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Research Management Cell,
Tribhuvan University, Sanothimi Campus, Sanothimi, Bhaktapur

Implications of Cognitive Learning Theory in ICT Education

Suresh Bahadur Diyal (Principal Author)
suresh.diyal@sac.tu.edu.np
Teaching Assistant, Department of ICT Education,
Sanothimi, Campus Sanothimi, Bhaktapur, TU, Nepal
ORCID: https://orcid.org/0009-0005-8329-4829

*Vijaya Malla (*Corresponding author)
vijaya.malla@sac.tu.edu.np
Teaching Assistant, Department of ICT Education
Sanothimi, Campus Sanothimi, Bhaktapur, TU, Nepal
ORCID iD: *https://orcid.org/0009-0006-3223-1841*

Abstract

This study examines how Cognitivist Learning Theory can be effectively applied in ICT education through the use of digital tools. While cognitivism emphasizes internal mental processes like attention, memory, and metacognition, its integration into technology-enhanced pedagogy, especially in developing contexts, remains underexplored. This mixed-method study utilized survey data from 65 ICT teachers, interviews with 12 instructors, and classroom observations in 10 Nepalese tertiary institutions. Data analysis focused on cognitivist principles such as schema activation, cognitive load management, metacognition, and learner motivation. Findings reveal that ICT tools, when aligned with cognitive principles, act as effective cognitive scaffolds. Teachers reported using multimedia, simulations, adaptive quizzes, gamified dashboards, and reflection journals to activate prior knowledge, manage cognitive load, and foster self-regulated learning. Observations confirmed improved conceptual organization, sustained attention, and learner persistence, though risks of cognitive overload from excessive multimedia were noted. The study identifies personalization, scaffolding, and timely feedback as crucial for strengthening cognitive engagement. This research contributes an implementation model and practical insights for integrating cognitivism into digital pedagogy, transforming ICT from a passive medium into an active enabler of deep learning.

Keywords*: Cognitivism, ICT education, cognitive load, multimedia learning, metacognition, schema theory.*

Introduction

The rapid integration of Information and Communication Technology (ICT) has profoundly reshaped educational paradigms, moving beyond traditional teacher-centric models towards dynamic, learner-focused environments (Sangrà & González-Sanmamed, 2010). Digital tools, including adaptive learning platforms, multimedia simulations, and Learning Management Systems (LMS), are increasingly leveraged to foster active learning, engagement, and higher-order thinking (Ertmer & Newby, 2013). Yet, while technology's role in pedagogy is evident, the underlying cognitive mechanisms through which learning occurs remain paramount (Bruner, 1966; Anderson, 1980). Cognitive psychology posits that learning involves

intricate mental processes such as attention, perception, memory, and metacognition, which are distinct from mere information transmission.

Meaningful learning, as Ausubel (1968) argued, relies on learners' ability to integrate new information with existing knowledge structures. Similarly, Sweller's Cognitive Load Theory (1988) highlights the critical role of working memory management in effective problem-solving and schema formation. These cognitive insights are particularly salient in ICT-rich learning environments, where digital tools can serve as powerful scaffolds to visualize abstract concepts, manage cognitive load, and facilitate deeper knowledge construction (Mayer, 2001; Fiorella & Mayer, 2015). Consequently, ICT should not be viewed as a mere delivery mechanism but as a strategic enabler of cognitive processes (Mooij, 2008).

In specialized fields like ICT education, learners frequently encounter abstract and layered concepts such as algorithms, network protocols (e.g., subnetting), or database normalization, which can present significant cognitive demands. Therefore, aligning digital instructional design with established cognitive principles is not just beneficial but crucial for effective learning outcomes (Paas, 2020; de Jong, 2010). This alignment ensures that technology use is theoretically grounded, optimizing mental processing rather than merely digitizing existing practices. Several constructs remain highly relevant in contemporary ICT pedagogy. Sweller's (1988) Cognitive Load Theory stresses that instructional design must reduce extraneous load and optimize germane processing for effective schema construction. For instance, in an ICT context, breaking down complex coding problems into smaller, manageable modules in an IDE (Integrated Development Environment) reduces extraneous cognitive load. Mayer's (2001) Cognitive Theory of Multimedia Learning further demonstrated that dual-channel processing, involving both visual and verbal modes, strengthens comprehension and retention (Fiorella & Mayer, 2018; Mayer, 2021). An example from ICT education would be using animated network diagrams with synchronized audio explanations to teach network topologies, rather than static text descriptions. Equally significant, Flavell's (1979) work on metacognition highlighted the learner's ability to monitor and regulate strategies, while Zimmerman (2002) extended this understanding by linking self-regulated learning with long-term achievement. In an ICT classroom, this could involve students using debugging tools to identify errors in their code, then reflecting on the process to improve their problem-solving strategy.

Cognitivism as a theoretical paradigm emerged in the mid-20th century as a response to the limitations of behaviorism, emphasizing the internal mental processes that shape learning. Learners are conceptualized not as passive recipients of information but as active processors who organize new knowledge into schemas and integrate it into existing cognitive structures (Anderson, 1980; Bruner, 1966). Several constructs remain highly relevant in contemporary ICT pedagogy. Sweller's (1988) Cognitive Load Theory stresses that instructional design must reduce extraneous load and optimize germane processing for effective schema construction. Mayer's (2001). Cognitive Theory of Multimedia Learning further demonstrated that dual-channel processing, involving both visual and verbal modes, strengthens comprehension and retention (Fiorella & Mayer, 2018; Mayer, 2021). Equally significant, Flavell's (1979) work on metacognition highlighted the learner's ability to monitor and regulate strategies, while Zimmerman (2002) extended this understanding by linking self-regulated learning with long-term achievement. More recent studies confirm that these cognitive processes remain central in digital environments. Liaw and Huang (2013) found that interactive ICT platforms enhanced learner motivation, metacognitive awareness, and knowledge retention, while Chiu and Churchill (2022) demonstrated that embedding metacognitive prompts in online courses significantly strengthened reflective learning. Adaptive systems, drawing directly on cognitive load principles, personalize complexity to learners' cognitive capacities and reduce overload (Kang & Kim, 2022; El-Sabagh, 2021).

Empirical studies increasingly affirm that ICT can function as a cognitive scaffold. Liaw and Huang (2013) reported that ICT-enhanced environments improved learner self-regulation and satisfaction. Mooij (2008) found that ICT-based environments, when designed for self-regulated learning, fostered learner autonomy and strategic thinking. Zheng et al. (2023) demonstrated that cognitive–motivational engagement mediates the relationship between ICT and achievement, highlighting how technology supports both affective and cognitive domains. Specific ICT applications align directly with cognitivist principles. Multimedia and visualization tools aid schema construction by externalizing abstract processes (Lindner, Schult, & Mayer, 2022). Simulations and animations reduce extraneous cognitive load by illustrating abstract systems step by step, which helps learners focus on essential processes (Fiorella & Mayer, 2020). Gamified learning systems foster persistence and engagement, motivating students to sustain cognitive effort (Huang, Hew, & Lo, 2022; Sailer & Homner, 2020). Adaptive platforms allow teachers to differentiate pathways based on learner performance, ensuring that students operate within their Zone of Proximal Development (Holmes, Porayska-Pomsta, & Holstein, 2021; Kang & Kim, 2022). In ICT education specifically, where abstract and layered topics are common, these affordances are particularly valuable. For example, animations of CPU–RAM interaction reduce memory load compared to text-based explanations (Mayer, 2001; Fiorella, 2023). Feedback-rich systems like Moodle quizzes or Google Forms support iterative self-regulation, consistent with Flavell's (1979) concept of metacognition.

Despite these advances, the cognitivist paradigm remains underexplored in ICT pedagogy relative to constructivist and behaviorist approaches (Ertmer & Newby, 2013; Zheng et al., 2023). Studies on digital pedagogy often foreground collaboration, discovery learning, or reinforcement, but fewer explicitly investigate cognitive mechanisms such as schema activation, cognitive load management, or metacognitive monitoring. This imbalance is particularly problematic in ICT education, where the content is abstract and cognitively demanding. Furthermore, much of the empirical evidence originates in developed contexts such as Europe, North America, and East Asia, leaving a notable absence of research in developing countries. In Nepal, for instance, ICT integration is expanding across heigher education, but teachers often adopt digital tools without explicit alignment to cognitive learning theory. This lack of theoretical grounding risks limiting the pedagogical effectiveness of ICT integration (Sangrà & González-Sanmamed, 2010; Mooij, 2008). There is therefore a pressing need for empirical research that investigates how cognitivist principles can be embedded into ICT education in the Nepalese context, where diverse learner backgrounds, infrastructural challenges, and limited teacher preparation create unique constraints.

The present study seeks to address these gaps by examining how Cognitivist Learning Theory can be applied in ICT education through digital tools. It pursues four main objectives. First, it investigates how ICT tools support cognitive processes such as attention, memory, schema activation, and metacognitive regulation. Second, it identifies strategies that teachers employ to align ICT use with cognitive principles, including advance organizers, multimedia scaffolds, feedback mechanisms, and adaptive personalization. Third, it explores the risks and challenges of ICT integration, particularly the problem of cognitive fatigue arising from excessive multimedia use. Finally, it proposes a practical implementation framework that translates cognitivist principles into actionable strategies for teachers, institutions, and policymakers.

This study makes several contributions to theory, practice, and policy, directly addressing its core objectives. Theoretically, it advances the underexplored relationship between Cognitivism and ICT pedagogy (objective 1), offering a structured framework for integrating cognitive principles into digital instruction. Empirically, it contributes evidence from Nepalese ICT classrooms, expanding the global conversation with insights from a

developing country context. Practically, it proposes a framework of strategies (objective 2) including advance organizers, multimedia scaffolding, metacognitive prompts, gamification, and adaptive learning that can guide teachers in designing cognitively supportive ICT learning environments. It also sheds light on the risks and challenges of ICT integration, such as cognitive fatigue (objective 3). More broadly, this research emphasizes that ICT should not be seen simply as a technological add-on but as a strategic scaffold for enhancing cognitive processes. By situating ICT within a cognitivist framework, it aims to inform curriculum design, teacher professional development, and education policy, ensuring that technology integration fosters not only engagement but also deeper, transferable, and sustainable learning outcomes, culminating in a practical implementation framework (objective 4).

Theoretical Framework

Cognitivist learning theory emphasizes the crucial role of internal mental processes such as attention, memory, schema activation, and metacognition in knowledge acquisition. Unlike behaviorism, which views learning as a response to external stimuli, cognitivism, championed by figures like Jean Piaget and Jerome Bruner, posits that learners are active processors of information. As Bruner (1966) noted, "to instruct someone in these disciplines is not a matter of getting him to learn facts and techniques... rather, it is a matter of leading him to think," emphasizing the construction of internal representations. David Ausubel (1968) further elaborated on meaningful learning, asserting that "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly," highlighting the importance of connecting new material to existing cognitive structures or schemas (Anderson, 1980).

Classic models profoundly influence contemporary instructional design. John Sweller's Cognitive Load Theory (1988) stresses the importance of minimizing extraneous load and optimizing germane load for effective schema development, stating that "Instructional procedures should avoid imposing extraneous cognitive load on working memory." Similarly, Richard Mayer's Cognitive Theory of Multimedia Learning (2001) underscores the role of dual-channel processing in enhancing comprehension, summarized by his "multimedia principle" that "students learn better from words and pictures than from words alone." Additionally, Flavell (1979) conceptualized metacognition as "knowledge and cognition about cognitive phenomena," emphasizing the learner's ability to monitor and regulate their own strategies. Barry Zimmerman (2002) further extended this, defining self-regulated learning as "self-generated thoughts, feelings, and actions that are cyclically adapted to the attainment of personal goals," thereby linking metacognitive control with long-term academic achievement."

More recent scholarship has expanded these ideas into digital learning contexts. Zheng et al. (2023) demonstrated that ICT-enhanced environments can regulate cognitive-motivational engagement, improving academic outcomes. Similarly, Chiu and Churchill (2022) found that metacognitive scaffolds embedded within online learning platforms significantly enhanced self-regulated learning. The central implication is that digital tools, when aligned with cognitivist principles, can optimize learners' internal processing, resulting in deeper comprehension and retention.

Methodology

This study adopted a mixed-methods design to explore how ICT tools are implemented within a cognitivist framework in Nepalese higher education. 65 ICT teachers ware selected from colleges and universities participated in surveys and, from them, conduct the interviews with 12 instructors, which examined their use of digital tools to support schema activation, cognitive load management, metacognitive regulation, motivation, and personalization. The survey combined closed and open-ended items, allowing for both quantitative trends and qualitative insights. To gain a deeper understanding of pedagogical reasoning and challenges,

semi-structured interviews were conducted with a subset of teachers, highlighting strategies such as multimedia use for load reduction, feedback for metacognition, and gamification for engagement.

Additionally, ten classroom observations were carried out to document real-time ICT integration, confirming reported practices while also revealing inconsistencies. Data analysis employed descriptive statistics, thematic coding, and triangulation across methods to ensure reliability and contextual grounding. Ethical protocols, including informed consent, confidentiality, and voluntary participation, were strictly followed. Together, these methods provided a well-rounded picture of how ICT teachers in Nepal apply digital tools to enhance cognitive learning processes.

Results and Discussion

This section presents findings organized around core cognitivist principles: schema activation, cognitive load management, metacognition, motivational engagement, and personalization. Data from surveys (n = 65), interviews (n = 12), and classroom observations (n = 10) were triangulated to generate thematic insights.

Schema Activation and Conceptual Organization

Teachers widely used digital whiteboards, mind maps, and visual presentations to link new concepts with prior knowledge. For instance, subnetting lessons often began with IP addressing simulations, enabling learners to activate existing schemas and ease transitions into new topics.

- **Observation Example***: "In an operating systems class, concept-mapping software helped students connect components (kernel, memory management, I/O), supporting schema construction*."

Table 1: ICT Tools for Schema Activation

ICT Tool	Cognitive Function	Example Use in Classrooms	Supporting Literature
Mind-mapping software	Schema activation, recall	Linking OS components	Lai et al., 2022
Simulations (IP tools)	Retrieval, transfer	Subnetting introduction	Ausubel, 1968
Digital whiteboards	Visual schema reinforcement	Revising prior topics	Zheng et al., 2023

These findings align with Ausubel's theory of meaningful learning (1968), emphasising advance organisers for schema activation. International evidence supports this approach: Lai et al. (2022) found that visualization tools in STEM significantly improved conceptual transfer.

Cognitive Load Management via Multimedia Learning

Multimedia tools (short screencasts, simulations, animations) were central in reducing extraneous cognitive load**.** Teachers observed that visual demonstrations of CPU–RAM interaction enhanced learner focus. However, overuse of multimedia led to fatigue, echoing Sweller's cognitive load theory (1988).

- **Teacher Quote:** *"Too many videos back-to-back actually tire them out. I've learned to space them out and include discussions."*

This is consistent with Mayer's multimedia learning principles (2001) and supported by Fiorella & Mayer (2020), who advocate segmenting multimedia content to optimize germane load.

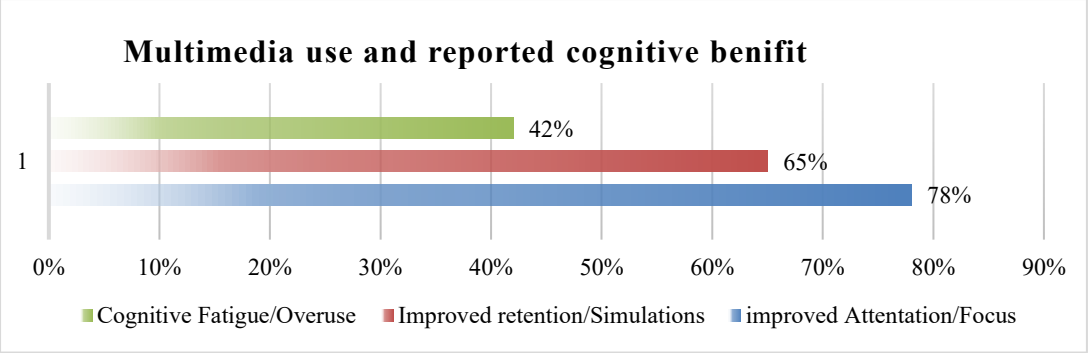

Figure 1: Multimedia Use and Reported Cognitive Benefits

The survey data (n = 65) highlights that multimedia use in ICT education has clear cognitive benefits but also presents challenges. A large majority of teachers (78%) reported that multimedia improved students' attention and focus, indicating its strong potential for managing cognitive engagement. Similarly, 65% of teachers observed that simulations enhanced retention, supporting Mayer's (2001) dual-channel processing principle. However, 42% cautioned that excessive reliance on multimedia led to cognitive fatigue, suggesting the need for careful design and balanced integration. These findings confirm that while multimedia is an effective cognitive scaffold, its impact depends on moderation and instructional alignment with cognitive load principles.

Metacognition Support through Feedback and Reflection

Feedback-driven ICT tools (Google Forms, Moodle quizzes, Quizziz) were widely used to support self-regulated learning. Students benefited from multiple attempts with immediate explanations, fostering metacognitive regulation.

- **Student Reflection:** *"I realized I was confusing IP classes with subnet masks. After two quiz attempts and reviewing explanations, it finally clicked."*

This aligns with Flavell's metacognition model (1979) and Zimmerman's (2002) theory of self-regulated learning. Recent studies confirm similar benefits: Chiu & Churchill (2022) found that metacognitive prompts in LMS platforms improved reflective thinking in higher education.

Cognitive-Motivational Engagement and Academic Outcomes

Gamified ICT elements (badges, leaderboards, dashboards) enhanced student persistence. Observations revealed quiet students excelling in online quizzes, supporting the role of ICT in **reducing participation anxiety**.

- **Teacher Observation:** *"Some students who never spoke in class are now top scorers in online quizzes."*

This demonstrates the synergy of cognitive effort and motivation, echoing Zheng et al. (2023), who showed that ICT fosters achievement via cognitive motivational engagement. International research by Huang et al. (2022) confirms gamification's role in sustaining learner effort.

Personalization and Differentiation through Adaptive Tools

Adaptive ICT tools enabled differentiated instruction. Teachers used LMS conditional release features to redirect weaker students to remedial content while allowing advanced learners to attempt challenges. This personalisation reflects Vygotsky's Zone of Proximal Development (applied within a cognitivist framework). Global evidence supports this: AI-based adaptive learning has been shown to reduce overload and improve mastery (Kang & Kim, 2022; Holmes et al., 2021).

Table 2: ICT-Supported Cognitivist Practices in Nepal vs. Global Findings

Cognitivist Principle	Nepalese Classroom Practice	International Evidence
Schema activation	Mind maps, simulations	Lai et al., 2022
Load management	Short screencasts, animations	Fiorella & Mayer, 2020
Metacognition	Quizzes with multiple attempts, reflections	Chiu & Churchill, 2022
Engagement	Gamified quizzes, dashboards	Huang et al., 2022; Zheng et al., 2023
Personalization	LMS conditional release	Kang & Kim, 2022; Holmes et al., 2021

The table illustrates how Nepalese classroom practices in ICT education align closely with established cognitivist principles and are consistent with international evidence. For schema activation, teachers frequently used mind maps and simulations to connect new concepts with prior knowledge, reflecting findings by Lai et al. (2022) on the effectiveness of visualization tools. In terms of load management, short screencasts and animations were employed to simplify complex topics, which corresponds to Fiorella and Mayer's (2020) recommendations on segmenting multimedia to reduce extraneous cognitive load. Metacognition was supported through multiple quiz attempts and reflection activities, echoing Chiu and Churchill's (2022) evidence that feedback-rich digital environments enhance reflective thinking. Likewise, student engagement was strengthened through gamified quizzes and dashboards, consistent with Huang et al. (2022) and Zheng et al. (2023), who emphasize the motivational role of gamification. Finally, personalization was facilitated through conditional release features in Implementation Framework The study findings suggest that ICT tools, when guided by cognitivist principles, can be deliberately structured to enhance mental processing and long-term learning outcomes. This section synthesizes those findings into a practical implementation framework that connects theory, pedagogy, and technology. learning management systems, aligning with global findings that adaptive systems improve differentiation and learner autonomy (Kang & Kim, 2022; Holmes et al., 2021). Overall, the convergence of Nepalese practices with international evidence suggests that cognitivist principles can be effectively implemented in diverse contexts through ICT.Practical The framework emphasizes strategies for activating prior knowledge, managing cognitive load, fostering metacognition, enhancing motivation and engagement, and personalizing learning pathways. Each strategy is linked with empirical evidence and pedagogical theory, providing both teachers and policymakers with actionable insights.

A fundamental principle of cognitivism is that new knowledge is best understood when linked to existing schemas. Teachers can facilitate this by using digital advance organizers such as concept maps, recap quizzes, and short review videos at the start of lessons. These tools enable learners to recall prior concepts and establish connections with upcoming material, thereby reducing abstraction and promoting meaningful learning. For example, an ICT teacher introducing subnetting may begin with an interactive simulation of IP addressing to reactivate earlier knowledge, which in turn makes the transition to complex topics smoother. Such strategies align with Ausubel's (1968) meaningful learning theory, which emphasizes the importance of anchoring new knowledge in prior cognitive structures.

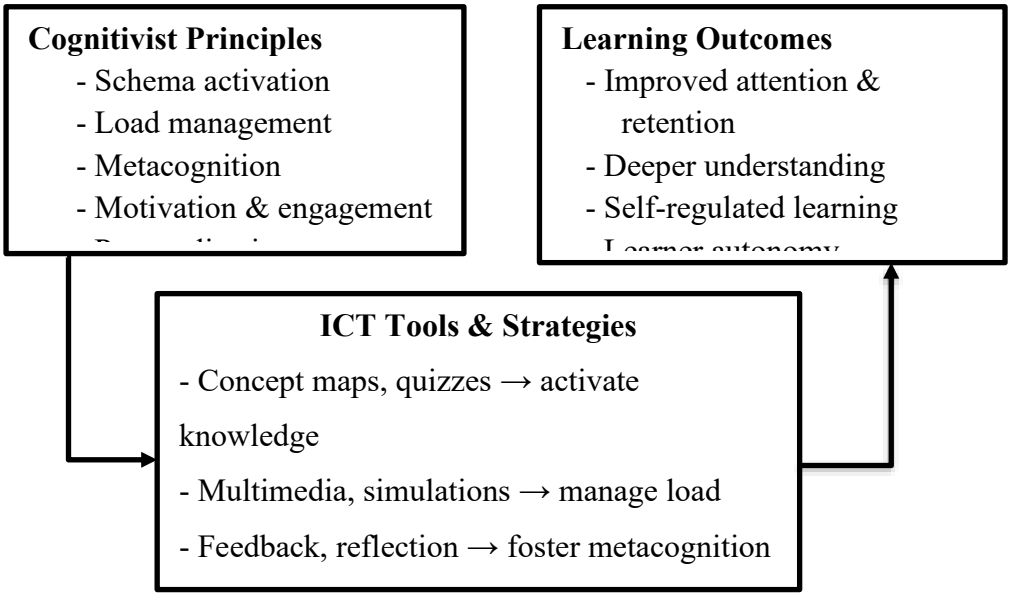

Figure 2: Cognitivist ICT Implementation Framework

Managing Cognitive Load

ICT subjects often involve abstract and technically dense material, making cognitive load management a critical instructional priority. Segmented multimedia resources such as screencasts, flow animations, and simulations can break down complex processes into manageable units. This approach is consistent with Mayer's (2001) dual-channel processing model and Sweller's (1988) cognitive load theory, which argue for the minimization of extraneous information and the optimization of germane processing. For example, presenting an animation of CPU–RAM interaction in short, modular clips allows learners to pause, replay, and focus on essential steps, thereby preventing overload. Teachers in this study observed that multimedia improved comprehension and retention, though some cautioned that excessive use led to fatigue. These insights affirm the importance of balance and instructional pacing in multimedia design.

Fostering Metacognition

Metacognition learners' ability to monitor, evaluate, and regulate their own learning is a central focus of cognitivist pedagogy. ICT tools provide unique opportunities for embedding feedback loops and reflective practices that strengthen metacognitive skills. In this study, platforms such as Google Forms, Moodle, and Quizziz were widely used to provide instant feedback and permit multiple quiz attempts. Students reported improved understanding after reviewing explanations and reflecting on errors, which demonstrates the role of digital feedback in reinforcing learning strategies. Reflection journals, where students summarized their weekly learning and identified areas of confusion, further promoted self-awareness. These findings align with Flavell's (1979) concept of metacognition and Zimmerman's (2002) self-regulated learning theory, underscoring that digital scaffolds can transform learners into active managers of their own cognition.

Enhancing Motivation and Engagement

Learning is not purely cognitive; it is also shaped by motivation and affective engagement. ICT tools that incorporate gamification such as leaderboards, badges, and dashboards can significantly enhance student persistence and willingness to engage with challenging material. Teachers observed that students who rarely participated in face-to-face classrooms became highly active in online quizzes and gamified platforms. This reflects Zheng

et al.'s (2023) findings that cognitive–motivational engagement is a key mediator between ICT use and achievement.

The study also revealed the necessity of balance: gamification must be tied to substantive learning goals rather than superficial competition. When paired with reflection and explanation tasks, gamification ensures that engagement remains cognitively meaningful rather than merely entertaining.

Personalizing Learning Pathways

Learners differ in prior knowledge, pace, and preferred learning strategies, making personalization a critical dimension of ICT pedagogy. Adaptive platforms and LMS features, such as conditional release of content, allow instruction to be differentiated according to learner performance. Teachers reported success in using these systems to direct stronger students toward advanced challenges while offering remedial exercises to those struggling with foundational material.

This aligns with Vygotsky's Zone of Proximal Development and reflects the broader cognitivist concern with ensuring that learners operate within optimal cognitive conditions. International research similarly demonstrates that adaptive learning reduces overload and fosters mastery (Kang & Kim, 2022; Holmes et al., 2021). In the Nepalese context, personalization also addresses equity, ensuring that students from diverse backgrounds can progress at their own pace without being left behind.

Framework Synthesis

The strategies outlined above converge in a unified model presented as the Cognitivist ICT Implementation Framework (Figure 2). The framework begins with the foundational cognitive principles of schema activation, load management, metacognition, motivation, and personalization. These are operationalized through ICT strategies such as advance organizers, multimedia scaffolds, metacognitive prompts, gamified dashboards, and adaptive learning tools. Together, these strategies generate measurable outcomes, including improved attention and retention, deeper conceptual understanding, enhanced self-regulation, greater learner autonomy, and sustainable academic performance.

The framework illustrates that ICT, when integrated with cognitivist learning theory, serves not merely as a delivery mechanism but as a transformative cognitive scaffold. This synthesis provides a roadmap for teachers, instructional designers, and policymakers seeking to align technology with evidence-based cognitive principles.

Conclusion and Recommendation

This study examined how Cognitivist Learning Theory can be applied in ICT education in the context of higher education in Nepal. The survey data, interviews, and classroom observations highlighted that digital tools are most effective when used as cognitive scaffolds rather than simple delivery mechanisms. Teachers frequently employed strategies such as concept maps, recap quizzes, and simulations to activate prior knowledge, while multimedia and animations helped reduce extraneous cognitive load. Feedback-rich platforms like Moodle and Google Forms supported metacognitive regulation, allowing students to reflect on their progress and adjust learning strategies. Similarly, gamification enhanced motivation, particularly for students who were less engaged in traditional classroom settings, and adaptive learning systems enabled personalized pathways, ensuring that learners remained within their optimal cognitive zones. At the same time, the study also uncovered limitations, including cognitive fatigue from overuse of multimedia and inadequate teacher training in cognitive instructional design, both of which hinder the full realization of ICT's potential.

Institutions need to provide more professional development opportunities focused on techno-pedagogical Cognitivism, while also investing in adaptive platforms and reliable infrastructure. Curriculum developers need to more focus in integrating cognitive principles into ICT education, and teacher training programs. By aligning theory with practice, ICT can

be repositioned as a strategic medium for developing deeper understanding, stronger metacognitive skills, and greater learner autonomy, thereby preparing students for success in increasingly knowledge-driven societies.

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