Journal of Education and Learning (EduLearn)
Vol. 20, No. 3, August 2026, pp. 2018~2032
ISSN: 2089-9823, DOI: 10.11591/edulearn.v20i3.27368

How CTML-based instructional video shapes students' acceptance of asynchronous learning: an integrated TAM-TPB approach

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Article Info

Article history:

Received Jan 11, 2026
Revised Mar 16, 2026
Accepted Jun 8, 2026

Keywords:

Asynchronous learning
CTML
TAM
TPB
Video

ABSTRACT

This study examines how the cognitive theory of multimedia learning (CTML)-based content quality shapes students' acceptance of asynchronous learning within an integrated technology acceptance model (TAM)-theory of planned behavior (TPB) framework. The CTML provides the theoretical foundation for designing instructional videos that minimize cognitive load to enhance learning effectiveness. The proposed model links content quality to perceived usefulness and perceived ease of use, which influence attitude, subjective norm, perceived behavioral control, and behavioral intention. A quantitative approach using structural equation modeling (SEM) with SmartPLS was employed to analyze responses from 258 university students who had experienced asynchronous online learning. The results indicate that content quality significantly impacts perceived ease of use (β=0.589) and perceived usefulness (β=0.316). In turn, perceived usefulness significantly influences attitude (β=0.461) and behavioral intention (β=0.200), while attitude (β=0.171), subjective norm (β=0.381), and perceived behavioral control (β=0.156) also significantly predict behavioral intention. These findings validate the integrated TAM-TPB framework and demonstrate that CTML-based content quality functions as a cognitive antecedent of technology acceptance in higher education.

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1. INTRODUCTION

E-learning represents one of the prominent delivery methods in contemporary education. The Internet is a primary catalyst for adopting e-learning, and the COVID-19 pandemic has significantly accelerated its expansion. E-learning encompasses both synchronous and asynchronous modalities, whereas blended learning refers to the strategic integration of these two modes [1].

The educational response to the pandemic gave rise to emergency remote teaching [2], a crisis-driven solution that differs fundamentally from structured and systematically designed online learning. Emergency remote teaching emerged as an immediate strategy to maintain educational continuity during large-scale disruptions, particularly when institutions were unprepared for a rapid transition to fully digital environments. This phenomenon highlights the importance of adaptive instructional design in ensuring the effectiveness and sustainability of remote learning practices [3], [4], while also signaling a global shift in traditional education systems toward more flexible and technology-integrated learning models [5].

In the post-pandemic era, blended instruction emerged as the dominant model, combining the strengths of synchronous interaction with the flexibility of asynchronous learning. It demonstrated that this approach fosters learning environments responsive to student needs [3], supported by findings from Norberg *et al.* [6] and Halverson *et al*. [7], which highlight the global adoption of blended learning due to its capacity for personalization and pedagogical effectiveness. Asynchronous learning, particularly its personalization feature [8], enables learners to tailor their learning process to individual needs, while its spatiotemporal flexibility enhances accessibility and reach.

Video-based asynchronous learning has evolved as a solution for self-paced learning, allowing learners to access materials at their own pace [9]. However, this model poses challenges related to learner engagement and the risk of academic isolation if not accompanied by interactive elements. Addressing these challenges requires deliberate instructional design, as synchronous presentation materials cannot be directly converted into asynchronous formats without modification.

The cognitive theory of multimedia learning (CTML), formulated by Austin [10], provides a systematic framework for designing instructional media grounded in multimedia design principles that enhance cognitive processing. Applying principles such as coherence, modality, segmenting, and signaling has been empirically shown to enhance comprehension and information retention [11], [12]. Nevertheless, several studies report that instructional practices in the field remain misaligned with these principles [13]. The effectiveness of CTML lies in its ability to manage cognitive load and integrate visual and verbal elements to facilitate efficient information processing.

Despite CTML's strength as a theoretical foundation for media development, in-depth empirical studies on learner responses and acceptance of videos designed using CTML principles remain limited. User acceptance is a critical determinant influencing learning motivation and student engagement. However, the literature integrating CTML with user-centered perspectives in the context of media acceptance remains scarce. Therefore, further research is needed to bridge this gap, particularly in evaluating the extent to which cognitively optimal multimedia designs are positively received by learners and identifying the factors that influence such acceptance.

Studies by Alassafi [8] explicitly indicate that e-learning—especially asynchronous learning—functions as a socio-technical system. This concept is rooted in the socio-technical systems theory proposed, which posits that work systems consist of two interdependent subsystems: the social and the technical. For optimal performance, both subsystems must be simultaneously optimized. Thus, user acceptance should be evaluated through the lens of both dimensions.

Based on this premise, the technology acceptance model (TAM) and the theory of planned behavior (TPB) are employed as an integrated framework to examine students' acceptance of asynchronous learning [14], [15]. TAM is one of the most validated and widely applied models in technology acceptance research [16]. It is a suitable theoretical foundation for assessing learners' experiences with technical systems. Meanwhile, TPB is recognized as one of the most influential theories in social psychology, emphasizing the psychological determinants of individual behavior [17]. Accordingly, TPB is adopted to examine the social dimension of technology acceptance. In this study, TAM and TPB are integrated as complementary approaches following the framework proposed to provide a comprehensive analysis of asynchronous learning acceptance [18].

Despite the extensive use of the CTML to explain learning effectiveness and cognitive outcomes, empirical studies rarely examine how CTML-based instructional design shapes learners' acceptance and intention to use asynchronous learning systems. Most technology acceptance studies in education rely on generic content quality indicators without explicitly grounding them in cognitive learning theory. Consequently, the processes by which cognitively optimal multimedia design affect perceived usefulness, perceived ease of use, and behavioral intention are theoretically insufficiently examined. This study addresses this gap by positioning CTML-based content quality as a cognitive antecedent within an integrated TAM-TPB framework, thereby extending multimedia learning theory into the domain of technology acceptance and learner intention in asynchronous higher education contexts.

Despite the extensive application of the TAM and the TPB in explaining students' adoption of e-learning systems, most existing TAM-TPB integrations in asynchronous learning contexts treat content quality as a generic evaluative construct. Content quality is typically operationalized in terms of clarity, completeness, or relevance without grounding these dimensions in a specific cognitive learning theory. As a result, prior models explain whether students perceive a system as useful or easy to use but remain theoretically limited in explaining why certain instructional designs produce these perceptions.

In parallel, CTML has been widely employed to explain learning outcomes such as comprehension, retention, and transfer. However, CTML has rarely been positioned within technology acceptance frameworks as an upstream determinant of perception formation. The majority of multimedia studies focus on cognitive performance rather than behavioral intention or system adoption. Consequently, there remains a conceptual gap between multimedia instructional design theory and technology acceptance research. Specifically, the role of cognitively grounded multimedia design principles as antecedents of perceived usefulness and perceived ease of use has not been sufficiently theorized within integrated TAM-TPB models.

Positioning CTML-based content quality as a cognitive antecedent within an integrated TAM-TPB framework provides a new perspective for understanding technology acceptance in asynchronous learning environments. Rather than treating content quality as a generic system attribute, CTML principles—such as coherence, signaling, and segmenting—are conceptualized as instructional design mechanisms that enhance learners' cognitive fluency, which subsequently shapes perceived usefulness, perceived ease of use, and behavioral intention. A key novelty of this research lies in the theoretical reconceptualization of multimedia content quality as a cognitively grounded construct derived from the CTML and its empirical integration as an upstream determinant within the TAM–TPB technology acceptance framework.

Three contributions to literature emerge from this study. First, CTML extends beyond learning effectiveness research by demonstrating its role in shaping technology acceptance and behavioral intention. Second, the integration of CTML-derived instructional design variables provides a theoretically grounded basis for strengthening TAM-TPB models, moving beyond generic system-quality measures. Third, empirical evidence indicates that cognitive fluency mechanisms function as antecedents of perceived usefulness and perceived ease of use, offering a deeper theoretical explanation of how instructional design influences technology adoption in asynchronous learning environments.

a. CTML and content design

The CTML, introduced by Mayer [19], explains how individuals process and learn from multimedia materials through dual verbal and visual information channels. According to CTML, learning becomes more effective when instructional materials are designed to support dual-channel processing, manage cognitive load, and promote meaningful learning [10]. Consequently, multimedia instruction should follow design principles such as coherence, signaling, redundancy, spatial and temporal contiguity, and segmenting to minimize extraneous cognitive load and direct learners' attention toward essential information. In asynchronous learning environments where instructor presence is limited, instructional videos designed according to CTML principles can foster more active and self-regulated learning. Prior studies show that CTML-based video design improves comprehension, retention, and learner satisfaction [8], [20], [21]. For instance, signaling highlights important information through cues, while segmenting allows learners to process content at their own pace, which is particularly beneficial in self-directed online learning.

Within asynchronous learning contexts, content quality becomes a critical factor shaping learners' perceptions of the learning experience. High-quality instructional videos that adhere to CTML principles may influence perceived usefulness and perceived ease of use, two central constructs of the TAM. When learners perceive instructional videos as clear, relevant, and easy to follow, the learning system is more likely to be viewed as useful and user-friendly, which in turn strengthens attitudes and behavioral intentions toward continued use [22], [23]. However, most previous studies conceptualize content quality as a general evaluative construct based on subjective perceptions of clarity or relevance, without explaining the cognitive mechanisms underlying these perceptions. CTML offers a theoretically grounded explanation by linking multimedia design principles to cognitive load management and processing fluency. Despite this theoretical relevance, empirical research connecting CTML-based instructional video design with TAM constructs in asynchronous learning remains limited [24], [25]. Addressing this gap, the present study examines how CTML-based instructional video content contributes to technology acceptance by influencing perceived usefulness and perceived ease of use.

b. TAM

The TAM, originally developed by Davis [26], is a widely recognized framework for predicting users' acceptance and use of information systems. The model posits that two key determinants—perceived usefulness and perceived ease of use—shape users' attitudes and behavioral intentions toward adopting a technology. Perceived usefulness refers to the extent to which individuals believe that using a system will enhance their performance, whereas perceived ease of use reflects the degree to which the system is perceived as effortless to use [14]. TAM has been widely validated across multiple domains, including business, healthcare, and education [27], [28]. In educational technology research, TAM has become a foundational model for explaining the adoption of e-learning platforms, digital tools, and multimedia-based learning environments, with numerous studies confirming that perceived usefulness and perceived ease of use significantly influence learners' attitudes and intentions to use educational technologies [28]–[30].

In asynchronous learning contexts, TAM helps explain how learners perceive both the learning system and its instructional content. Video-based instruction, particularly when designed according to CTML principles, can influence learners' perceptions of usefulness and ease of use by making content clearer and easier to follow [31], [32]. When instructional videos are perceived as effective and accessible, learners are more likely to accept and continue using asynchronous learning platforms. However, despite TAM's strong explanatory power, its original formulation does not explicitly incorporate psychological or instructional design factors such as content quality. Integrating CTML-based instructional content as an external factor influencing perceived usefulness and perceived ease of use therefore strengthens the model's predictive relevance in educational contexts and provides deeper insight into how instructional design supports technology acceptance in environments with limited instructor interaction [8].

c. TPB

The TPB, formulated by Ajzen, explains behavioral intention through three primary predictors: attitude, subjective norm, and perceived behavioral control [15], [17]. "Attitude" refers to an individual's evaluation of performing a behavior; subjective norm represents perceived social influence from important others, and perceived behavioral control reflects the perceived ease or difficulty of performing the behavior based on available resources and opportunities. In asynchronous learning contexts, TPB helps explain why students adopt online platforms. Research indicates that learners are more likely to engage with asynchronous learning when they perceive it as beneficial, experience social encouragement from peers or instructors, and believe in their capability to manage self-regulated learning activities [33]–[35]. By incorporating psychological and contextual dimensions beyond system perception, TPB complements and extends the TAM framework, providing a more comprehensive explanation of students' acceptance behavior in digital learning environments.

d. Limitations of existing TAM-TPB studies in asynchronous learning

Prior TAM-TPB studies in asynchronous learning contexts consistently identify content quality as an important predictor of perceived usefulness and behavioral intention. However, most studies operate on content quality in generic terms—such as clarity, relevance, or completeness—without grounding it in a specific cognitive theory. Consequently, the mechanisms through which instructional content influences perceived usefulness and perceived ease of use remain insufficiently explained. Moreover, the integration of cognitive instructional design theories into TAMs remains limited, as TAM-TPB frameworks primarily focus on perception and behavioral intention while overlooking how multimedia design principles shape the cognitive processing experiences that precede perception formation.

Although TAM-TPB integrations are widely established in educational technology research, their theoretical development has increasingly become incremental. Many studies replicate similar structural relationships while introducing contextual variables without reconceptualizing core constructs, particularly regarding content-related predictors that are often treated as external variables without cognitive theoretical grounding. This limitation reduces explanatory depth and confines acceptance research to variance explanation rather than theoretical integration. Addressing this gap, the present study advances TAM-TPB research by embedding CTML as a cognitively grounded explanatory layer within the perception formation process.

e. Integration of CTML, TAM, and TPB

The amalgamation of CTML, TAM, and TPB provides a robust framework for comprehending the impact of instructional material design on learners' adoption of asynchronous learning environments. TAM emphasizes the perceived characteristics of a system, specifically its utility and user-friendliness, whereas TPB integrates psychological and social elements that influence behavioral intentions. CTML offers a theoretical framework for the production of instructional content that enhances cognitive processing.

In this integrated model, CTML-based content functions as an external variable influencing perceived usefulness and perceived ease of use. Videos designed with CTML principles—such as signaling, coherence, and segmentation—are more likely to be perceived by students as useful and easy to understand [8], [22]. These perceptions, grounded in TAM, form the basis for learners' attitudes toward using the asynchronous learning platform.

Moreover, perceived usefulness and perceived ease of use are hypothesized to influence, not only attitudes proposed in the original TAM, but also subjective norm and perceived behavioral control, which are key constructs of TPB. When students perceive instructional videos as beneficial and easy to use, they are more likely to believe that others expect them to engage with the platform (subjective norm) and to feel confident in their ability to complete learning tasks independently (perceived behavioral control). This expanded relationship suggests that learners' perceptions of system usability and usefulness can extend beyond individual evaluation to shape social expectations and self-regulatory confidence within asynchronous learning environments.

The integration proposed in this study is mechanistic rather than merely structural. CTML principles—particularly signaling, coherence, and segmentation—reduce extraneous cognitive load and optimize cognitive processing, allowing learners to experience greater cognitive fluency and reduced mental effort. When instructional materials minimize irrelevant information, highlight essential elements, and present content in manageable segments, learners perceive the system as easier to process and more useful for achieving learning outcomes. Consequently, perceived usefulness and perceived ease of use emerge as cognitive judgments grounded in multimedia processing experiences. In this framework, CTML principles act as upstream cognitive mechanisms that shape TAM perceptions, which subsequently activate TPB constructs—attitude, subjective norm, and perceived behavioral control—ultimately influencing behavioral intention toward asynchronous learning.

As shown in Figure 1, CTML principles operate through cognitive load reduction and enhanced processing fluency, which perceived ease of use and perceived usefulness. These perceptions subsequently activate socio-psychological determinants within the TPB framework, ultimately forming behavioral intentions. The structural model derived from this mechanism is presented in Figure 2.

The model reflects the multidimensional nature of learning acceptance by linking instructional content quality to system perception (TAM) and social-cognitive mechanisms (TPB). It recognizes that engagement with asynchronous learning is shaped not only by technological attributes but also by how instructional content facilitates cognitive processing and aligns with motivational expectations. Rather than treating CTML as an additional predictor, this study re-theorizes content quality within the TAM-TPB framework by positioning it as a cognitive fluency mechanism. By reducing extraneous load and enhancing processing clarity, CTML principles shape perceptions of usefulness and ease of use, which subsequently drive behavioral intention.

Prior research has generally treated content quality, TAM constructs, and TPB components as separate analytical domains. However, this study proposes a research framework in Figure 2. This framework not only provides novel theoretical integration but also offers practical implications for instructional designers. By aligning video content design with CTML principles, educators and developers can indirectly enhance learners' motivation, sense of control, and intention to persist in asynchronous learning contexts. To the best of our knowledge, this study is among the first to empirically position CTML-based instructional content quality as a cognitive antecedent within an integrated TAM-TPB acceptance model in asynchronous higher education contexts. By doing so, it bridges cognitive multimedia learning theory and socio-psychological TAMs in a unified explanatory framework.

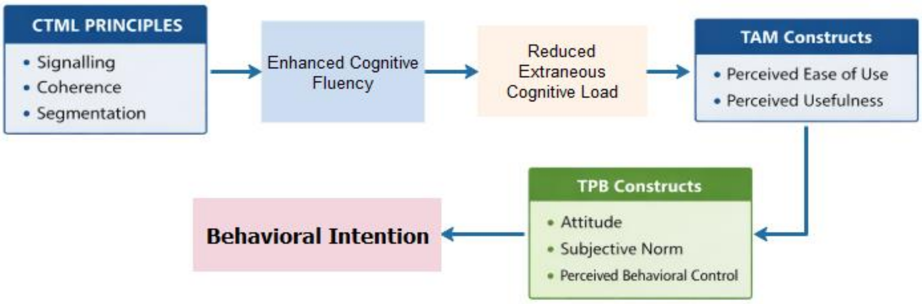

Figure 1. Conceptual integration of CTML principles with TAM–TPB

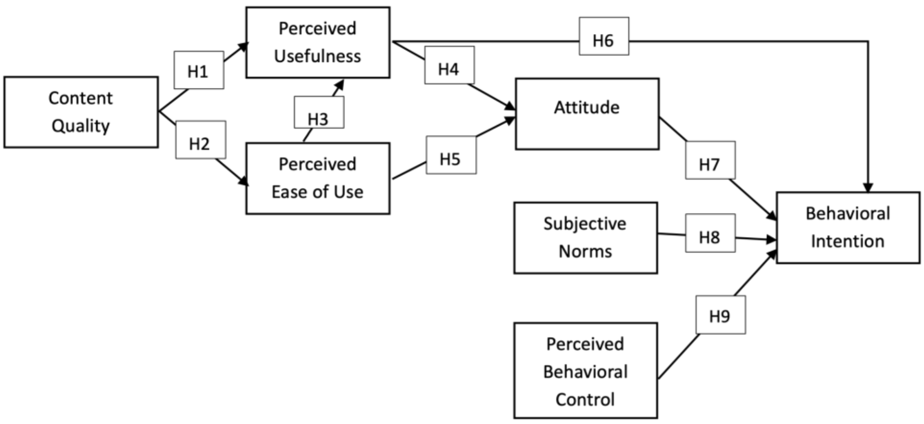

Figure 2. Research framework with structural research model for hypothesis testing

f. Hypotheses development

This study proposes a conceptual framework that connects content quality to students' behavioral intention to participate in asynchronous learning, integrating the CTML, the TAM, and the TPB. Instructional videos developed based on CTML principles are expected to influence students' perceptions of system attributes (TAM), which subsequently affect psychological and behavioral outcomes (TPB). The proposed hypotheses are as follows:

- CTML-based content and TAM constructs

The quality of instructional content, especially when developed utilizing CTML principles, significantly influences learners' perspectives. High-quality videos are more likely to be regarded as beneficial and user-friendly, thus supporting the following hypotheses:

H1: content quality has a positive effect on perceived usefulness.
H2: content quality has a positive effect on perceived ease of use.

- Interrelations within TAM

Extensive research has established the causal paths between perceived ease of use, perceived usefulness, and attitude. A system that is perceived as easy to use is often judged as more useful, and both perceptions contribute to the formation of a favorable attitude:

H3: perceived ease of use has a positive effect on perceived usefulness.
H4: perceived usefulness has a positive effect on attitude.
H5: perceived ease of use has a positive effect on attitude.

- TAM and TPB constructs on behavioral intention

Attitude, in conjunction with perceived utility and other variables of the TPB, serves as a crucial predictor of the intention to adopt asynchronous learning. These links illustrate the motivational and normative mechanisms that influence learners' adoption of the system:

H6: perceived usefulness has a positive effect on behavioral intention.
H7: attitude has a positive effect on behavioral intention.
H8: subjective norms have a positive effect on behavioral intention.
H9: perceived behavioral control has a positive effect on Behavioral Intention.

These nine hypotheses provide a structured basis for testing the integrated framework that explores how content quality, as informed by multimedia learning theory, interacts with users' perceptions and social-cognitive factors to shape their intention to engage in asynchronous learning environments.

- Mediating effects

Based on CTML, instructional content designed to reduce cognitive load enhances learners' cognitive fluency, which is reflected in higher perceived ease of use and perceived usefulness. These perceptions are expected to mediate the relationship between content quality and behavioral intention. Therefore, the following mediation hypotheses are proposed:

H10: perceived ease of use mediates the relationship between content quality and behavioral intention.
H11: perceived usefulness mediates the relationship between content quality and behavioral intention.

g. Limitations of prior TAM-TPB studies in asynchronous learning

Although TAM and TPB have been widely applied to investigate students' acceptance of e-learning and asynchronous learning environments, prior studies exhibit several conceptual limitations. First, content quality is often treated as a generic system attribute, without a clear theoretical explanation of why certain instructional materials are perceived as easy or useful. Second, many TAM–TPB studies emphasize social influence and motivational factors while underrepresenting cognitive design mechanisms that shape learners' interaction with instructional content. As a result, the cognitive processes underlying technology acceptance in self-paced asynchronous learning remains insufficiently theorized.

By integrating CTML into the TAM-TPB framework, this study responds to these limitations by conceptualizing content quality as a cognitively grounded construct. CTML provides an explicit explanation of how multimedia design principles reduce extraneous cognitive load and enhance cognitive fluency, which in turn influences learners' perceptions and behavioral intentions. This integration advances prior acceptance models by embedding cognitive learning theory into the explanation of technology acceptance.

2. METHOD

2.1. Data collection

This study employed a quantitative approach using a cross-sectional survey design to examine students' acceptance of asynchronous learning by integrating constructs from TAM, TPB, and CTML. Data was collected through a structured questionnaire developed from established indicators of each theoretical construct, with all items measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The study population consisted of students from Universitas Negeri Yogyakarta who had experienced asynchronous learning using CTML-based instructional videos. Using purposive sampling, 258 valid responses were obtained based on the criteria that participants had prior experience with asynchronous online learning and voluntarily agreed to participate in the survey. Prior to data collection, the instrument underwent expert evaluation for content validity and was refined through a pilot test. Ethical considerations were ensured through informed consent, participant anonymity, and voluntary participation.

Although the sample size met the recommended threshold for PLS-SEM analysis, the use of purposive sampling from a single public university may limit the generalizability of the findings. Therefore, the results should be interpreted within the context of Indonesian higher education, particularly post-pandemic asynchronous learning environments. In addition, voluntary participation may introduce self-selection bias, as students who are more engaged in digital learning may be more inclined to respond. While the primary focus of the study was theory integration, several contextual factors—such as prior online learning experience, academic discipline, and year of study—may also influence technology acceptance. These variables were recorded descriptively but were not included as statistical control variables in the structural model to maintain model parsimony and theoretical clarity. Future research may incorporate these factors to examine potential moderating or confounding effects.

2.2. Definition of variables

The measurement items in this study were designed in accordance with the research objectives, conceptual framework, and an examination of pertinent literature. The fundamental elements of the TAM were drawn from Davis [26], whereas the elements originating from the TPB were based on Ajzen's research [15]. The content quality concept was developed by synthesizing principles from Mayer's CTML [10]. Table 1 presents the comprehensive operational definitions of each variable.

Table 1. Definition of variables

Research variable	Operability definition	Reference scale
Content quality	The extent to which instructional videos comply with CTML principles (e.g., coherence, signaling, and segmentation) and support learning clarity and engagement.	[32], [36]
Perceived ease of use	The degree to which a student perceives asynchronous learning platforms and materials (videos) as easy to understand and operate.	[26], [37]
Perceived usefulness	The extent to which a student believes that using asynchronous video-based learning improves learning efficiency and performance.	[26], [37]
Attitude	A student's overall favorable or unfavorable evaluation of using asynchronous learning in the form of CTML-based video content.	[17], [26]
Subjective norm	The perceived social pressure from peers, instructors, or the academic environment to engage in asynchronous learning.	[17]
Perceived behavioral control	The degree to which students perceive they have the resources, skills, and opportunities to effectively participate in asynchronous learning.	[17]
Behavioral intention	The degree to which students' express willingness and intention to continue using asynchronous video-based learning in the future.	[38]

2.3. Data analysis

The collected data was analyzed using structural equation modeling (SEM) with SmartPLS. The analysis was conducted in two stages: evaluation of the measurement model and evaluation of the structural model. Convergent validity was assessed using the average variance extracted (AVE), with values above 0.50 indicating acceptable validity, while internal consistency reliability was evaluated using Cronbach's alpha and composite reliability, with thresholds above 0.70 [39]. In the structural model, path coefficient analysis was applied to test the significance of the hypothesized relationships using bootstrapping with 5,000 subsamples. The coefficient of determination (R^2) was used to assess explanatory power, with values of 0.25, 0.50, and 0.70 indicating weak, moderate, and substantial explanatory levels, respectively [40]. PLS-SEM was selected due to the exploratory and theory-extending nature of the study, which integrates constructs from CTML, TAM, and TPB to explain and predict behavioral intention in asynchronous learning contexts.

Mediation analysis was conducted to examine the indirect effects of content quality on behavioral intention through perceived ease of use and perceived usefulness using bootstrapping with 5,000 resamples, where indirect effects were considered significant when the bias-corrected confidence interval excluded zero. Because the study relied on self-reported questionnaire data collected at a single time point, potential common method bias (CMB) was also assessed. Procedural remedies included ensuring respondent anonymity, randomizing item order, and separating predictors and criterion constructs in the questionnaire. Statistically, Harman's single-factor test indicated that no single factor explained the majority of variance, and full collinearity tests showed variance inflation factor (VIF) values below the recommended threshold of 3.3, suggesting that CMB is unlikely to bias the results. Nevertheless, the cross-sectional self-report design remains a methodological limitation, and future studies may consider multi-source data or temporal separation of measurements to further mitigate method-related bias.

2.3.1. Outer model and scale validation

This study's outer model evaluation sought to evaluate the reliability and validity of the reflective constructs. This includes the examination of indicator reliability, internal consistency reliability, and convergent validity. Outer loading values were employed to assess the reliability of individual items, with a commonly recommended threshold of 0.70 or above. Table 2 and Figure 2 indicate that all indicators exhibited satisfactory loadings over the 0.70 threshold, signifying robust item reliability across constructs. No indicator was found to fall below the acceptable threshold, thereby supporting the adequacy of the measurement items in representing their respective latent variables.

Internal consistency was evaluated by composite reliability and Cronbach's alpha. Table 2 demonstrates that all constructs satisfied the minimum reliability threshold, with composite reliability values over 0.70, signifying robust internal consistency among questions assessing the same latent variable (Chin, 1998). Cronbach's alpha scores surpassed the required level of 0.70, varying from 0.792 (perceived usefulness) to 0.944 (content quality), thereby affirming the reliability of the measurement devices. Furthermore, rho_A, which provides a more reliable estimate in PLS-SEM, corroborated these findings with all values surpassing 0.80.

Convergent validity was assessed using AVE. The AVE values of 0.50 signify that a construct accounts for over fifty percent of the variance in its indicators. All constructs in this study surpassed the minimum AVE requirement, with values ranging from 0.645 (perceived ease of use) to 0.850 (content quality), demonstrating robust convergent validity throughout the model, as shown in Table 2.

Moreover, the visual depiction in Figure 3 illustrates that each latent variable is well represented by its corresponding indicators, so affirming that the measurement model satisfies the standards for both reliability and validity. This validation confirms the appropriateness of the outer model for subsequent investigation in the structural model. To ensure measurement accuracy and reduce potential bias, all questionnaire items were randomized, and respondents remained anonymous throughout the data collection process. In conclusion, the measurement model demonstrates acceptable levels of indicator reliability, internal consistency, and convergent validity, ensuring that the constructs are psychometrically sound and appropriate for use in the subsequent structural model analysis.

Table 2. Result of outer model

Model	Cronbach's alpha	rho_A	Composite reliability	AVE
Attitude	0.908	0.908	0.935	0.783
Behavioral intention	0.826	0.835	0.897	0.743
Content quality	0.941	0.941	0.958	0.850
Perceived behavioral control	0.872	0.878	0.913	0.724
Perceived ease of use	0.817	0.821	0.879	0.645
Perceived usefulness	0.792	0.804	0.865	0.618
Subjective norm	0.844	0.859	0.905	0.761

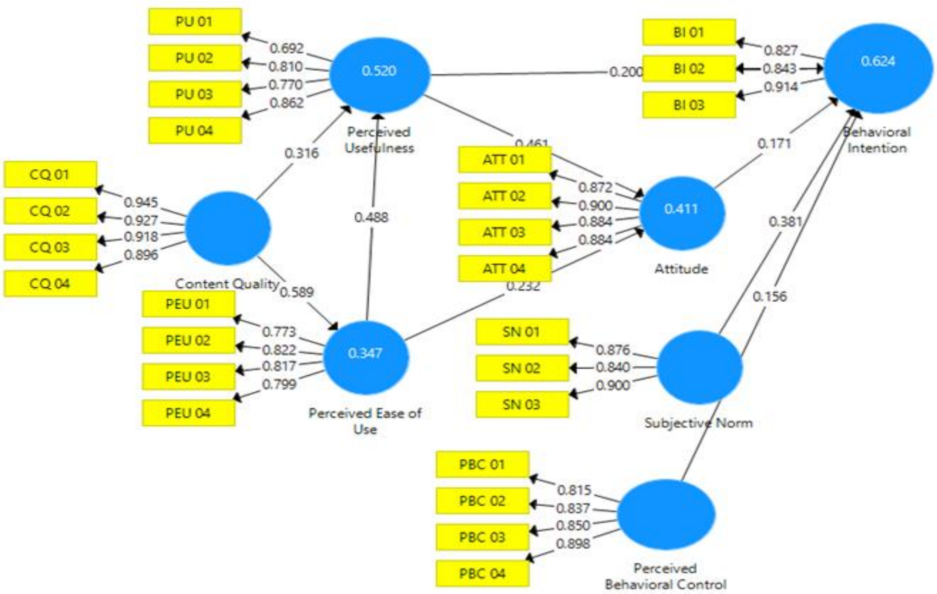

Figure 3. Visual representation of the outer model

2.3.2. Inner model based on t-statistics and path coefficients

The inner model analysis examined the relationships between constructs and the model's predictive power using path coefficients and R^2 values with a bootstrapping procedure of 5,000 resamples. The results indicated that all proposed hypotheses (H1–H9) were statistically supported as shown in Table 3. Attitude significantly influenced behavioral intention (β=0.171; t=2.506; p=0.013), suggesting that positive attitudes toward asynchronous learning increase students' intention to use it. Content quality significantly affected both perceived ease of use (β=0.589; p<0.001) and perceived usefulness (β=0.316; p<0.001), indicating that CTML-based instructional video design enhances perceptions of usability and usefulness. Perceived ease of use also influenced attitude (β=0.232; p=0.005) and perceived usefulness (β=0.488; p<0.001), while perceived usefulness positively affected attitude (β=0.461; p<0.001) and behavioral intention (β=0.200; p=0.003). In addition, perceived behavioral control (β=0.156; p=0.034) and subjective norm (β=0.381; p<0.001) significantly influenced behavioral intention. The R^2 value for behavioral intention was 0.624, indicating that the integrated TAM-TPB-CTML model explains 62.4% of the variance in students' intentions to adopt asynchronous video-based learning.

Table 3. Result of hypothesis and inner model

No	Hypothesis	Relationship	Path coefficient	t-values	p-values	Hypothesis (yes/no)
1	H1	Attitude → behavioral intention	0.171	2.506	0.013	Yes
2	H2	Content quality → perceived ease of use	0.589	12.588	0	Yes
3	H3	Content quality → perceived usefulness	0.316	4.935	0	Yes
4	H4	Perceived behavioral control → behavioral intention	0.156	2.122	0.034	Yes
5	H5	Perceived ease of use → attitude	0.232	2.809	0.005	Yes
6	H6	Perceived ease of use → perceived usefulness	0.488	7.493	0	Yes
7	H7	Perceived usefulness → attitude	0.461	5.643	0	Yes
8	H8	Perceived usefulness → behavioral intention	0.2	2.939	0.003	Yes
9	H9	Subjective norm → behavioral intention	0.381	5.245	0	Yes

2.3.3. Discriminant validity: Fornell and Larcker criterion

Discriminant validity was assessed using the criterion, which compares the square root of the AVE of each construct to its correlations with other constructs [41]. As shown in Table 4, the square root of the AVE for each construct (displayed on the diagonal) exceeds the correlation between that construct and all other latent variables. For instance, the square root of AVE for attitude is 0.885, greater than its correlation with behavioral intention (0.645) and other constructs. Similarly, all other constructs demonstrate this pattern, indicating that each construct shares more variance with its indicators than with other constructs. This result confirms that the model satisfies the discriminant validity requirement, indicating that all latent variables are empirically distinct and that the measurement model is valid and reliable for further analysis.

Table 4. Result of discriminant validity

Variables	Attitude	Behavioral intention	Content quality	Perceived behavioral control	Perceived ease of use	Perceived usefulness	Subjective norm
Attitude	0.885						
Behavioral intention	0.645	0.862					
Content quality	0.567	0.597	0.922				
Perceived behavioral control	0.685	0.669	0.660	0.851			
Perceived ease of use	0.543	0.596	0.589	0.627	0.803		
Perceived usefulness	0.618	0.657	0.603	0.658	0.674	0.786	
Subjective norm	0.640	0.729	0.680	0.692	0.623	0.651	0.873

2.3.4. Structural model assessment

The structural model was evaluated based on path coefficients, coefficient of determination (R^2), predictive relevance (Q^2), and model fit indices. The R^2 values demonstrate that the model accounts for 62.4% of the variance in behavioral intention, 52.0% in perceived usefulness, 41.1% in attitude, and 34.7% in perceived ease of use. The results indicate moderate to strong explanatory power, especially for behavioral intention and perceived usefulness, which are key elements in the proposed paradigm. The details are shown in Table 5.

The blindfolding process was employed to evaluate predictive significance. All Q^2 values exceeded zero (attitude=0.318; behavioral intention=0.454; perceived ease of use=0.220; and perceived usefulness=0.314), signifying adequate predictive capacity for all endogenous constructs. The model fit was assessed via the standardized root mean square residual (SRMR). The SRMR value of 0.077 is beneath the suggested threshold of 0.08, indicating that the proposed model exhibits an acceptable level of fitness.

Table 5. Structural model evaluation

Construct	R^2	Q^2
Attitude	0.411	0.318
Behavioral intention	0.624	0.454
Perceived ease of use	0.347	0.220
Perceived usefulness	0.520	0.314

2.3.5. Mediation effects analysis

The mediation analysis indicates that content quality influences behavioral intention indirectly through multiple cognitive and attitudinal pathways. The indirect effect through perceived usefulness was β=0.063, while the sequential mediation through perceived ease of use and perceived usefulness was β=0.058. The total indirect effect of content quality on behavioral intention was β=0.144. As no direct path from content quality to behavioral intention was specified in the model, the influence can be interpreted as fully mediated through TAM and TPB constructs. The indirect effect of content quality on behavioral intention via perceived ease of use was statistically significant, indicating a partial mediation effect.

2.3.6. Common method bias

The first CMB test was conducted using Harman's single factor test with a single-construct confirmatory factor analysis (CFA) approach on SmartPLS software. The results of the analysis showed that the value of R^2 in each construct was in the range of 0.438 to 0.624. The variance of the data is not concentrated on a single construct, so it can be concluded that there is no dominance of one common factor in the research model. Thus, the data of this study does not show the existence of a common method bias problem. The mediation effects of content quality on behavioral intention are shown in Table 6.

Table 6. Mediation effects of content quality on behavioral intention

Mediation Path	Indirect effect (β)	t-value	p-value	Mediation type
Content quality→perceived ease of use→ behavioral intention	0.058	>1.96	<0.05	Partial mediation
Content quality→perceived usefulness→ behavioral intention	0.063	>1.96	<0.05	Partial mediation

3. RESULTS AND DISCUSSION

The importance of CTML becomes particularly salient in asynchronous learning environments, where instructor presence and real-time clarification are limited. In such contexts, learners rely heavily on the clarity and structure of instructional multimedia to regulate their own understanding. CTML-based design enhances cognitive fluency by reducing extraneous load and structuring information flow, thereby functioning as a substitute for immediate instructional guidance. This heightened reliance on cognitive design quality has important theoretical implications for understanding technology acceptance in asynchronous settings.

Specifically, the integration of CTML with TAM-TPB reshapes the causal logic of technology acceptance by positioning cognitive design quality as an upstream determinant of perception formation. Rather than viewing perceived usefulness and ease of use as isolated system evaluations, this model suggests that these perceptions are rooted in learners' cognitive processing experiences. In this framework, cognitive design precedes and conditions social-psychological mechanisms, thereby linking instructional theory with behavioral intention formation in a unified explanatory structure.

3.1. Structural relationships in the integrated model

The results indicate that CTML-based content quality significantly influences perceived ease of use and perceived usefulness, highlighting the importance of cognitively optimized instructional design in shaping students' perceptions of asynchronous learning systems. Unlike many previous TAM-TPB studies in e-learning that conceptualize content quality as a generic system attribute, the present study anchors this construct in specific multimedia learning principles derived from the CTML. According to CTML, instructional materials designed using principles such as signaling, coherence, and segmentation can reduce extraneous cognitive load and enhance cognitive processing efficiency [19], [36], [42]. In the asynchronous learning environments—where instructor guidance is limited—such design features become particularly important in supporting learners’ self-regulated understanding.

The findings further show that CTML-based design has a stronger influence on perceived ease of use than on perceived usefulness. This pattern suggests that when instructional videos are cognitively optimized, learners first experience improved processing fluency and reduced mental effort. Cognitive load theory explains that minimizing irrelevant information and structuring content into manageable segments allows learners to process information more efficiently [43]–[45]. Learners often interpret this processing fluency as system usability before translating it into judgments about instructional value. Similar patterns have been reported in prior digital learning studies, which demonstrate that well-designed multimedia materials enhance perceived usability and engagement in online learning platforms [46]–[48].

Consistent with classical TAM formulations, perceived ease of use significantly predicts perceived usefulness, indicating that systems perceived as easier to use are also perceived as more beneficial for learning tasks [49]. However, an important nuance emerges in the present study: perceived usefulness exerts a stronger influence on attitude than on behavioral intention directly. This suggests that usefulness primarily shapes evaluative judgment before influencing intention, supporting a layered mediation structure in which cognitive evaluations translate into attitudinal responses before affecting behavioral decisions. Similar mediation patterns have been identified in educational technology adoption studies, where perceived usefulness influences behavioral intention indirectly through attitudinal mechanisms.

The mediation results further clarify the mechanism through which instructional design influences technology acceptance. CTML-based content quality does not directly predict behavioral intention but operates indirectly through learners’ perceptions of ease of use and usefulness. This finding aligns with theoretical perspectives in cognitive load theory, which emphasize that instructional design affects behavioral outcomes by shaping mental effort and information processing efficiency [44], [45]. By empirically demonstrating these indirect pathways, the present study provides a cognitively grounded explanation of how multimedia design principles translate into acceptance-related perceptions and ultimately behavioral intention in asynchronous learning environments.

3.2. The role of social and behavioral factors

Beyond cognitive perceptions, the results highlight the importance of socio-psychological factors in shaping technology acceptance. Subjective norm and perceived behavioral control, derived from the TPB, both show significant effects on behavioral intention, with subjective norm demonstrating the strongest influence. This finding indicates that students’ adoption of asynchronous learning systems is strongly affected by perceived expectations from lecturers, peers, and institutional environments. Such results are consistent with TPB-based studies suggesting that social influence plays a critical role in shaping behavioral intention in educational contexts [15], [17]. In collectivist learning environments, behavioral decisions are often influenced not only by personal evaluation but also by expectations from important social groups, including instructors and peers [8].

Perceived behavioral control also significantly influences behavioral intention, indicating that students’ confidence in managing self-directed learning tasks contributes to their willingness to adopt asynchronous learning platforms. This finding aligns with prior research emphasizing the importance of self-regulation and digital competence in online learning environments [50]–[52]. When learners believe they possess sufficient skills and resources to navigate asynchronous systems independently, their intention to continue using such platforms increases. Overall, the integrated TAM-TPB-CTML model demonstrates substantial explanatory power, suggesting that combining cognitive instructional design theory with technology acceptance and behavioral frameworks provides a more comprehensive explanation of technology adoption in digital learning environments.

3.3. Practical implications for asynchronous learning design

The findings of this study provide several practical implications for instructional designers and higher education institutions seeking to enhance engagement with asynchronous learning platforms. First, instructional video development should systematically apply CTML principles to optimize cognitive processing. Segmentation strategies—such as dividing content into concise modules of approximately five to seven minutes—can help learners regulate cognitive load and maintain sustained attention. Signaling techniques, including visual highlights, structured headings, and verbal emphasis, can further guide learners toward essential information and improve comprehension [42], [53], [54]. At the same time, the coherence principle suggests that unnecessary graphics, background music, and excessive animation should be minimized to prevent cognitive overload.

Second, instructional designers should align multimedia elements with the modality principle by ensuring that narration complements visual content rather than duplicating on-screen text. This alignment supports efficient processing across verbal and visual channels, thereby enhancing perceived usability and instructional clarity [32]. Providing learner-control features—such as pause, replay, and navigational options—may further strengthen perceived ease of use by allowing students to regulate their learning pace within asynchronous environments.

Third, the strong influence of subjective norms indicates that technology acceptance is shaped not only by instructional design quality but also by institutional communication and social reinforcement. Lecturer endorsement of asynchronous modules, peer discussions linked to video content and clearly communicated participation expectations can strengthen students' behavioral intention to engage with asynchronous learning systems. In educational contexts where institutional authority and peer influence remain important, reinforcing positive normative expectations may significantly enhance technology adoption. Overall, the results suggest that effective asynchronous learning environments require an integrated approach that combines cognitively optimized instructional design with institutional support mechanisms. By aligning multimedia design practices, faculty development initiatives, and platform-level support systems with established multimedia learning principles, higher education institutions can strengthen both learning effectiveness and sustained technology acceptance in digital learning environments.

3.4. Limitations and future research

While this study provides theoretical and empirical contributions by integrating CTML with TAM and TPB, several limitations should be acknowledged. The sample was drawn from a single public university in Indonesia using purposive sampling, which may limit external validity since institutional culture, technological infrastructure, and digital readiness may vary across institutions and countries. The relatively strong influence of subjective norms may also reflect the collectivist socio-cultural context of Indonesian higher education, where behavioral decisions are shaped not only by personal evaluation but also by institutional expectations and peer influence. In addition, the cross-sectional design captures perceptions at a single point in time and does not allow causal inference or examination of how technology acceptance evolves as students gain experience with asynchronous learning. The study also relied on self-reported data collected through a single survey instrument, which may introduce potential common method bias despite procedural and statistical controls. Future research may therefore benefit from longitudinal designs, multi-source data such as platform usage logs or academic performance indicators, and the inclusion of additional psychological variables—such as self-efficacy, intrinsic motivation, or cognitive engagement—as well as contextual factors like prior online learning experience, academic discipline, and year of study to further strengthen the explanatory power of the integrated framework.

4. CONCLUSION

This study demonstrates that students' acceptance of asynchronous video-based learning is shaped not only by technological functionality or social influence but also by cognitively optimized instructional design. By positioning CTML-based content quality as a cognitive antecedent within an integrated TAM-TPB framework, the study advances the theoretical integration between multimedia learning theory and TAMs. The findings show that CTML-based instructional design influences behavioral intention indirectly through perceived ease of use and perceived usefulness, as multimedia design principles enhance cognitive fluency by reducing extraneous cognitive load and improving processing efficiency. These cognitive perceptions subsequently activate attitudinal and normative determinants that shape behavioral intention in asynchronous learning environments. The study extends CTML beyond its traditional focus on comprehension and retention to explain technology acceptance behavior and highlights cognitive fluency as a key mechanism linking instructional design with behavioral adoption in self-paced digital learning contexts. Practically, the findings suggest that applying CTML principles in asynchronous video design can support both learning effectiveness and sustained technology adoption, while future research should validate this integrative framework across diverse institutional contexts, employ longitudinal designs, and incorporate additional psychological variables to further refine multimedia-based TAMs in higher education.

FUNDING INFORMATION

Authors state no funding information.

AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author, [P], upon reasonable request. The data are not publicly available due to ethical considerations related to participant confidentiality and institutional regulations.

REFERENCES

[1] G. V. Davidson-Shivers, K. L. Rasmussen, and P. R. Lowenthal, *Web-based learning*, vol. 8, no. 3. Cham: Springer International Publishing, 2018.

[2] C. B. Hodges, S. Moore, B. B. Lockee, T. Trust, and M. A. Bond, "The difference between emergency remote teaching and online learning," in *Handbook of Research in Online Learning: Insights and Advances*, 2024, pp. 511–522.

[3] J. Stein and C. R. Graham, *Essentials for blended learning: a standards-based guide*, First Edit. New York: Taylor & Francis, 2014.

[4] W. Bao, "COVID-19 and online teaching in higher education: a case study of Peking University," *Human Behavior and Emerging Technologies*, vol. 2, no. 2, pp. 113–115, Apr. 2020, doi: 10.1002/hbe2.191.

[5] S. Dhawan, "Online learning: a panacea in the time of COVID-19 crisis," *Journal of Educational Technology Systems*, vol. 49, no. 1, pp. 5–22, Sep. 2020, doi: 10.1177/0047239520934018.

[6] A. Norberg, C. D. Dziuban, and P. D. Moskal, "A time-based blended learning model," *On the Horizon*, vol. 19, no. 3, pp. 207–216, Aug. 2011, doi: 10.1108/10748121111163913.

[7] L. R. Halverson, C. R. Graham, K. J. Spring, J. S. Drysdale, and C. R. Henrie, "A thematic analysis of the most highly cited scholarship in the first decade of blended learning research," *The Internet and Higher Education*, vol. 20, 2014, doi: 10.1016/j.iheduc.2013.09.004.

[8] M. O. Alassafi, "E-learning intention material using TAM: a case study," *Materials Today: Proceedings*, vol. 61, pp. 873–877, 2022, doi: 10.1016/j.matpr.2021.09.457.

[9] E. A. Hanushek, G. Schwerdt, L. Woessmann, and L. Zhang, "General education, vocational education, and labor-market outcomes over the lifecycle," *Journal of Human Resources*, vol. 52, no. 1, pp. 48–87, 2017, doi: 10.3368/jhr.52.1.0415-7074R.

[10] K. A. Austin, "Multimedia learning: cognitive individual differences and display design techniques predict transfer learning with multimedia learning modules," *Computers and Education*, vol. 53, no. 4, pp. 1339–1354, 2009, doi: 10.1016/j.compedu.2009.06.017.

[11] A. Pate and S. Posey, "Effects of applying multimedia design principles in PowerPoint lecture redesign," *Currents in Pharmacy Teaching and Learning*, vol. 8, no. 2, pp. 235–239, 2016, doi: 10.1016/j.cptl.2015.12.014.

[12] T. Bland, M. Guo, and T. A. Dousay, "Multimedia design for learner interest and achievement: a visual guide to pharmacology," *BMC Medical Education*, vol. 24, no. 1, p. 113, 2024, doi: 10.1186/s12909-024-05077-y.

[13] S. Benken, J. Mucksavage, R. Yudkowsky, D. Woo, M. Collins, and J. J. H. Cheung, "A multimedia evaluation of pharmacy faculty PowerPoint slides in a critical care course," *American Journal of Pharmaceutical Education*, vol. 87, no. 5, p. 100066, May 2023, doi: 10.1016/j.ajpe.2023.100066.

[14] F. D. Davis and V. Venkatesh, "A critical assessment of potential measurement biases in the technology acceptance model: three experiments," *International Journal of Human-Computer Studies*, vol. 45, no. 1, pp. 19–45, Jul. 1996, doi: 10.1006/ijhc.1996.0040.

[15] I. Ajzen, "The theory of planned behaviour: reactions and reflections," *Psychology & Health*, vol. 26, no. 9, pp. 1113–1127, Sep. 2011, doi: 10.1080/08870446.2011.613995.

[16] B. Šumak, M. Heričko, and M. Pušnik, "A meta-analysis of e-learning technology acceptance: the role of user types and e-learning technology types," *Computers in Human Behavior*, vol. 27, no. 6, pp. 2067–2077, Nov. 2011, doi: 10.1016/j.chb.2011.08.005.

[17] I. Ajzen, "Perceived behavioral control, self-efficacy, locus of control, and the theory of planned behavior," *Journal of Applied Social Psychology*, vol. 32, no. 4, pp. 665–683, Apr. 2002, doi: 10.1111/j.1559-1816.2002.tb00236.x.

[18] S. Taylor and P. A. Todd, "Understanding information technology usage: a test of competing models," *Information Systems Research*, vol. 6, no. 2, pp. 144–176, Jun. 1995, doi: 10.1287/isre.6.2.144.

[19] R. E. Mayer, "The past, present, and future of the cognitive theory of multimedia learning," *Educational Psychology Review*, vol. 36, no. 1, p. 8, Mar. 2024, doi: 10.1007/s10648-023-09842-1.

[20] K. K. Kanmodi *et al.*, "The understanding of digital communication experts and oral cancer at-risk persons on oral cancer, their uptake of educational mobile health applications on oral cancer, and their opinions on how a good application of such should look like: findings from," *BMC Oral Health*, vol. 25, no. 1, p. 224, Feb. 2025, doi: 10.1186/s12903-025-05614-1.

[21] J.-J. Boté-Vericad, "Information-seeking and content creation: the impact of YouTube educational videos on learning practices in library and information science," *Journal of Librarianship and Information Science*, vol. 58, no. 1, pp. 270–284, Mar. 2026, doi: 10.1177/09610006241309102.

[22] R. AlShaikh, N. Al-Malki, and M. Almasre, "The implementation of the cognitive theory of multimedia learning in the design and evaluation of an AI educational video assistant utilizing large language models," *Heliyon*, vol. 10, no. 3, p. e25361, Feb. 2024, doi: 10.1016/j.heliyon.2024.e25361.

[23] J. Quinn and F. Darby, "The learner-centered instructional designer," in *Purposes, Processes, and Practicalities of Creating Online Courses in Higher Education*, New York: Routledge, 2023.

[24] S. Islam, M. Islam, A. K. Tamanna, M. N. Sakib, A. L. Aziz, and M. Fahlevi, "The potential of online learning: investigating pre-use expectations, intentions, actual use and post-use outcomes in massive open online courses (MOOCs)," *Cogent Psychology*, vol. 12, no. 1, Dec. 2025, doi: 10.1080/23311908.2025.2500157.

[25] L. Lai, L. She, and C. Li, "Online teaching model in the context of blended learning environment: experiential learning and TAM," *Education and Information Technologies*, vol. 29, no. 13, pp. 17235–17259, Sep. 2024, doi: 10.1007/s10639-024-12465-w.

[26] F. D. Davis, "A technology acceptance model for empirically testing new end-user information systems," Massachusetts Institute of Technology, 1985.

[27] S. O'Connor, S. Kennedy, Y. Wang, A. Ali, S. Cooke, and R. G. Booth, "Theories informing technology enhanced learning in nursing and midwifery education: a systematic review and typological classification," *Nurse Education Today*, vol. 118, p. 105518, Nov. 2022, doi: 10.1016/j.nedt.2022.105518.

[28] H. Luo and W. Li, "Impact of microlearning on developing soft skills of university students across disciplines," *Frontiers in Psychology*, vol. 16, Apr. 2025, doi: 10.3389/fpsyg.2025.1491265.

[29] Y. Yao, P. Wang, Y. Jiang, Q. Li, and Y. Li, "Innovative online learning strategies for the successful construction of student self-awareness during the COVID-19 pandemic: Merging TAM with TPB," *Journal of Innovation & Knowledge*, vol. 7, no. 4, p. 100252, Oct. 2022, doi: 10.1016/j.jik.2022.100252.

[30] A. M. Al-Abdullatif and A. A. Gameil, "The effect of digital technology integration on students' academic performance through project-based learning in an e-learning environment," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 11, p. 189, Jun. 2021, doi: 10.3991/ijet.v16i11.19421.

[31] A. M. Sayaf, M. M. Alamri, M. A. Alqahtani, and W. M. Alrahmi, "Factors influencing university students' adoption of digital learning technology in teaching and learning," *Sustainability*, vol. 14, no. 1, p. 493, Jan. 2022, doi: 10.3390/su14010493.

[32] L. Fiorella and R. E. Mayer, "Eight ways to promote generative learning," *Educational Psychology Review*, vol. 28, no. 4, pp. 717–741, Dec. 2016, doi: 10.1007/s10648-015-9348-9.

[33] G. Schettino, L. Hodačová, D. Caso, and V. Capone, "Physicians' adoption of massive open online courses content in the workplace: an investigation on the training transfer process through the theory of planned behavior," *Computers in Human Behavior*, vol. 154, no. May 2023, p. 108151, May 2024, doi: 10.1016/j.chb.2024.108151.

[34] N. Shaya, R. Madani, and L. Mohebi, "An application and extension of the UTAUT model factors influencing behavioral intention to utilize mobile learning in UAE higher education," *Journal of Interactive Learning Research*, vol. 34, no. 1, pp. 153–180, 2023, doi: 10.70725/172931cofjid.

[35] M. S. S. Siqueira, P. O. Nascimento, and A. P. Freire, "Reporting behaviour of people with disabilities in relation to the lack of accessibility on government websites: analysis in the light of the theory of planned behaviour," *Disability, CBR & Inclusive Development*, vol. 33, no. 1, p. 52, May 2022, doi: 10.47985/dcidj.475.

[36] R. E. Mayer, "Incorporating motivation into multimedia learning," *Learning and Instruction*, vol. 29, pp. 171–173, Feb. 2014, doi: 10.1016/j.learninstruc.2013.04.003.

[37] F. D. Davis, "User acceptance of information technology: system characteristics, user perceptions and behavioral impacts," *International Journal of Man-Machine Studies*, vol. 38, no. 3, pp. 475–487, Mar. 1993, doi: 10.1006/imms.1993.1022.

[38] F. D. Davis, R. P. Bagozzi, and P. R. Warshaw, "User acceptance of computer technology: a comparison of two theoretical models," *Management Science*, vol. 35, no. 8, pp. 982–1003, Aug. 1989, doi: 10.1287/mnsc.35.8.982.

[39] J. F. Hair Jr., L. M. Matthews, R. L. Matthews, and M. Sarstedt, "PLS-SEM or CB-SEM: updated guidelines on which method to use," *International Journal of Multivariate Data Analysis*, vol. 1, no. 2, p. 107, 2017, doi: 10.1504/IJMDA.2017.087624.

[40] J. Hair, C. L. Hollingsworth, A. B. Randolph, and A. Y. L. Chong, "An updated and expanded assessment of PLS-SEM in information systems research," *Industrial Management & Data Systems*, vol. 117, no. 3, 2017, doi: 10.1108/IMDS-04-2016-0130.

[41] C. Fornell and D. F. Larcker, "Structural equation models with unobservable variables and measurement error: algebra and statistics," *Journal of Marketing Research*, vol. 18, no. 3, pp. 382–388, 1981.

[42] J. G. Cromley and R. Chen, "A meta-analysis of Richard Mayer's multimedia learning research: Searching for boundary conditions of design principles across multiple media types," *Educational Research Review*, vol. 49, 2025, doi: 10.1016/j.edurev.2025.100730.

[43] P. Evans, M. Vansteenkiste, P. Parker, A. Kingsford-Smith, and S. Zhou, "Cognitive load theory and its relationships with motivation: a self-determination theory perspective," *Educational Psychology Review*, vol. 36, no. 1, 2024, doi: 10.1007/s10648-023-09841-2.

[44] J. Sweller, "Cognitive load theory and individual differences," *Learning and Individual Differences*, vol. 110, p. 102423, Feb. 2024, doi: 10.1016/j.lindif.2024.102423.

[45] P. A. Kirschner, J. Sweller, F. Kirschner, and J. Zambrano R., "From cognitive load theory to collaborative cognitive load theory," *International Journal of Computer-Supported Collaborative Learning*, vol. 13, no. 2, 2018, doi: 10.1007/s11412-018-9277-y.

[46] I. Adhayanti and S. R. Pakadang, "Development of a medicinal chemistry e-module using a team-based learning strategyDevelopment of a medicinal chemistry e-module using a team-based learning strategy," *JINoP (Jurnal Inovasi Pembelajaran)*, vol. 11, no. 1, pp. 1–14, May 2025, doi: 10.22219/jinop.v11i1.28934.

[47] I. Pérez-Porta *et al.*, "Adding multimedia animations to exercise therapy provides no additional benefit for rotator cuff–related shoulder pain: a randomized clinical trial," *Journal of Clinical Medicine*, vol. 14, no. 22, 2025, doi: 10.3390/jcm14227964.

[48] R. SissyLia, S. M. Siahaan, and A. Fathurohman, "Analysis of the needs for the development of interactive multimedia based on augmented reality in physics learning," *Journal Evaluation in Education (JEE)*, vol. 6, no. 1, 2024, doi: 10.37251/jee.v6i1.1287.

[49] V. Venkatesh and F. D. Davis, "A theoretical extension of the technology acceptance model," *Management Science*, vol. 46, no. 2, pp. 186–205, 2000.

[50] C. van Dorresteijn *et al.*, "What factors contribute to effective online higher education? A meta-review," *Technology, Knowledge and Learning*, vol. 30, no. 1, pp. 171–202, Mar. 2025, doi: 10.1007/s10758-024-09750-5.

[51] I. Tymchuk, S. Pohorila, V. Kaplinskyi, O. Popov, and N. Derstuganova, "Enhancing online learning quality through digital competencies of students," *Salud, Ciencia y Tecnología - Serie de Conferencias*, vol. 3, Aug. 2024, doi: 10.56294/sctconf2024.1128.

[52] X. Yang and J. Du, "The effect of teacher self-efficacy, online pedagogical and content knowledge, and emotion regulation on teacher digital burnout: a mediation model," *BMC Psychology*, vol. 12, no. 1, p. 51, Jan. 2024, doi: 10.1186/s40359-024-01540-z.
[53] P. G. Schrader and E. E. Rapp, "Does multimedia theory apply to all students? The impact of multimedia presentations on science learning," *Journal of Learning and Teaching in Digital Age (JOLTIDA)*, vol. 1, no. 1, pp. 32–46, 2016.
[54] J. Buchner, "How to create educational videos: from watching passively to learning actively," *R&E Source*, vol. 12, pp. 1–10, 2018.

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