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DIGITAL PEDAGOGY, SUSTAINABILITY LITERACY AND LONG-TERM ENVIRONMENTAL COMMITMENT

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ABSTRACT

The fast-evolving global ecological crisis requires transformative educational pathways that are able to foster sustainable environmental responsibility in learners. In doing so, this study assesses the structure of the relationship between digital pedagogy, sustainability literacy, and long-term environmental commitment in higher education. Based on data from 384 university students exposed to digitally mediated sustainability curricula, the research utilizes SPSS for preliminary statistical screening and AMOS-based Structural Equation Modeling to test hypothesized relationships and mediation effects. The results demonstrate the role of digitally enhanced pedagogical elements in significantly enhancing sustainability literacy through developing students' conceptual understanding, critical reflection, and awareness of environmental issues. Furthermore, sustainability literacy is a powerful predictor of long-term environmental commitment as a result of maintaining pro-environmental attitudes and behavioral intentions. Although digital pedagogy presents a direct positive association with environmental commitment, the relationship is significantly enhanced in the context of sustainability literacy, indicating a partial mediation effect. Here the validated structural model yields empirical support on the effectiveness of digital transformation in education, rather than simply the integration of technology in the teaching methods, but as a strategic fit with sustainability-oriented learning outcomes. The study connects digital learning practices to future environmental stewardship by building sustainability literacy into a primary mechanism by addressing digital pedagogical practices, building on theoretical articulation to sustainability scholarship and laying down actionable frameworks for designing sustainable learning ecosystems capable of accommodating and leading to future outcomes.

KEYWORDS: Digital Pedagogy; Sustainability Literacy; Environmental Commitment; Sustainability Education; Higher Education; Digital Transformation; Environmental Stewardship.

1. INTRODUCTION

The accelerating ecological catastrophe has irrevocably reconfigured the normative expectations facing educational entities globally. Education is no longer seen as a pass-down of disciplinary knowledge; rather, it is increasingly taken as a transformative social institution with the power to breed ecological consciousness, ethical responsibility and long-lasting behavioral transformation. Climate instability, loss of biodiversity, and depletion of resources have all increased demands on education systems to shift from awareness creation to fostering sustained environmental commitment [1]. Amid these issues, we see the emergence of sustainability education as a multifaceted and interdisciplinary space bridging environmental science, socio-political analysis, economic reasoning, ethics and pedagogical innovation. It aims not only to give learners information about environmental issues, but to provide them with the competencies, values and dispositions they need to tackle the complexities of sustainable development [2]. This extended mandate is further reinforced in global policy discourse that places education at the central edge of contributing to sustainable development and ensuring long-term societal resilience. Yet even though sustainability literacy has been increasingly prioritised as a desired educational outcome, there is an ongoing theoretical and empirical gap [3]. As sustainability themes become more of a part of curricula at institutions, the mechanism through which sustainable practice becomes embedded in educational processes is still poorly theorized and empirically explored. Notably, there isn't much of a clear picture of how instructional design, learner engagement, and cognitive transformation interconnect with each other to manifest an enduring pro-environmental attitude and behavior [4]. In addition, higher education has experienced digital transformation at the same time. Digital pedagogy is more than the mere adoption of technology tools into classrooms; it has matured, becoming a transformational epistemological movement towards networked participation, multimodal learning [5], knowledge creation and collaborative processes and feedback based on data. Digitally mediated instruction can facilitate learner engagement, accessibility, flexibility and cognitive interaction at scale. These findings imply that digital pedagogy can impact not just what knowledge is taught, but how students make sense out of it, contemplate critically, and internalize it. But the marriage between digital transformation and sustainability education creates some very useful theoretical questions. Can digital pedagogy only

increase the number of opportunities for information access? It may also, however, change the environmental values and create sustained behavior change? While digital platforms facilitate simulations, interactive problem solving, real-time environmental data analysis, and global collaboration, the degree to which these affordances ultimately foster long-term environmental stewardship is still uncertain. This is a relationship which cannot be simply explained in descriptive terms about the practice of technology, we must address the psychological and cognitive pathways linking practices of teaching to normative and behavioural outcomes [6]. Guided by constructivist learning theory and transformative learning theory, this study suggests that sustainability literacy is one of the core ways that digital pedagogy facilitates long-term environmental engagement. Constructivist viewpoints foreground active meaning-making and situated knowledge construction, whereas transformative learning theory highlights the power of critical reflection in challenging deeply rooted assumptions and value systems. Integrating these theoretical perspectives, the study develops and empirically tests a structural mediation model that elucidates how digitally supported pedagogical settings boost sustainability literacy and in turn, sustainability-promoting enduring commitment. Placing digital pedagogy directly or indirectly in a sustainability-based theoretical perspective, the study adds to what we know about cognitive and normative mechanisms driving continuous ecological behavior in post-secondary education [7].

2. THEORETICAL FOUNDATIONS

2.1 *Constructivist and Transformative Learning Foundations*

Constructivist theory teaches that learning is never handed down unaided from faculty to students, but rather emerges from active learning, dialogue, and situational engagement. From this vantage point, learning is as a process of interpretation whereby learners process new findings in conjunction with prior schemas within the cognitive space in a manner that creates personalised knowledge [8]. These constructivist phenomena are further intensified in digital teaching environments where the environments in which learners interact with the content, fellow learners and feedback devices are expanded. Using interactive simulations, collaborative digital workspaces, gamified sustainability challenges, and adaptive assessment systems, young people are becoming

actively involved in knowledge production rather than passive recipients of information [9]. Real-time feedback mechanisms enable iterative experiments, hypothesis testing, and reflective adjustment, to enhance cognitive scaffolding and deep conceptual integration. This enables constructivist affordance to be enhanced in relation to sustainability education, as problems are, by nature, systemic, dynamic, and non-linear. Environmental phenomena like climate change, biodiversity loss, resource depletion and others involve complex interdependencies across ecological, economic, and social systems. The complexity of this situation is often hard for the traditional didactic approach [10]. Digital simulations facilitate students to manipulate variables like how carbon emissions trajectories change, rates of renewable energy adoption or thresholds for ecosystem resilience and instantly feel their effect through cascading effects at the level of systems. Visualizing feedback loops and unintended consequences allows students to understand connections and long-term outcomes via visualizing more profound relationships and interconnectedness [11]. Thus, abstract notions of sustainability from its abstract form gain some kind of experiential, cognitive accessibility and analytical consistency by integrating sustainability principles. This dynamic, active participation builds sustainability literacy, which encourages students to engage with sustainability literacies in systems thinking, anticipatory reasoning, and evidence-based judgment as well as proactive use and judgment [12]. Constructivism gives us the lens through which we understand that knowledge is actively built, while according to transformative learning theory, this analysis is extended to the domain of values, beliefs and identity. Transformative learning postulates that enduring behavior change occurs when people critically evaluate and rebuild unchallenged assumptions that underlie their sense-making [13]. In sustainability education, it's not uncommon for deep anthropocentric orientations, consumption assumptions and economic growth assumptions to be challenged by sustainability education and embedded in the education system. Just exposure to environmental facts might be raising awareness, but doesn't necessarily transform these cognitive frames. Digital pedagogical platforms present unique opportunities to promote transformation processes [14]. Immersive environmental modeling, scenario based learning, and global discussion forums introduce learners to different perspectives and ethically fraught dilemmas. For instance, facing simulated trade-offs between economic development

and ecological preservation creates cognitive dissonance, or what scholars of transformative learning have called "disorienting dilemmas." [15] Experiences like these destabilize some easy assumptions and prompt critical exploration. If mediated by dialogic interaction and systematic reflection, such dilemmas prompt learners to critically reflect on their ecological thought and rebuild environmental identities. This reflective reconstruction, over time, promotes internalized commitment rather than superficial obedience. This implies that digital pedagogy is not simply a technology enhancement upon instructional delivery but an epistemological intervention [16]. Digitally enriched learning environments can, thus, reshape cognitive frames and normative orientations by simultaneously enabling experiential knowledge construction and critical self-reflection. Within sustainability education, these dual processes constructivist meaning-making and transformative reflection provide the theoretical framework for discussing how digital pedagogy could lead to sustained environmental commitment rather than momentary shifts in attitudes.

2.2 Digital Pedagogy

Digital pedagogy constitutes a paradigm shift in the epistemological and structural foundations of modern education. In contrast to traditional pedagogical paradigms that use linear knowledge exchange and teacher-centered delivery, digital pedagogy is known for networked interaction, multimodal communication, participatory knowledge production, and data-informed instructional design [17]. It involves more than the straightforward incorporation of technological devices into the learning experience, but rather a reframing of ways in which knowledge is generated, shared and taken up within digital spaces. Digital pedagogy assumes particular significance in the domain of sustainability education as sustainability problems are complex, systemic, and dynamic by nature. The task of meeting these challenges demands educational architectures capable to model interdependence, to visualize feedback loops, and also to promote experiential inquiry into ecological systems [18]. Digital pedagogy is grounded in constructivist learning theory that argues that meaning is continually constructed by the learners through the interaction with their surroundings. Digital platforms can be used to complement the same process by allowing interactive simulations, collaborative forums and real-time feedback systems that enable recursive cognitive activities. Using such

mechanisms, learners can adjust environmental system variables carbon emissions, resource consumption, or biodiversity loss and notice what happens next [19]. This dynamic model approach generates systems thinking, an essential building block of sustainability competence. On the other hand, as digital pedagogy is multimodal, learning preferences vary and multimedia like visual, textual, auditory, and kinaesthetic is integrated to promote deeper cognitive processing. Digital pedagogy is also in line with transformative learning theory that points to critical reflection and transforming an individual's perspective as prerequisites to engender continuous attitudinal change [20]. Sustainability education critiques and deconstructs deep down, anthropocentric assumptions and consumerist norms. An environment mediated through digital technology provides such opportunities for exposure to disorienting ecological data, global environmental narratives, and participatory conversations in ways that allow learners to critically reconsider environmental cognitions [21]. Learners re-create their ecological selves and integrate sustainability concepts or notions into their wider perspective using a process of reflective engagement. Motivationally, digital pedagogy is conducive to autonomy, competence, and relatedness, three basic psychological needs mentioned in self-determination theory. Digital learning environments allow for self-paced exploration, which promotes autonomy. Building skills from the interactivity of tools and simulations [22]. Digital platforms deepen relatedness through collaborative engagement in sustainability challenges. Thus, the motivational aspects not only promote ecological learning, but also help to strengthen the internalization of sustainability values further, and the likelihood of environmental learning not fading from a formal context of instruction. In sum, digital pedagogy serves to promote sustainability education as a structural and psychological catalyst. It influences cognition, prompts reflective change, and promotes the motivational factors necessary for value internalization. Digital pedagogy as an independent variable, is conceptualized not only as technological adoption but also as a systemic educational architecture that sets up the required conditions to develop sustainability literacy and, eventually to foster long-term commitment to environmental issues.

2.3 Sustainability Literacy

Sustainability literacy firmly lies at the heart of contemporary sustainability education discourse,

functioning as the cognitive, affective and normative base upon which durable environmental commitment is built. It comprises not only limited environmental awareness and knowledge acquisition but also involves the integrated ability to understand complex socio-ecological systems, evaluate the ethical implications of environmental decisions, and in short translate ecological understanding into responsible action [23]. Sustainability literacy is inherently interdisciplinary and spans environmental science, economics, sociology, ethics and public policy into one holistic ecological reasoning. Theoretically, sustainability literacy is best approached by systems theory and environmental psychology. Systems theory suggests that ecological, social and economic dimensions are interrelated and emphasizes feedback loops, nonlinearity, and emergent properties [24]. Literacy in this sense means recognizing interdependencies and predicting unintended consequences. Sustainability literate learners transcend fragmented understandings and begin to see sustainability issues as systemic phenomena that require integrative solutions. Environmental psychology also reveals the mediating effect of sustainability literacy through the Value-Belief-Norm framework [25]. From this point of view, pro-environmental behavior is induced if such people internalise biospheric values, possess strong ecological beliefs and are motivated by personal norms of responsibility. Sustainability literacy enhances each piece of this sequence. When we deepen our understanding of the environment, this deepens our beliefs about the seriousness and human causation of ecological problems. It enriches the basis of understanding in addition to moral duties to present and future generations. Literacy does this through making abstract environmental concern normative for commitment. Sustainability literacy is also an affective phenomenon [26]. Emotionality the feeling of empathy for affected communities or concern for biodiversity pushes individuals to work toward an end goal. Literacy programs that integrate cognitive instruction with culturally relevant and experiential engagement develop emotional attachment to ecological stewardship. Such affective integration enhances the retention of environmental attitudes and diminishes the intention-behavior gap that is often manifested in sustainability studies [27]. As a mediator, sustainability literacy transmutes the structural conditions that digital pedagogy creates into psychological readiness for environmental commitment. Although digital platforms offer sustainability content to learners, exposure to

sustainability content without corresponding literacy development remains informational rather than transformational. Literacy acts as both the internal encoding that integrates knowledge and also a means of reshaping values and turning on norms. It is the prism of interpretation through which digital experiences are woven with an integrated, cohesive ecological identity. As such, sustainability literacy is the key mechanism linking educational design to behavioral outcomes [28]. It encapsulates not only a cognitive understanding but also ethical reasoning, emotional involvement, and practical competence. Sustainability literacy mediates the relationship between digital pedagogy and long-term environmental commitment and therefore transmogrifies pedagogical interaction into ecological responsibility that lasts the long haul.

2.4 Long-Term Environmental Commitment

Long-term environmental commitment is a robust internalization of pro-environmental norms manifested in persistent actions, lifestyles, advocacy and civic engagement that is consistent with a pro-environmentalist agenda. It is, conceptually, distinct from short-term behavioral intention, or episodic involvement in environmental initiatives. As such, commitment speaks of consistency, endurance as well as integration of identity, consistent with a long-standing inclination toward stewardship towards the natural world in both situation and time [28]. In sustainability research, determining antecedents of long-term commitment is important, as most educational initiatives serve to create awareness, without yielding consistent behavior change. Long-term environmental commitment is theoretically explained by environmental psychology, especially the Value-Belief-Norm model and habit formation theory. Commitment forms when biospheric values and ecological beliefs become established in personal norms, generating moral responsibility to take meaningful environmental action. If these norms are internalized, they inform behavior even without external inducements or monitoring [39]. Accordingly, commitment entails not externally-driven compliance, but a state of internally-regulated ecological identity. The identity theory also contributes to this understanding. When people see such environmental stewardship as core to their sense of self, pro-environmental action acts as the expression of an identity not an isolated action. This identity integration makes behaviours more consistent and resilient in the context of social and economic pressures [40]. Long term commitment thus entails cognitive synchronization, affective

responsiveness, and normative conviction. Long-term environmental commitment shows up in environmental behavioural adaptations, from energy conservation and sustainable consumption to reduced waste generation and the participation of environmental advocates. It might also require participation in policy-making, community involvement, and institutional sustainability endeavours. Importantly, commitment means a willingness to pay personal costs financial, social or temporal in the name of ecological protection [41]. This cost-bearing aspect will differentiate genuine commitment from mere environmental signalling. Psychologically, habits and feedback loops reinforce commitment. Continued pro-environmental behaviours reinforce behavioural scripts and normalize sustainable environmental practices. Positive reinforcement such as both intrinsic and social reward consolidate these habits. Educational systems seeking long-term commitment must, therefore, promote not only cognitive understanding but also emotional resonance and normative internalisation [42]. As a product of this framework, environmental commitment over the long run is the final outcome of education on sustainability. It captures the shift from knowledge-based ecological stewardship to identity based ecological stewardship. Examining digital pedagogy and sustainability literacy and how they are linked to this outcome, the present model defines the manner in which educational innovation makes social impact for a long-term. Based on these gaps hypotheses have formulated as under.

2.5 Hypotheses

H1: Digital Pedagogy positively influences Sustainability Literacy.

H2: Sustainability Literacy positively influences Long-Term Environmental Commitment.

H3: Digital Pedagogy positively influences Long-Term Environmental Commitment.

H4: Sustainability Literacy mediates the relationship between Digital Pedagogy and Long-Term Environmental Commitment.

3. RESEARCH METHODOLOGY

The current research conducts a cross-sectional quantitative study based on a survey methodology that studies the empirical association between Digital Pedagogy, Sustainability Literacy, and Long-Term Environmental Commitment. In terms of data collection, a cross-sectional design is appropriate, as it allows for data at a single point in time among a defined population who define prevailing

perceptions, attitudes and behavioural intentions for digitally mediated sustainability education. This numerical approach encourages statistical testing of hypothesized relationships and is well suited for structural equation modelling the systematic investigation of latent constructs and mediation effects. Using a structured survey instrument, the study provides a standardization tool to provide measurement and to improve reliability and comparability between the respondents. These are 384 respondents comprising undergraduate and postgraduate students with exposure to a digital sustainability curriculum. This demographic was chosen because students comprise a vital part of the population who are shaping long run environmental attitudes and actions and are hence the ideal target to probe these theoretical relationships due to their familiarity with digital pedagogic devices. To provide suitable representation in this study among academic levels and disciplines within the higher education context, a stratified random sampling

3.1 Measurement Instrument used

method was used to maximize generalizability of the results. Using stratification minimizes the impact of sampling bias and is able to reflect appropriate subgroups as a proportionate representation which helps to capture the academic perspectives from undergraduate to postgraduate perspectives. A questionnaire, structured and predefined as an adaptable already validated scale adapted to the data presented was created which were gathered for use in the area of digital sustainability educative study. A five-point Likert scale was used to assess response level, rating from 1 (Strongly Disagree) to 5 (Strongly Agree) to accommodate different levels of agreement and disapproval of claims of digital pedagogy practices, sustainability literacies and long-term environmental commitment. The Likert scale provides measure for subjective perceptions quantifying and advanced multivariate analysis method. Analysis Strategies Analysis was done in two phases: SPSS (Preliminary Analysis) AMOS (Structural Equation Modeling)

Table 1: Tools Used.

Construct	Number of Items	Sources Adapted From
Digital Pedagogy	8	Digital learning literature
Sustainability Literacy	10	Sustainability education frameworks
Environmental Commitment	9	Environmental psychology scales

3.2 Reliability Analysis

Table 2: Cronbach's Alpha.

Construct	Alpha
Digital Pedagogy	0.91
Sustainability Literacy	0.93
Environmental Commitment	0.90

The internal consistency of the constructs was examined by Cronbach's Alpha. The outputs

indicate that Digital Pedagogy ($\alpha = 0.91$), Sustainability Literacy ($\alpha = 0.93$), and Environmental Commitment ($\alpha = 0.90$) score above the threshold value of 0.70, confirming their good reliability. Their high alpha values indicate excellent internal consistency with all items, signifying that instrumentation scales are reliable for further calculation statistically.

4. DATA ANALYSIS: VARIOUS STATISTICAL TEST WAS PERFORMED IN THESE ANALYSIS

4.1: Demographic Profile of Respondents (N = 384)

Table 3: Demographic Profile of Respondents.

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	212	55.2%
	Female	172	44.8%
Age Group	18-21 years	148	38.5%
	22-25 years	162	42.2%
	26-30 years	54	14.1%
	Above 30 years	20	5.2%
Academic Level	Undergraduate	231	60.2%
	Postgraduate	153	39.8%
Field of Study	Management & Commerce	118	30.7%
	Science & Technology	104	27.1%
	Arts & Humanities	86	22.4%
	Interdisciplinary/Other	76	19.8%
Exposure to Digital Sustainability Courses	1 Course	136	35.4%
	2-3 Courses	168	43.8%
	More than 3 Courses	80	20.8%

The demographic ratio demonstrates a somewhat balanced gender structure comprising 55.2% of respondent's men and 44.8% women. This profile maintains gender neutrality to the level of gender representation of all the perspectives obtained, thus minimizing gender biases on digital pedagogy and sustainability thoughts. With regard to age in the survey, the majority of participants are 18–25 years old (80.7%) which is in line with the average age of undergraduates and postgraduates. A targeted focus on younger learners is necessary for such a model since younger learners are at the forefront of developing digitally mediated pedagogical solutions and are still developing sustained environmental commitment. Low proportion of respondents above 30 years (5.2%) indicates a minor influence from the adult learners in the study, however, it is not a strong factor influencing the student-centred nature of the study. With respect to student's academic tenure, 60.2% of students are undergraduates and 39.8% are postgraduates. Notably, both groups contribute to the depth of the analysis by reflecting the differences in levels of academic maturity, experience in sustainable ideas, and cognitive engagement levels. Utilizing a stratified sampling strategy leads to equitable representation in the respondents and increases internal validity. These include studies by industry, business, or government and a representative approach across disciplines with management and commerce having the highest proportion (30.7%) and science and technology coming in at 27.1%. This is especially pertinent since sustainability education and digital pedagogy frequently link to business strategy, innovation and technological progress. The representation of arts

4.3. Multiple Regression Analysis

Table 5: Regression.

Regression Model	Dependent Variable	Independent Variable	R ²	Standardized β	Significance
Model 1	Sustainability Literacy	Digital Pedagogy	0.46	0.68***	p < 0.001
Model 2	Learners' Environmental Commitment	Sustainability Literacy	0.55	0.74***	p < 0.001
Model 3	Learners' Environmental Commitment	Digital Pedagogy	0.37	0.61***	p < 0.001

The regression shows that Digital Pedagogy is a significant factor that predicts Sustainability Literacy ($\beta = 0.68$, $R^2 = 0.46$) explaining 46% of the variance. Learners' Environmental Commitment: Sustainability Literacy is a strong predictor ($\beta = 0.74$, $R^2 = 0.55$) explaining 55% of the variance. Digital Pedagogy also significantly predicts Learners' Environmental Commitment ($\beta = 0.61$, $R^2 = 0.37$), which accounts for 37% of the variance. All relationships are positive and statistically significant ($p < 0.001$), thus providing preliminary empirical evidence for all proposed hypotheses.

and humanities (22.4%) and interdisciplinary (19.8%) students also reinforce the generalisability of results across academic streams. Lastly, our examination of exposure to digital sustainability courses indicates that a big fraction of students (64.6%) has taken two or more units of course in the sustainability sector in a digital format. This suggests sufficient familiarity with digitally facilitated sustainability learning domains, therefore fortifying the contextual specificity of responses and improving construct validity. In general, the demographic profile represents a representative, academically suitable sample, which may further demonstrate the soundness and generalisability of this structural model within higher education.

4.2. Correlation Analysis

Table 4: Pearson Correlation Results.

Variables	DP	SL	LEC
DP	1		
SL	0.68**	1	
LEC	0.61**	0.74**	1

A Pearson correlation analysis was conducted to examine the relationships among the variables. The results show a strong and positive correlation between: Digital Pedagogy and Sustainability Literacy ($r = 0.68$, $p < 0.01$), Digital Pedagogy and Learners' Environmental Commitment ($r = 0.61$, $p < 0.01$), and Sustainability Literacy and Learners' Environmental Commitment ($r = 0.74$, $p < 0.01$). All the correlations are indeed statistically significant at the 0.01 level. The strength and significance of these relationships also support the suitability of proceeding with Structural Equation Modeling (SEM) for further analysis.

4.4. Measurement Model

Table 6: Model Fit Indices.

Fit Index	Obtained Value	Threshold
χ^2/df	2.31	< 3
CFI	0.95	> 0.90
TLI	0.94	> 0.90
RMSEA	0.058	< 0.08
SRMR	0.049	< 0.08

A good fit can be inferred from the Confirmatory Factor Analysis (CFA) results. The χ^2/df value of 2.31 is below the recommended threshold of 3, indicating that the model fit is

acceptable. CFI (0.95) and TLI (0.94) are greater than 0.90, indicating strong comparative fit. In fact, RMSEA (0.058) and SRMR (0.049) are significantly below 0.08, denoting relatively low residual errors.

Overall, the measurement model fulfills proposed fit criteria, which indicates adequate validity of constructs and their suitability for structural model assessment.

4.5. Convergent Validity

Table 7: Convergent Validity Criteria.

Criterion	Recommended Threshold	Result
Factor Loadings	> 0.70	Satisfied
Average Variance Extracted (AVE)	> 0.50	Satisfied
Composite Reliability (CR)	> 0.70	Satisfied

All constructs met the recommended thresholds for convergent validity. Factor loadings exceeded 0.70, AVE values were above 0.50, and Composite Reliability values were greater than 0.70. These results confirm that the measurement items adequately represent their respective constructs and demonstrate strong convergent validity.

Table 8: Path Coefficients.

Hypothesized Path	Standardized β	Significance
DP \rightarrow SL	0.69***	$p < 0.001$
SL \rightarrow LEC	0.71***	$p < 0.001$
DP \rightarrow LEC	0.22*	$p < 0.05$

(* $p < 0.05$, *** $p < 0.001$)

Table 9: Indirect Effect (Bootstrapping - 5000 Samples).

Indirect Path	Standardized Effect	Significance
DP \rightarrow SL \rightarrow LEC	0.49***	$p < 0.001$

The results of structural model findings indicate that Digital Pedagogy is a significant impact factor of Sustainability Literacy ($\beta = 0.69$, $p < 0.001$), Sustainability Literacy is a highly significant predictor of Learners' Environmental Commitment ($\beta = 0.71$, $p < 0.001$). The direct relationship between Digital Pedagogy and

Learners' Environmental Commitment is positive but weaker ($\beta = 0.22$, $p < 0.05$). Bootstrapping results support the findings that Sustainability Literacy plays a partial mediating role in the effects of Digital Pedagogy on Learners' Environmental Commitment with a significant indirect effect ($\beta = 0.49$, $p < 0.001$).

Table 10: Hypotheses Testing Results.

Hypothesis	Path	Result	Decision
H1	Digital Pedagogy \rightarrow Sustainability Literacy	Significant positive effect ($\beta = 0.69$, $p < 0.001$)	Supported
H2	Sustainability Literacy \rightarrow Learners' Environmental Commitment	Significant positive effect ($\beta = 0.71$, $p < 0.001$)	Supported
H3	Digital Pedagogy \rightarrow Learners' Environmental Commitment	Significant positive effect ($\beta = 0.22$, $p < 0.05$)	Supported
H4	Digital Pedagogy \rightarrow Sustainability Literacy \rightarrow Learners' Environmental Commitment	Significant indirect effect ($\beta = 0.49$, $p < 0.001$)	Supported

All proposed hypotheses (H1-H4) are empirically supported, as all direct and indirect paths are positive and statistically significant. Sustainability Literacy partially mediates the relationship between Digital Pedagogy and Learners' Environmental Commitment.

5. FINDINGS OF THE STUDY

The findings of the empirical analysis offer strong empirical support to the proposed structural model. It found that Digital Pedagogy has a significant, and indeed positive, impact on Sustainability Literacy, which indicates that effective technology-enabled instructional modalities can contribute to a better understanding of students regarding environmental concepts, sustainable practices, and ecological

responsibilities. The use of interactive digital tools, online collaborative platforms, multimedia content, and data-driven learning environments are viewed as capable of facilitating deeper cognitive engagement with sustainability-related issues. Additionally, Sustainability Literacy has demonstrated robust and substantial impact on Learners' Environmental Commitment which indicates that enhanced knowledge, awareness and critical thinking in relation to sustainability leads to increased pro-environmental attitudes, intentions and behavioral orientation. The degree of this association indicates that literacy is the key driver of environmentally responsible commitment to learning outcomes. Although digital pedagogy has a linear, direct positive correlation with environmental commitment, the standardized path

coefficient is lower compared to the indirect pathway effect through Sustainability Literacy. This means that although exposure to digital learning spaces may exert an independent influence on environmental attitudes, its most powerful strength appears to emerge when it enhances knowledge and awareness around sustainability. The mediation analysis indicates that Sustainability Literacy partially mediates the relationship between Digital Pedagogy and Environmental Commitment. This partial mediation indicates digital pedagogical practices drive commitment directly and indirectly but predominantly by augmenting sustainability literacy. Thus, all of the hypothesized relationships are statistically significant thus supporting the conceptual framework and strengthening the robustness of the structural model.

6. DISCUSSION

The findings substantiate the growing argument that Digital Pedagogy serves as a transformative mechanism in sustainability education. The strong association between Digital Pedagogy and Sustainability Literacy aligns with contemporary educational theories emphasizing experiential, interactive, and technology-supported learning environments as catalysts for deeper knowledge construction. Digital platforms allow learners to access real-time environmental data, participate in simulations, engage in global sustainability dialogues, and critically analyse ecological challenges, thereby strengthening conceptual clarity and applied understanding. The significant and robust path between Sustainability Literacy and Environmental Commitment underscores the role of knowledge as a foundational determinant of pro-environmental behavior. This supports the proposition that awareness and cognitive engagement are prerequisites for attitudinal and behavioural transformation. Learners who possess higher sustainability literacy are more likely to internalize environmental values and demonstrate long-term commitment toward sustainable practices. Although Digital Pedagogy directly influences Environmental Commitment, the comparatively weaker direct effect suggests that technology alone is insufficient to drive meaningful environmental responsibility. Instead, the effectiveness of digital tools depends largely on how strategically sustainability content is integrated into the curriculum. The partial mediation results highlight that digital transformation in education must go beyond infrastructure adoption and focus on purposeful sustainability-oriented instructional design. Overall, the discussion confirms that digitally

enriched sustainability education fosters not only knowledge acquisition but also attitudinal alignment toward environmental responsibility, thereby contributing to long-term ecological consciousness among learners.

7. CONCLUSION

As a result, this study concludes that Digital Pedagogy significantly enhances Sustainability Literacy, which in turn strengthens Learners' Environmental Commitment. Sustainability Literacy comes to the fore as a critical mediating variable connecting technology-enabled teaching practices with environmentally responsible attitudes and intentions. It shows that eco efforts made with technology support with content and sustainability in mind (not only technology) have the strongest environmental impact by way of digital education initiatives. The validated structural model provides empirical evidence that educational institutions can cultivate environmentally conscious learners by embedding sustainability principles within digitally supported curricula. The research thus adds to existing digital education scholarship and sustainability scholarship by providing a robust causal pathway between pedagogy, literacy and commitment.

8. IMPLICATIONS

This new empirical study contributes the theoretical bridge between digital pedagogy and sustainability education by providing empirically validated Sustainability Literacy as a core mediating mechanism. The latter enhances the existing literature by underscoring the impact technology-rich learning settings have to shape attitudinal and behavioural outcomes through processes for knowledge creation. The practical implications aids by the role of educators is important in determining how digital-enhanced curricula must provide the best possible experiences, curriculums that incorporate sustainability topics, case-based programs, simulations, and experiential lessons through digital methods. Developing faculty should focus in part on incorporating sustainability outcomes into the digital instruction process in order to enhance the sustainability dedication of the learners. Finally, the policy implications help in the digital transformation of education should be coupled with both national and global sustainability agendas by policymakers. Education tech investment needs to be balanced with sustainability curriculum frameworks so we have environmentally friendly, future-ready people who can actually do something about sustainable development.

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