test on variables

Variable	R <sup>2</sup>	R <sup>2</sup> Adjusted
ATU	0.538	0.532
AU	0.538	0.535
BI	0.590	0.584
PU	0.595	0.592

Effect size analysis in Table 8 reveals substantial variation in the contribution of each relationship. The largest effects are observed for PEOU  $\rightarrow$  PU ( $f^2 = 1.469$ ) and BI  $\rightarrow$  AU ( $f^2 = 1.166$ ), confirming their dominant influence within the model. Moderate effects appear for ATU  $\rightarrow$  BI ( $f^2 = 0.421$ ) and PEOU  $\rightarrow$  ATU ( $f^2 = 0.267$ ), while PU  $\rightarrow$  ATU ( $f^2 = 0.042$ ) shows minimal contribution. This pattern reinforces the central role of usability, indicating that intuitive interaction is more influential than perceived functional value in shaping student responses to the learning system.

**Table 8.** Results of the f-square test on variables

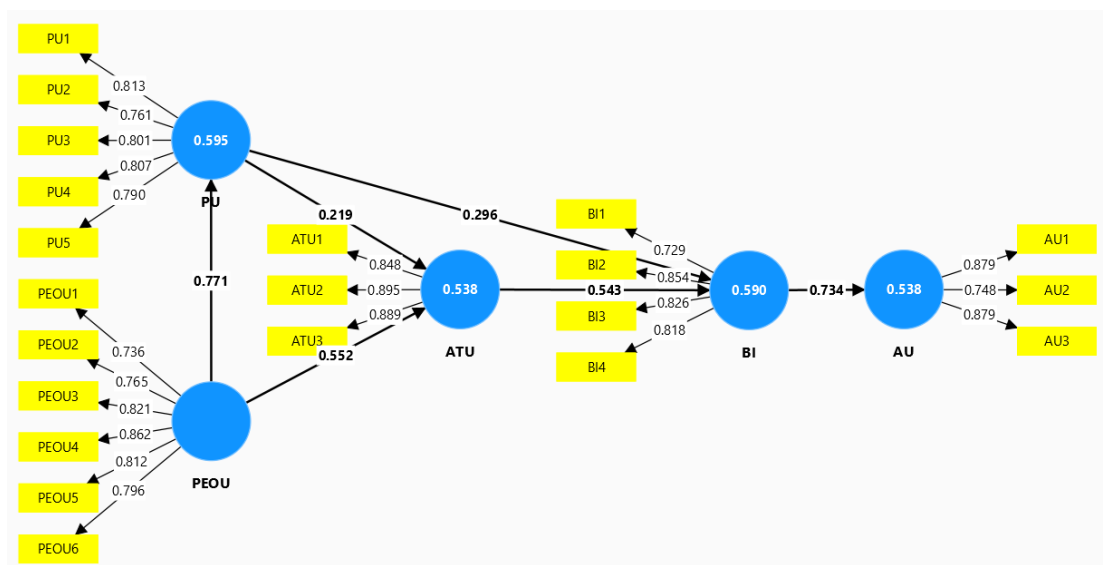
Variable	f <sup>2</sup>
ATU > BI	0.421
BI > AU	1.166
PEOU > ATU	0.267
PEOU > PU	1.469
PU > ATU	0.042
PU > BI	0.125

**Table 9.** Q-Square test

Variable	Q <sup>2</sup>
ATU	0.408
AU	0.365
BI	0.370
PEOU	0.000
PU	0.369

Predictive relevance testing in Table 9 shows that all endogenous constructs achieve positive Q<sup>2</sup> values, confirming adequate predictive capability. The highest value is observed for ATU (Q<sup>2</sup> = 0.408), followed by BI and PU, indicating that the model effectively predicts student perceptions and behavioural tendencies. The Q<sup>2</sup> value of zero for PEOU reflects its role as an exogenous construct and does not indicate model weakness. Overall, the results demonstrate that the model maintains satisfactory predictive performance across key acceptance variables.

Figure 2 illustrates the structural relationships estimated through PLS-SEM, integrating both measurement and structural components. The model highlights PEOU as the foundational driver, strongly influencing PU and ATU, which subsequently shape behavioural intention. PU also contributes directly to BI, reflecting a rational evaluation pathway alongside attitudinal influence. The strongest linkage is observed between BI and AU, indicating that intention translates effectively into actual use. The R<sup>2</sup> values embedded in the model confirm moderate explanatory power, demonstrating that perceptions of usability and usefulness collectively shape attitudes, intentions, and actual engagement with the visual novel learning system.



**Figure 2.** Structural model algorithm

### Discussion

The empirical findings confirm the robustness of the TAM in explaining user acceptance within narrative-based digital learning, while revealing a contextual shift in the relative influence of its core constructs. Although all hypothesized relationships are significant, PEOU emerges as the dominant determinant, strongly influencing both PU ( $\beta = 0.771$ ) and ATU ( $\beta = 0.552$ ). This pattern indicates that, in immersive narrative environments, acceptance is primarily driven by interactional fluency rather than functional evaluation, where intuitive

system navigation shapes both cognitive appraisal and affective responses toward the learning experience.

The predominance of PEOU is closely linked to cognitive load regulation, where suboptimal interface design introduces extraneous demands that hinder content processing (Sari et al., 2024). The strong relationship between PEOU and PU suggests that perceived usefulness is largely contingent upon the learner's ability to interact efficiently with the system. Extending prior findings (Wu et al., 2022), reduced interactional friction not only sustains engagement but also facilitates the comprehension of complex, interconnected SDG concepts. In this context, the interface functions as a critical mediator that either enables or constrains higher-order cognitive processing.

A notable divergence from conventional TAM findings is the relatively weak influence of PU on ATU ( $\beta = 0.219$ ) compared to the stronger effect of PEOU. While prior studies identify perceived usefulness as the primary driver of attitudes (Montenegro-Rueda et al., 2023), the present results indicate that, in narrative-driven contexts, experiential qualities embedded in usability outweigh utilitarian considerations. This suggests that TAM relationships are context-sensitive, particularly in immersive environments where affective engagement and interaction quality mediate the translation of functional value into attitudinal responses, reinforcing critiques of TAM's limited capacity to capture experiential dimensions (Rosli et al., 2022).

The strong relationship between BI and AU ( $\beta = 0.734$ ) confirms the model's predictive validity, consistent with prior meta-analytic evidence (Or, 2024). However, the relatively limited effect of PU on BI ( $\beta = 0.296$ ) indicates that behavioral commitment is driven less by utilitarian evaluation and more by attitudinal dispositions shaped through prior interaction experiences. This pattern highlights the central role of experiential coherence, where perceived interaction quality outweighs functional considerations in sustaining continued use.

The integration of the 17 SDGs within a unified narrative structure addresses the persistent fragmentation of sustainability education across isolated themes (Adams et al., 2023; Djirong et al., 2024). This approach promotes relational understanding by embedding complex global issues within an interactive framework, enabling learners to perceive interdependencies across social, economic, and environmental dimensions. Such findings reinforce the view that experiential and context-rich environments are more effective for fostering systems-level comprehension than static instructional formats (André, 2024), while extending prior research that has largely remained descriptive in examining game-based SDG learning (Ho et al., 2022).

These findings are particularly relevant in contexts where SDG awareness remains uneven (Padilla et al., 2025; Papavasileiou et al., 2025). The consistently high acceptance across TAM constructs indicates that narrative-based digital media can effectively transform passive exposure into active cognitive and behavioral engagement, positioning interactive storytelling as a scalable strategy to address limitations in conventional sustainability education.

Several limitations warrant consideration. The single-institution sample restricts external validity across diverse contexts, while the cross-sectional design limits insight into longitudinal outcomes such as sustained engagement and knowledge retention. Future research should adopt longitudinal and mixed-method approaches that combine perceptual and objective measures, as well as comparative analyses across digital media types to determine whether the dominance of usability is specific to narrative environments or reflects a broader trend in technology-enhanced learning.

## CONCLUSION

This study shows that the 2D visual novel *Liora Island* is a successful tool for teaching all 17 Sustainable Development Goals (SDGs) through a single story. The results prove that

Ease of Use is the most important factor in helping students handle the complex information within the SDGs. Theoretically, this research moves the TAM into the new area of sustainability education, showing that today's digital native students accept complex global topics more easily when they are presented through a simple, user-friendly interface. Beyond this specific study, the findings suggest a global shift in how we teach, moving away from memorizing facts toward using narrative based digital tools that allow students to solve real world problems. While this research focused on one school's acceptance of the technology, it provides a clear model for how schools worldwide can use storytelling to make global sustainability goals more engaging and less overwhelming. This marks a necessary transformation in education, where digital stories help bridge the gap between complex global policies and student understanding.

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