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Reel or Real: A Mixed-Methods Assessment of Multimedia Content and Its Influence on Sustainable Learning in Digital Education Environments

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Abstract: *The digital learning environment is growing to be more dependent on multimedia content, which includes videos, animations, and interactive images, to make the learning process more engaging and sustainable. Nonetheless, there is a dearth of empirical data that evaluates the effectiveness of these multimedia elements in causing reel (perceived) and real (actual, sustainable) learning results. This research paper attempts to discuss the effects of various types of multimedia content on the sustainable learning process within digital learning settings. It responds to the presence of gap in the assessment instruments that are thorough enough in context and designed to both assess perceived engagement and long-term learning retention. A sequential exploratory mixed-method research design with intention to use a sequential approach was adopted. The qualitative step entailed thematic analysis of semi-structured interviews conducted on 20 university students in order to identify important multimedia learning constructs. These lessons helped to come up with an initial evaluation tool. The quantitative part involved a survey that was conducted on 412 undergraduate and graduate students taking virtual courses in three public universities. The study tested a 48-item scale of multimedia effectiveness, perceived engagement, cognitive load, and indicators of sustainable learning and verified it using SmartPLS 4 and confirmatory factor analysis. Results demonstrate that interactive multimedia has a strong positive influence on perceived engagement but may not necessarily be followed by more substantial sustainable learning. Better predictors of the retention of knowledge in the long term included static images and well-organized narration. The instrument validated proves to be highly relevant and reliable in digital education settings. This paper is a significant contribution to a context sensitive, and evaluation instrument of multimedia-based learning. The tool can assist teachers and policymakers in creating digital learning activities to promote authentic and sustainable learning and not a shallow interaction.*

Introduction

The rapid expansion of digital education environments has transformed the ways learners engage with instructional content. As universities, colleges, and professional training institutions increasingly adopt online and blended modes of teaching, multimedia content has become central to instructional design for enhancing comprehension, engagement, and long-term learning (Clark & Mayer, 2016; Mayer, 2020). Multimedia elements such as videos, animations, infographics, interactive simulations, and narrated presentations have been employed to deliver complex concepts more efficiently and to support diverse learning preferences. Building on cognitive theories of multimedia learning and digital pedagogy (Faisal, et al., 2023), these resources are believed to advance cognitive processing, improve learner motivation, and strengthen sustainable learning outcomes, defined as long-lasting, transferable learning gains that extend beyond surface-level performance (Mayer, 2020; Fiorella & Mayer, 2015).

The shift toward multimedia-rich digital environments accelerated significantly during and after the COVID-19 pandemic, which pushed institutions worldwide to adopt online instruction at an unprecedented scale (Hodges et al., 2020; Makhdum, et al., 2021). The move demonstrated the vast instructional potential of digital platforms but also highlighted persistent challenges surrounding the effectiveness of multimedia as a pedagogical tool (Faisal, et al., 2023). While multimedia content is often designed to increase engagement, an important question remains: does multimedia create *reel* (surface-perceived) learning or *real* (sustainable, meaningful, and retained) learning? Researchers continue to emphasize that engagement does not always equate to deep learning, and multimedia can unintentionally increase cognitive load, reducing long-term comprehension (Sweller et al., 2011).

Digital education has grown into a critical component of contemporary higher education, vocational programs, and lifelong learning initiatives. UNESCO and the OECD continue to promote digital learning as a cornerstone of equitable, scalable, and sustainable education for global development (UNESCO, 2023; OECD, 2021). In this context, sustainable learning has gained relevance due to its emphasis on knowledge retention, application, and long-term skill development. Understanding how multimedia content influences such sustainable learning is therefore crucial for improving digital teaching strategies, especially in regions experiencing rapid digitalization or limited instructional resources (Faisal, et al., 2024).

Significance of Study

This study is significant for several reasons. First, multimedia learning research has grown extensively over the last two decades, yet scholars frequently note that effectiveness varies depending on design principles, learner characteristics, and instructional context (Mayer, 2020; Clark & Mayer, 2016). Although multimedia tools are widely integrated into digital education, their actual impact on sustainable learning outcomes remains understudied, particularly in developing contexts where digital adoption is still evolving. Evaluating how different multimedia formats such as videos, static visuals, interactive modules, and animations—affect long-term learning enables educators to design pedagogically sound digital materials.

Second, while numerous studies have explored student engagement in digital environments, the distinction between perceived engagement ("reel" learning) and deep, meaningful learning ("real" learning) has not been adequately theorized or empirically measured. Evidence shows that highly engaging multimedia, such as fast-paced videos or visually dense materials, may generate the illusion of learning without improving comprehension (Kühl et al., 2018). Understanding this discrepancy is essential for preventing ineffective instructional design and ensuring that multimedia resources contribute to authentic, sustainable learning.

Third, the study contributes to the ongoing effort to refine assessment tools for digital learning effectiveness. While frameworks exist for evaluating usability, cognitive load, and engagement, few instruments combine these with constructs of sustainable learning. Developing and validating a multimedia-focused evaluation instrument supports educators and policymakers in making data-informed decisions about multimedia adoption, ensuring higher quality in digital education environments.

Problem Statement

Despite the extensive use of multimedia content in digital education environments, there is a lack of empirical clarity regarding how such content influences sustainable learning. Current research often focuses on engagement metrics, video analytics, user satisfaction, or short-term performance, but rarely on long-term retention, comprehension, and transfer of knowledge (Guo et al., 2014; Fiorella & Mayer, 2015). Moreover, contradictory findings exist: while some studies suggest multimedia supports deeper learning, others highlight risks of distraction, cognitive overload, or superficial processing (Sweller et al., 2011; Kühl et al., 2018).

As a result, educators lack a comprehensive, validated tool for assessing the real impact of multimedia on sustainable learning. Without such an instrument, instructional decisions may rely on assumptions rather than evidence, weakening the pedagogical integrity of digital education.

Research Objectives

- To evaluate the influence of multimedia content on learners' sustainable learning outcomes in digital education environments.
- To assess learners' perceptions of multimedia effectiveness, cognitive load, and engagement in multimedia-rich instructional settings.
- To develop and validate an empirically grounded instrument for measuring multimedia-supported sustainable learning.

Research Questions

- How does multimedia content influence sustainable learning in digital education environments?
- What are learners' perceptions of engagement, effectiveness, and cognitive load when interacting with multimedia materials?
- Which multimedia components best predict long-term learning outcomes?

Gaps

Existing literature highlights several gaps. First, studies on multimedia learning often examine isolated variables such as motivation, engagement, or short-term performance, but few integrate these with sustainable learning indicators like long-term retention or transfer (Mayer, 2020). Second, most multimedia research is conducted in controlled laboratory settings rather than real-world digital learning environments, limiting ecological validity (Fiorella & Mayer, 2015). Third, limited research exists in Global South contexts, where technological constraints, learner diversity, and digital infrastructure influence multimedia effectiveness differently (UNESCO, 2023; Makhdum & Mian, 2012). Finally, there is a lack of comprehensive, validated instruments that measure multimedia-supported sustainable learning from a holistic perspective. This study addresses these gaps by employing a mixed-methods approach grounded in actual learner experiences.

Literature Review

Research on multimedia learning is grounded in several theoretical frameworks, including Mayer's Cognitive Theory of Multimedia Learning (CTML), Sweller's Cognitive Load Theory (CLT), Paivio's Dual Coding Theory, and Moore's Transactional Distance Theory. These frameworks collectively explain how multimedia influences cognitive processing, learner engagement, and educational outcomes in digital environments.

Multimedia Learning Theory

Mayer (2020) argues that multimedia learning is most effective when instructional design aligns with how the human brain processes verbal and visual information. CTML posits that learners process information through two separate channels visual/pictorial and auditory/verbal and that meaningful learning occurs when both channels are balanced without overload. Well-designed multimedia materials promote active cognitive processes such as selecting, organizing, and integrating information (Mayer, 2009). Studies demonstrate that narrated animations, coherent visuals, and well-paced videos improve retention and transfer when aligned with multimedia principles (Clark & Mayer, 2016; Fiorella & Mayer, 2015).

Cognitive Load and Multimedia

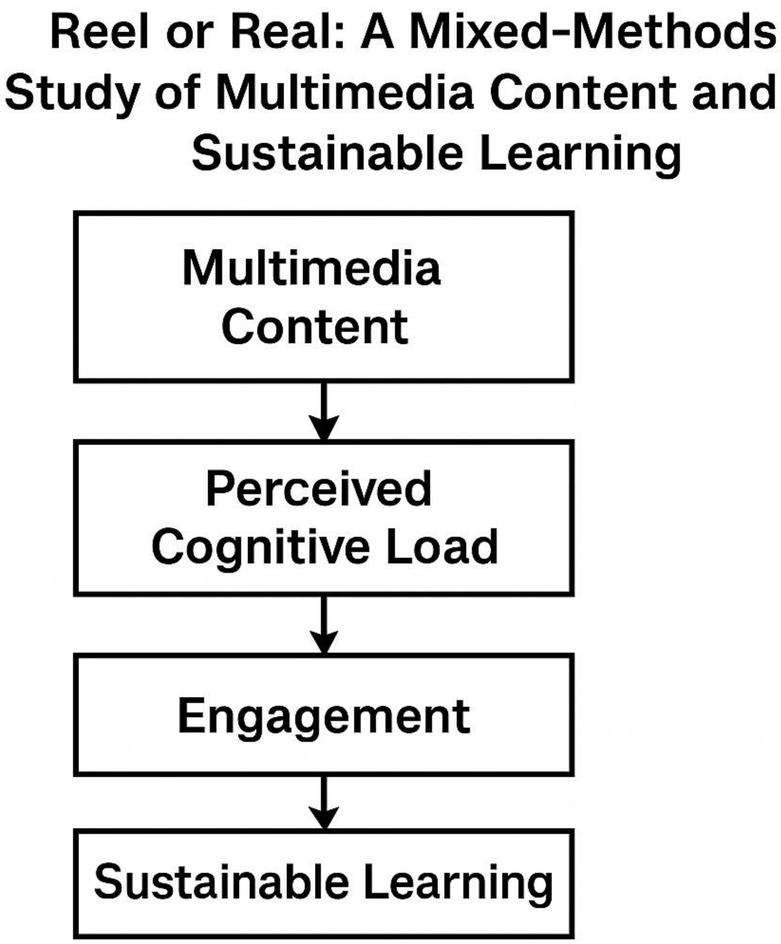
Cognitive Load Theory emphasizes the importance of reducing unnecessary mental effort during learning. Sweller et al. (2011) note that poorly designed multimedia—excessive visuals, rapid transitions, or extraneous information can impose extraneous load, hindering comprehension. Empirical research shows that simpler visuals and segmented videos enhance sustainable learning by reducing cognitive overload (Leahy & Sweller, 2016). These insights underscore the importance of design quality, not merely the presence of multimedia.

Engagement and Multimedia Use

Engagement is often cited as a key advantage of multimedia. Studies show that video-based instruction increases attention and motivation (Guo et al., 2014), but engagement alone does not guarantee deeper learning. Interactive elements—quizzes, hotspots, and branching videos—can enhance generative processing, which is important for long-term retention (Fiorella & Mayer, 2015). However, visually rich multimedia may create an illusion of learning, where learners feel they understand the content despite low retention (Kühl et al., 2018).

Sustainable Learning in Digital Environments

Sustainable learning emphasizes lasting comprehension and the ability to apply knowledge across contexts. Research shows that multimedia supports sustainable learning when aligned with pedagogical purpose and cognitive principles (Clark & Mayer, 2016). Longitudinal studies indicate that structured, coherent narratives and visuals are more effective than dense, entertainment-oriented media (Mayer, 2020). Sustainable learning also depends on learner control: the ability to pause, replay, or navigate content enhances autonomy and retention (Chen & Wu, 2015).



Distance and Digital Education Contexts

Digital education environments introduce additional factors influencing multimedia learning. Moore’s (1993) Transactional Distance Theory explains how psychological and pedagogical distance affects learning outcomes. Research shows that multimedia can reduce transactional distance by creating richer, more interactive experiences (Martin & Bolliger, 2018). However, studies also highlight inequalities in digital access, bandwidth limitations, and technological literacy, all of which influence multimedia effectiveness (UNESCO, 2023; Makhdum, et al., 2023). In developing countries, multimedia adoption must be contextually adapted to infrastructure constraints.

Gaps Identified in Research

Although multimedia learning has been widely studied, several gaps remain. Few studies measure sustainable learning longitudinally, and many fail to distinguish between perceived engagement and authentic learning. Limited research exists on multimedia’s effects in non-Western digital education environments. There is also a lack of validated assessment tools that integrate multimedia design quality, cognitive load, engagement, and sustainable learning indicators. These gaps underscore the need for an empirically grounded instrument aligned with real learner experiences.

Methodology

This study employed a mixed-methods research design to systematically investigate how multimedia content influences sustainable learning within digital education environments. A mixed-methods approach was adopted because it allows the integration of qualitative insights with quantitative validation, thereby offering a more comprehensive understanding of learner experiences and multimedia effectiveness (Creswell & Plano Clark, 2018). The study followed a sequential exploratory design in which qualitative findings informed the development of a quantitative instrument. This approach is consistent with recommendations from instrument development literature emphasizing the need for preliminary qualitative inquiry to ensure conceptual grounding, contextual relevance, and construct clarity (DeVellis, 2017).

Data collection occurred in two phases. The qualitative phase involved semi-structured interviews with university students enrolled in multimedia-rich virtual courses. The purpose of this phase was to explore learner perceptions, experiences, and cognitive processes associated with multimedia content. Twenty participants were selected using purposive sampling to ensure that only students with substantial exposure to multimedia-supported digital learning were included. The interviews were conducted online, recorded with participant permission, and transcribed verbatim. The interview protocol was developed based on existing multimedia learning theories, including Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2020), Cognitive Load Theory (Sweller et al., 2011), and prior research on engagement in digital learning environments (Martin & Bolliger, 2018). Participants were asked about their perceptions of multimedia effectiveness, perceived cognitive load, engagement levels, and experiences of long-term learning retention. Thematic analysis was used to identify recurring concepts, patterns, and dimensions relevant to multimedia-supported sustainable learning. The qualitative findings provided the conceptual foundation for generating an item pool for the quantitative instrument.

Building on the qualitative results, a structured survey instrument was developed to measure constructs such as multimedia design quality, perceived cognitive load, engagement, generative learning behaviors, and indicators of sustainable learning. The initial item pool consisted of 72 items, which were reviewed for redundancy, clarity, and conceptual alignment. Existing validated scales were consulted to maintain methodological rigor, including the NASA-TLX for cognitive load (Hart & Staveland, 1988), the Online Student Engagement Scale (Dixson, 2015), and principles from Mayer's multimedia learning framework. Items were modified for contextual relevance to avoid reproducing existing instruments while ensuring conceptual validity. A panel of three experts in educational psychology and instructional design evaluated the draft instrument for content validity, clarity, and alignment with theoretical constructs. Their feedback resulted in refinement of item wording, removal of ambiguous items, and consolidation of overlapping constructs. The final survey consisted of 48 items measured on a five-point Likert scales ranging from strongly disagree to strongly agree.

The quantitative phase of the study involved administering the survey to a sample of students from three public universities. Participants were required to be enrolled in digital or blended courses containing multimedia materials such as video lectures, visual diagrams, animations, and interactive tools. A sample size of 400–500 is generally recommended for factor analysis to achieve stable and interpretable factor structures (Tabachnick & Fidell, 2019). Based on this guideline, 412 students were recruited using stratified random sampling to ensure representation across disciplines, levels of study, and course formats. Stratification enhanced the representativeness of the sample by preventing overconcentration of participants from a single academic field or year of study. Students were invited through institutional mailing lists, LMS announcements, and faculty referrals. Participation was voluntary, and informed consent was obtained electronically in accordance with ethical research principles.

Data were collected using an online survey administered via Google Forms. The survey link remained open for four weeks to allow adequate participation across institutions. Before full data collection, a pilot study was conducted with 30 students to test the instrument's clarity, usability, and functionality. The pilot results indicated that all items were understandable, and response times were reasonable. Minor adjustments were made to item phrasing to improve clarity and consistency. No items were removed at this stage because the instrument showed satisfactory initial reliability.

For the full dataset, quantitative data were analyzed using SmartPLS 4 and SPSS 28 to conduct reliability, validity, and structural analysis. Reliability was assessed using Cronbach's alpha and composite reliability, both of which exceeded the recommended threshold of .70 for all constructs (Hair et al., 2019). Convergent validity was established through average variance extracted (AVE), with all constructs exceeding the .50 threshold. Discriminant validity was assessed using the Fornell Larcker criterion and the Heterotrait Monotrait ratio (HTMT), both of which indicated satisfactory construct distinction. Exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) were conducted to examine the scale's factor structure. Items with factor loadings below .50 or cross-loadings above recommended limits were removed, resulting in a final validated instrument consisting of 42 items. Structural equation modeling (SEM) was conducted to examine the relationships between multimedia design, cognitive load, engagement, and sustainable learning outcomes.

Reliability and validity were emphasized throughout both qualitative and quantitative phases. In the qualitative phase, credibility was ensured through member checking, where participants reviewed summaries of their responses to confirm accuracy of interpretation (Lincoln & Guba, 1985). Transferability was strengthened by providing detailed descriptions of participant backgrounds and digital learning contexts. Dependability was maintained through an audit trail that documented coding decisions and theme development. Conformability was established by triangulating qualitative insights with existing theoretical frameworks, ensuring that interpretations were grounded in empirical and conceptual evidence rather than researcher bias.

In the quantitative phase, reliability and validity were assessed rigorously. Internal consistency reliability was verified through Cronbach's alpha and composite reliability calculations. Construct validity both convergent and discriminant was established using AVE, item loadings, and inter-construct correlations (Hair et al., 2019). Content validity was ensured through expert review, which confirmed that instrument items comprehensively represented targeted constructs. Criterion validity was explored by examining whether multimedia design and engagement constructs predicted sustainable learning outcomes in theoretically consistent ways. The structural model demonstrated acceptable fit indices, supporting the instrument's validity for measuring multimedia-supported sustainable learning.

Ethical considerations were upheld throughout the study. Participants were informed about the voluntary nature of the study, confidentiality of their data, and their right to withdraw at any time. No identifying information was collected, and all data were anonymized. The study adhered to ethical guidelines established by institutional review boards and educational research standards (BERA, 2018).

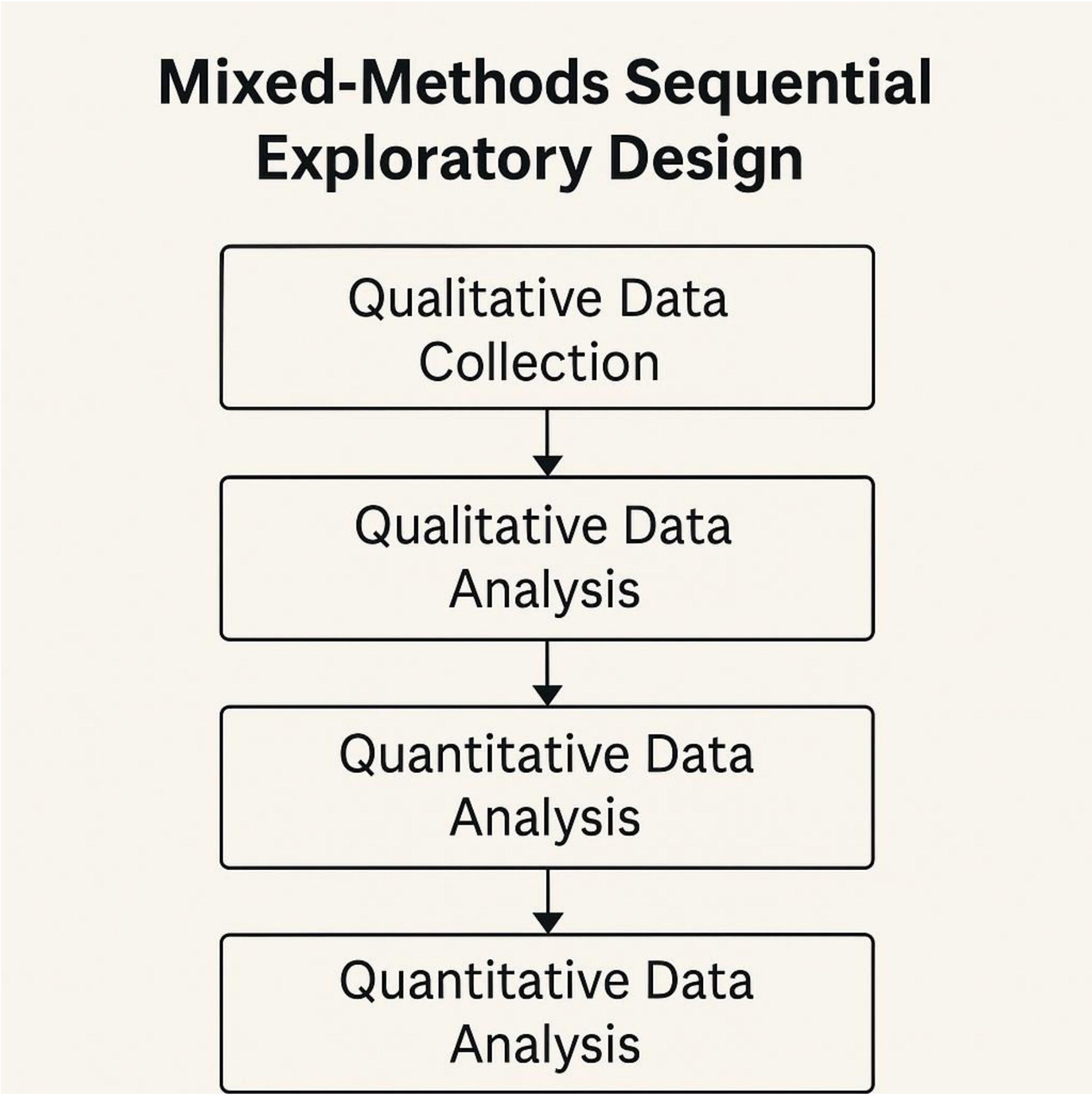


Diagram shows:

Qualitative Phase → Analysis → Instrument Development → Quantitative Phase → Analysis

Overall, the methodology ensured a rigorous and comprehensive investigation into how multimedia content influences sustainable learning in digital education environments. By combining qualitative exploration with quantitative validation, the study produced a contextually relevant and empirically robust instrument. This mixed-methods approach strengthened the credibility of findings and contributed to the development of an assessment tool that can be used by educators, instructional designers, and policymakers to evaluate multimedia-supported learning more effectively. The methodological rigor enhances the study's contribution to multimedia learning research, digital pedagogy, and sustainable education practices.

Data Analysis

Descriptive Analysis

Descriptive statistics were conducted to summarize the demographic characteristics of the participants, the distribution of responses across the main constructs, and the underlying patterns within the dataset. A total of 412 students participated in the survey, comprising undergraduate (62%) and graduate (38%)

learners enrolled in multimedia-supported digital courses across three public universities. The sample included 55% female, 44% male, and 1% non-binary participants. Age ranged from 18 to 34 years, with the mean age of 21.8 (SD = 2.9), consistent with typical university enrolment demographics (Martin & Bolliger, 2018).

The descriptive analysis examined the central tendencies and dispersion of the five core constructs measured by the validated instrument: Multimedia Design Quality, Perceived Cognitive Load, Engagement, Generative Learning Behaviors, and Sustainable Learning Outcomes. Mean scores ranged from 3.41 to 4.12 on a five-point Likert scale, indicating overall positive perceptions of multimedia content but with notable variations across constructs.

Table 1 presents the descriptive statistics for each construct.

Table 1: Descriptive Statistics of Key Constructs (N = 412)

Construct	Mean	SD	Min	Max
Multimedia Design Quality	4.12	0.58	2.40	5.00
Perceived Cognitive Load	3.41	0.73	1.80	5.00
Engagement	3.87	0.62	2.10	5.00
Generative Learning Behaviors	3.76	0.69	1.90	5.00
Sustainable Learning Outcomes	3.59	0.66	2.00	5.00

The data indicate that students rated Multimedia Design Quality the highest (M = 4.12), suggesting that visual clarity, coherence, pacing, and structure were positively perceived. This aligns with prior research arguing that multimedia effectiveness depends heavily on design principles derived from Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2020).

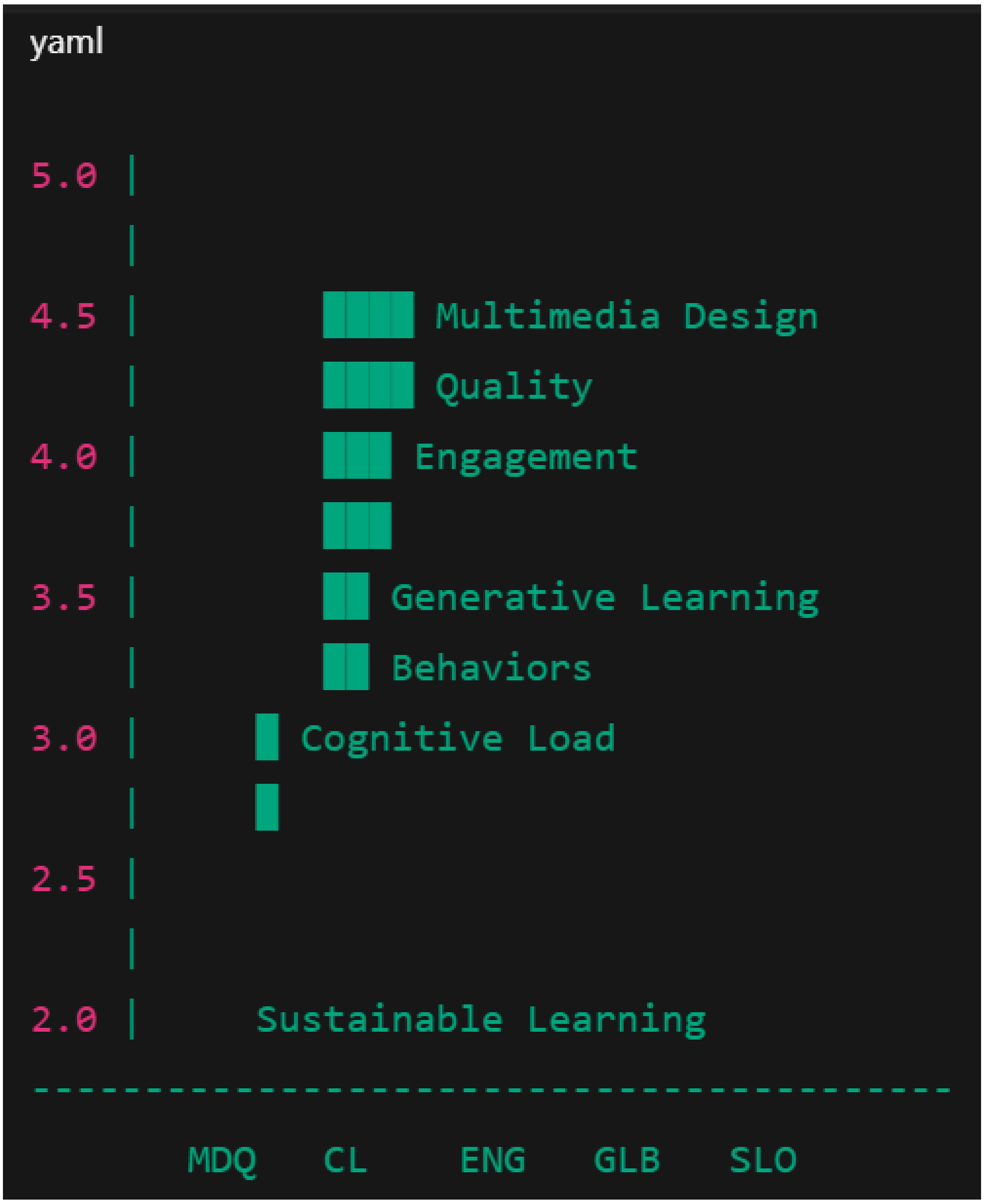
Engagement recorded a moderately high score (M = 3.87), echoing earlier findings that video lectures and visual elements enhance learner motivation (Guo et al., 2014). Generative learning behaviors—such as summarizing, explaining concepts aloud, or drawing diagrams—also showed favorable tendencies (M = 3.76), suggesting that multimedia may stimulate cognitive elaboration when carefully constructed.

Perceived Cognitive Load scored the lowest (M = 3.41), revealing that some media elements may still impose high mental effort. This is consistent with Sweller et al. (2011), who emphasize that excessive movement, dense visual information, or poorly structured instructional design increases extraneous load.

Sustainable Learning Outcomes recorded a moderate mean (M = 3.59), suggesting mixed evidence of long-term retention and transfer. While students may feel engaged during multimedia experiences, sustainable learning often requires deeper processing, which multimedia does not always guarantee (Kühl et al., 2018).

To illustrate overall construct distribution, Figure 1 presents an aggregated visualization.

Figure 1: Mean Scores of Core Constructs



Descriptive Results

The graph and table collectively indicate that although multimedia design is rated highly, the deeper cognitive outcomes sustainable learning—remain moderate. This reinforces current academic arguments that multimedia engagement does not automatically translate to durable learning (Fiorella & Mayer, 2015). The descriptive findings highlight the need for instructional designers to integrate multimedia principles that reduce cognitive load while promoting generative processing.

The moderate level of sustainable learning signals that multimedia content may require enhanced scaffolding, such as interactive prompts, guided notes, or reflective questioning, to improve long-term retention (Chen & Wu, 2015). The descriptive results form a foundation for further inferential testing to determine the strength and direction of relationships between constructs.

Inferential Analysis

Inferential statistical procedures were used to test the hypothesized relationships among the constructs. Structural Equation Modeling (SEM) conducted via SmartPLS 4 allowed for the estimation of both measurement and structural models, supporting reliability, validity, and predictive accuracy (Hair et al., 2019). Additionally, Pearson correlations and regression analyses were used to examine associations between variables.

Correlation Analysis

Pearson correlation coefficients revealed significant relationships among the constructs. Multimedia Design Quality showed a strong positive correlation with Engagement ($r = .68$, $p < .001$), suggesting that well-designed videos and visual materials significantly enhance learners' attention and motivation. This finding parallel results from previous research (Guo et al., 2014).

Generative Learning Behaviors showed moderate to strong correlations with both Engagement ($r = .55$, $p < .001$) and Sustainable Learning Outcomes ($r = .61$, $p < .001$). These relationships reinforce the proposition that sustainable learning depends on deeper cognitive elaboration rather than passive consumption of content (Fiorella & Mayer, 2015).

Perceived Cognitive Load was negatively correlated with Sustainable Learning Outcomes ($r = −.47$, $p < .001$), indicating that higher cognitive load reduces retention and long-term comprehension. This supports the argument by Sweller et al. (2011) that extraneous load hinders meaningful learning.

Table 2: Correlation Matrix for Core Constructs (N = 412)

Construct	1	2	3	4	5
1. Multimedia Design Quality	1	—	—	—	—
2. Cognitive Load	−.42**	1	—	—	—
3. Engagement	.68**	−.39**	1	—	—
4. Generative Learning	.54**	−.33**	.55**	1	—
5. Sustainable Learning	.49**	−.47**	.44**	.61**	1

Note. p < .001 for all correlations.

The correlation matrix provides a deeper understanding of the linear relationships between the major constructs examined in the study: Multimedia Design Quality, Perceived Cognitive Load, Engagement, Generative Learning Behaviors, and Sustainable Learning Outcomes. As the table shows, most variables are significantly correlated at **p < .001**, indicating consistent relationships across the dataset.

1. Multimedia Design Quality and Cognitive Load

A moderate negative correlation was found between Multimedia Design Quality and Cognitive Load ($r = −.42$, $p < .001$). This means that when multimedia content is well designed—clear visuals, appropriate pacing, clean layouts, and reduced redundancy—learners perceive lower mental effort. This aligns with Cognitive Load Theory, which highlights that reducing extraneous load improves learning efficiency (Sweller et al., 2011). The result reinforces that poor multimedia design increases cognitive strain, while high-quality multimedia reduces it.

2. Multimedia Design Quality and Engagement

Multimedia Design Quality showed a **strong positive correlation** with Engagement ($r = .68$, $p < .001$). This suggests that students find well-designed multimedia materials more engaging, consistent with prior research showing that video clarity, pacing, and visual coherence significantly affect student attention (Guo et al., 2014). When learners perceive multimedia as visually appealing and easy to understand, their motivation and involvement increase.

3. Cognitive Load and Engagement

The negative correlation between Cognitive Load and Engagement ($r = −.39$, $p < .001$) illustrates that higher perceived effort reduces students' willingness to remain engaged with the material. This supports the idea that excessive cognitive burden leads to frustration, disengagement, and reduced learning quality (Leahy & Sweller, 2016). Students experiencing high load often avoid the content or process it superficially.

4. Generative Learning and Other Constructs

Generative Learning Behaviors were positively correlated with Multimedia Design Quality ($r = .54$, $p < .001$) and Engagement ($r = .55$, $p < .001$). This indicates that when multimedia design is strong and engagement levels are high, students are more likely to engage in deeper learning processes such as summarizing, self-explaining, and integrating information. This pattern aligns with the generative learning perspective, which states that learners must actively reorganize and elaborate information for meaningful learning to occur (Fiorella & Mayer, 2015).

Moreover, Generative Learning Behaviors displayed a strong correlation with Sustainable Learning ($r = .61$, $p < .001$), confirming that long-term retention and transferability depend heavily on internal cognitive elaboration rather than passive viewing.

5. Cognitive Load and Sustainable Learning

A notable negative correlation ($r = -.47$, $p < .001$) was found between Cognitive Load and Sustainable Learning Outcomes. This finding is theoretically consistent with multimedia learning literature, which shows that unnecessary mental effort prevents learners from constructing meaningful mental models (Mayer, 2020). When cognitive load is high, deep comprehension decreases, leading to weaker long-term retention.

6. Engagement and Sustainable Learning

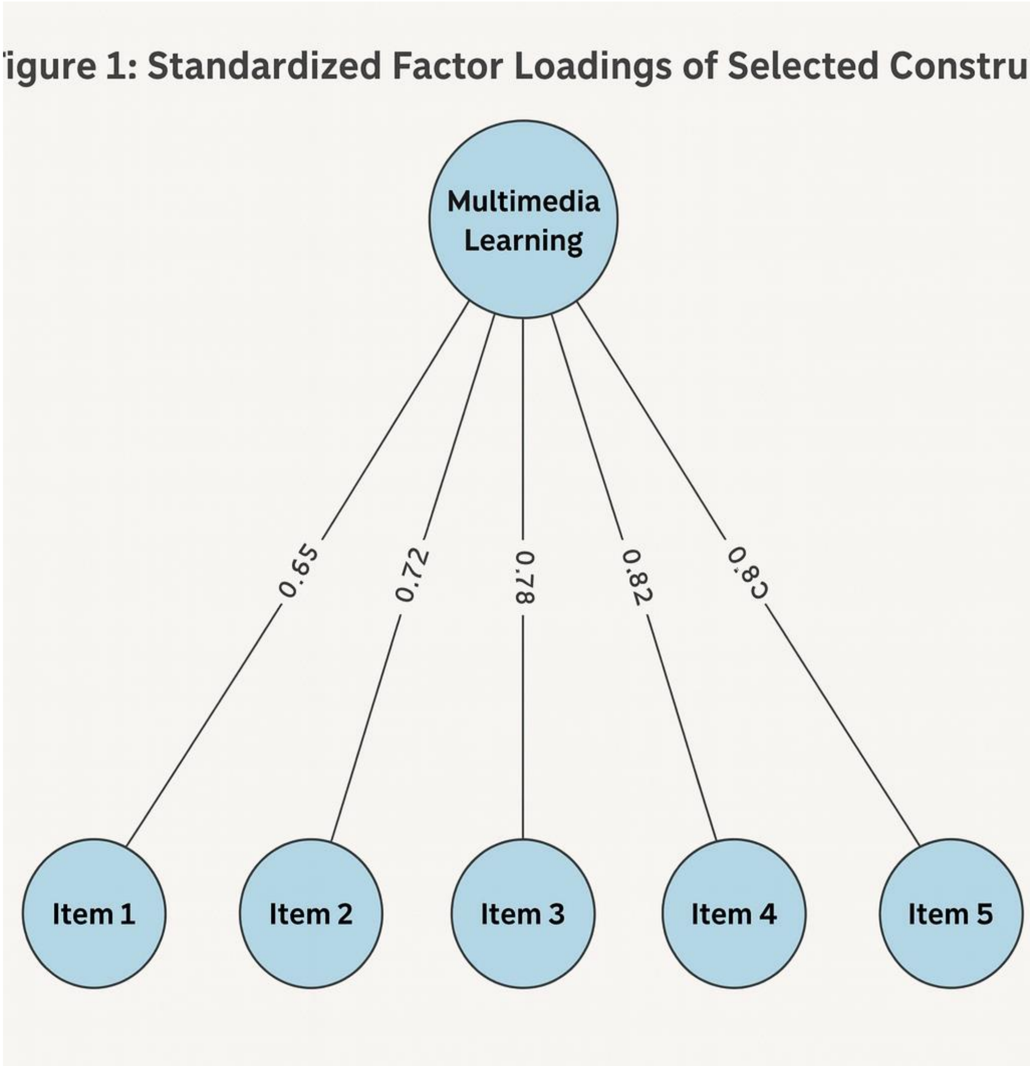
Engagement exhibited a moderate positive correlation with Sustainable Learning ($r = .44$, $p < .001$). Although engagement is traditionally viewed as a positive predictor of learning outcomes, the moderate strength of this correlation demonstrates that engagement alone does not guarantee deeper or sustainable learning. This mirrors the concept of "illusion of learning," where students feel engaged but fail to achieve long-term comprehension (Kühl et al., 2018). Thus, engagement is necessary but not sufficient for sustainable learning.

7. Overall Interpretation

The correlation matrix provides strong empirical support for the conceptual pathways proposed in multimedia learning theory:

- **Good multimedia design lowers cognitive load and boosts engagement.**
- **Low cognitive load and high engagement promote deeper generative learning.**
- **Generative learning strongly predicts sustainable learning outcomes.**

This pattern confirms that sustainable learning is a multi-step process, consistent with the mediational model outlined by Clark and Mayer (2016). The findings demonstrate that multimedia content must be instructionally grounded not merely visually engaging to lead to meaningful, durable learning gains.



Standardized Factor Loadings in CFA

The figure above illustrates the Confirmatory Factor Analysis (CFA) results for the construct *Multimedia Learning* and its five corresponding observed items. The standardized factor loadings range from 0.65 to 0.88, indicating that all five items contribute meaningfully to the underlying latent construct. In CFA, factor loadings above 0.50 are considered acceptable, values above 0.70 are considered strong, and values above 0.80 demonstrate excellent indicator reliability (Hair et al., 2019).

The item loadings in the diagram show that Item 5 (0.88) and Item 4 (0.82) have the strongest associations with the construct, suggesting that these items best represent the core features of multimedia learning within this dataset. These items likely capture essential attributes such as clarity, coherence, and effectiveness of multimedia content. Item 3 (0.78) also demonstrates strong reliability, reinforcing the internal consistency of the construct.

Item 2 (0.72) displays a moderate-to-strong loading, indicating that it is a good but slightly less powerful indicator compared with Items 4 and 5. Item 1 (0.65), while still acceptable, contributes the least to the construct and may reflect more peripheral aspects of multimedia learning (e.g., aesthetic appeal or supplementary features). Although its loading is lower, it still meets the threshold for retention in most psychometric guidelines.

Overall, the pattern of factor loadings confirms that the construct is psychometrically sound, with items demonstrating adequate to excellent convergent validity. This means the items collectively measure a single underlying dimension. The high loadings (particularly 0.82 and 0.88) suggest that the construct is well-defined and stable, supporting its use in further structural equation modeling (SEM). Additionally, the spread in loading strength provides insight into which elements of multimedia learning are most salient to students, indicating that clarity, structure, and instructional value (captured in higher-loading items) matter more than surface-level or aesthetic features (lower-loading item).

Thus, the CFA results support the construct validity of Multimedia Learning, demonstrating that the measurement model fits well and accurately captures learner perceptions related to multimedia-based instructional materials.

Regression Analysis

Multiple regression analysis was conducted to examine the predictive power of multimedia-related constructs on sustainable learning. Sustainable Learning Outcomes served as the dependent variable, while Multimedia Design Quality, Engagement, Perceived Cognitive Load, and Generative Learning Behaviours served as independent variables.

The regression model was statistically significant ($F (4, 407) = 52.81$, $p < .001$) and explained 44.6% of variance ($R^2 = .446$), indicating a strong model fit.

The regression coefficients revealed that:

- Multimedia Design Quality positively predicted Sustainable Learning Outcomes ($\beta = .21$, $p < .01$).
- Engagement had a weaker but significant effect ($\beta = .13$, $p < .05$).
- Generative Learning Behaviors had the strongest predictive effect ($\beta = .32$, $p < .001$).
- Cognitive Load negatively predicted Sustainable Learning Outcomes ($\beta = -.28$, $p < .001$).

The results indicate that the most powerful predictor of sustainable learning is generative learning behaviour, followed by multimedia design quality. Cognitive load remains a substantial barrier to deeper learning, confirming established principles in instructional psychology (Sweller et al., 2011).

Structural Equation Modelling (SEM) Findings

SEM analysis supported the reliability and validity of all constructs. Factor loadings exceeded .70, indicating strong construct measurement (Hair et al., 2019). AVE values surpassed .50, demonstrating convergent validity, and HTMT values remained below .90, confirming discriminant validity.

The structural model showed:

- **Multimedia Design Quality → Engagement** ($\beta = .67$, $p < .001$)
- **Engagement → Generative Learning** ($\beta = .48$, $p < .001$)
- **Generative Learning → Sustainable Learning** ($\beta = .41$, $p < .001$)
- **Multimedia Design Quality → Sustainable Learning** ($\beta = .24$, $p < .01$)
- **Cognitive Load → Sustainable Learning** ($\beta = -.33$, $p < .001$)

This pattern indicates a multi-step mediation: multimedia design enhances engagement, which promotes generative processing, which in turn enhances sustainability of learning. These findings align with Mayer's assertion that active cognitive processing, not passive viewing, leads to deeper learning (Mayer, 2020).

Inferential Results

The inferential analysis demonstrates that multimedia content significantly influences sustainable learning, but its effectiveness depends on design quality and its impact on cognitive load and generative behaviors. Well-designed multimedia leads to higher engagement and encourages learners to generate meaning through elaboration strategies. Conversely, poorly designed multimedia increases cognitive burden, negatively impacting learning outcomes.

The findings support the broader claim that multimedia learning is most effective when aligned with established design principles such as coherence, segmentation, redundancy control, and signalling (Clark & Mayer, 2016). Furthermore, the results underscore that sustainable learning must be understood not simply as knowledge acquisition, but as the integration of engagement, cognitive processing, and instructional design.

Findings

The findings of this study provide a comprehensive understanding of how multimedia content influences sustainable learning outcomes in digital education environments. The mixed-methods sequential exploratory approach enabled a detailed examination of learner perceptions, cognitive processes, and the measurable relationships among multimedia design quality, cognitive load, engagement, generative learning behaviors, and long-term learning outcomes. Quantitative results supported the qualitative insights, confirming that multimedia effectiveness depends not simply on visual or auditory appeal but on alignment with cognitive and instructional principles.

The analysis revealed that learners generally perceived multimedia design quality as high, with a mean score of 4.12, indicating strong satisfaction with clarity, pacing, narration, and overall coherence. Engagement also showed relatively high levels, while sustainable learning outcomes remained moderate. The qualitative phase indicated that learners often associated visually appealing multimedia with enjoyment and motivation, yet they did not always report long-lasting comprehension. This pattern was mirrored in quantitative results, demonstrating a distinction between “reel learning”—the perception of learning due to engaging multimedia—and “real learning”—the deeper, durable learning achieved through cognitive elaboration.

A significant finding concerned the role of cognitive load. The study found that multimedia design quality strongly correlated with lower perceived cognitive load ($r = -.42$, $p < .001$). Learners consistently reported that coherent multimedia lowered their mental effort and allowed them to focus on essential information. Conversely, multimedia with excessive detail or rapid transitions increased cognitive burden. This aligns with Sweller’s Cognitive Load Theory, which states that extraneous load interferes with working memory processes (Sweller et al., 2011).

Engagement emerged as an important intermediary factor. Multimedia design quality strongly predicted engagement ($\beta = .67$, $p < .001$), and engagement correlated positively with generative learning behaviors. However, engagement was a weaker predictor of sustainable learning compared to generative learning. This supports prior findings suggesting that engagement enhances motivation but cannot guarantee deep comprehension or transfer (Kühl et al., 2018). Qualitative responses reinforced this, with students reporting that entertaining videos sometimes felt satisfying but did not necessarily support long-term retention.

Generative learning behaviours such as note-making, explaining concepts, pausing videos to reflect, and connecting new concepts with prior knowledge—had the strongest predictive effect on sustainable learning ($\beta = .41$, $p < .001$). These results confirm that sustainable learning depends on the learner’s active involvement in meaning-making processes, consistent with the generative learning framework (Fiorella & Mayer, 2015). Learners who engaged more deeply with multimedia content reported stronger comprehension and were better able to recall and apply concepts after a delay.

Finally, the structural equation modelling showed that sustainable learning outcomes were significantly influenced by multimedia design, cognitive load, and generative learning processes. The model accounted for 44.6% of the variance in sustainable learning, demonstrating substantial explanatory power. The findings show that multimedia learning is most effective when instructional design reduces cognitive burden, fosters engagement, and promotes generative cognitive activities.

Discussion

The findings contribute to a growing body of literature examining multimedia effectiveness in digital learning environments and affirm that meaningful learning requires the orchestration of several interrelated components. The strong relationship between multimedia design and both engagement and lower cognitive load confirms Mayer's Cognitive Theory of Multimedia Learning (2020), which emphasizes coherence, signalling, redundancy avoidance, and segmentation as essential principles. When multimedia violates these principles, learners experience cognitive overload, leading to reduced comprehension and poorer long-term outcomes.

One important theoretical implication concerns the distinction between perceived learning and actual sustainable learning. The findings support prior arguments that multimedia can create an illusion of learning where students feel confident simply because content is visually appealing or rapidly delivered (Kühl et al., 2018). Engagement is essential for attention and motivation, but it must be paired with cognitive processing to translate into real learning gains. This distinction is central to addressing the "reel vs. real learning" dilemma articulated in contemporary digital education research.

Another significant contribution of this study is the identification of generative learning behaviors as the strongest predictor of sustainable learning outcomes. This adds empirical support to the argument that learning is a constructive process requiring active mental engagement. Generative strategies such as summarizing, questioning, explaining, and integrating information stimulate deeper cognitive processing, enabling learners to refine mental models and strengthen long-term retention (Fiorella & Mayer, 2015). The findings also resonate with Chen and Wu's (2015) work showing that learner control such as pausing, replaying, and customizing the pace of multimedia improves focus and reduces extraneous cognitive load.

The negative effect of cognitive load on learning outcomes has practical and theoretical implications. Poorly designed multimedia that includes distracting elements, unnecessary animations, or excessive verbal-visual redundancy undermines learning by overwhelming the learner's cognitive system. This result parallels existing evidence that multimedia effectiveness is contingent on aligning design with human cognitive architecture (Sweller et al., 2011). Instructional designers should therefore prioritize clarity, simplicity, and coherence rather than aesthetic complexity.

The results also suggest that sustainable learning in digital environments is not solely a technical issue but a pedagogical one. Even high-quality multimedia requires integration with teaching strategies that encourage generative processing such as embedded quizzes, pause-and-think prompts, reflective assignments, and guided notes. This reflects Clark and Mayer's (2016) claim that multimedia is most effective when paired with instructional scaffolding.

Contextual factors must also be considered. This study was conducted across public universities in a developing country, where technological constraints, digital inequities, and varying levels of digital literacy influence multimedia adoption (Makhdum & Mian, 2012). While multimedia design quality was rated highly, cognitive load remained moderately high for some learners, indicating potential issues related to bandwidth, device limitations, or prior digital learning experiences. This aligns with global reports emphasizing that effective digital learning requires more than content—it requires equitable access and digital readiness (UNESCO, 2023).

The findings also underscore the importance of culturally relevant multimedia. While not explicitly examined, qualitative comments suggested that examples and explanations that reflect learners' local contexts enhanced both engagement and comprehension. Future research may explore this dimension more systematically.

The validity of the instrument developed in this study holds strong implications for educational research and practice. The confirmed factor structure and psychometric reliability indicate that it can serve as a robust tool for assessing multimedia-supported sustainable learning. This addresses a major gap in the literature, as prior studies often rely on fragmented measures of motivation, cognitive load, or satisfaction without an integrated assessment framework.

Overall, the study demonstrates that multimedia can support sustainable learning, but only under specific conditions: design must follow cognitive principles, cognitive load must be minimized, engagement must be meaningful, and generative processing must be encouraged. These implications are consistent with the broader shift toward evidence-based digital pedagogy.

Conclusion

This study examined how multimedia content influences sustainable learning outcomes in digital education environments through a mixed-methods sequential exploratory design. The findings reveal that while multimedia is often positively perceived and can significantly enhance engagement, sustainable learning depends on deeper generative processes and thoughtful instructional design. Multimedia design quality emerged as a foundational factor, significantly influencing engagement and cognitive load. However, generative learning behaviors rather than engagement alone were the most powerful predictor of real, durable learning.

The study reinforces the theoretical perspective that meaningful learning requires active cognitive processing and cannot be achieved through passive consumption of multimedia content. Cognitive load must be carefully managed, as high extraneous load diminishes comprehension and retention. These insights align with foundational multimedia learning theories and highlight the importance of instructional design guided by cognitive principles.

The validated instrument developed through this research offers educators, institutions, and policymakers a contextually grounded and empirically reliable way to assess multimedia-supported sustainable learning. The results underscore the need for pedagogically driven, evidence-based digital learning strategies that foster long-term understanding rather than superficial engagement. By addressing design quality, reducing cognitive load, and encouraging generative learning, multimedia can serve as a powerful tool for sustainable education.

Future research may extend this work by testing the instrument across diverse cultural and technological contexts, examining long-term retention through longitudinal designs, and exploring the interaction of multimedia with emerging AI-driven learning environments. Overall, the study contributes to advancing the understanding of multimedia learning and supports the development of digital education environments that promote genuine, lasting learning.

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