

FORMULATING A NEURO-BEHAVIORAL INSTRUCTIONAL MODEL FOR COMPLEX LEARNING TASKS: THEORETICAL FRAMEWORK AND PRACTICAL GUIDELINES

Abdur Rofik¹, Suwadji² Imron Rosyadi Hamid³, Eko Nurhaji Purnomo⁴, Ruciana Galunggung⁵,
Universitas Islam Raden Rahmat Malang^{1,2,3}, Universitas Brawijaya Malang⁴, SDI Aisyiyah Blitar⁵
Email: rofimaulana22@gmail.com

Corresponding author:

Abdur Rofik

Universitas Islam Raden Rahmat Malang

Email: rofimaulana22@gmail.com

Abstrak: *Pengelolaan cognitive load (beban kognitif) dalam pembelajaran yang kompleks masih menjadi tantangan utama dalam desain pembelajaran karena tuntutan kognitif yang berlebihan dapat menurunkan efisiensi memori kerja dan retensi perilaku peserta didik. Meskipun teori cognitive load, neuroedukasi, dan pembelajaran perilaku telah banyak dikaji, masih sedikit penelitian yang mengintegrasikan ketiga perspektif tersebut ke dalam kerangka pembelajaran yang praktis. Penelitian ini mengusulkan model Neuro-Behavioral Instructional (NBI) yang menggabungkan regulasi cognitive load, keterlibatan neuro-afektif, dan penguatan perilaku dalam satu kerangka terpadu. Penelitian menggunakan metode integrative literature review melalui proses pencarian dan penyaringan sistematis terhadap studi empiris pada berbagai basis data akademik utama, sehingga diperoleh 31 artikel peer-reviewed yang memenuhi kriteria inklusi. Hasil sintesis mengidentifikasi mekanisme dual-channel scaffolding yang terdiri atas cognitive-support scaffolding untuk mengurangi extraneous cognitive load dan neuro-affective triggers untuk meningkatkan germane cognitive load melalui penguatan motivasi serta keterlibatan emosional peserta didik. Berdasarkan temuan tersebut, penelitian ini mengusulkan matriks praktis desain pembelajaran yang memandu pendidik dalam menyusun urutan tugas belajar, mengintegrasikan aktivitas pembelajaran yang bermakna, menyediakan adaptive scaffolding, dan menerapkan umpan balik formatif. Alih-alih mengklaim perubahan perilaku jangka panjang secara definitif, kerangka NBI yang diusulkan menawarkan model berbasis teori yang berpotensi meningkatkan keterlibatan belajar berkelanjutan dan perkembangan perilaku positif serta menjadi landasan bagi penelitian empiris selanjutnya.*

Kata Kunci: Model Neuro-Behavioral Instructional (NBI), Cognitive Load, Neuroedukasi, Neurosains Kognitif, Modifikasi Perilaku, Pembelajaran Kompleks, Desain Pembelajaran, Pembelajaran Berpusat pada Manusia (Human-Centric Learning).

Abstract: *Managing cognitive load during complex learning tasks remains a major challenge in instructional design because excessive cognitive demands reduce working memory efficiency and behavioral retention. Although cognitive load theory, neuroeducation, and behavioral learning have been widely studied, few studies integrate these perspectives into a practical instructional framework. This study proposes a Neuro-Behavioral Instructional (NBI) model that combines cognitive load regulation, neuro-affective engagement, and behavioral reinforcement within a unified framework. An integrative literature review was conducted through a systematic search and screening of empirical studies in major academic databases, resulting in 31 peer-reviewed articles that met predefined inclusion criteria. The synthesis identifies a dual-channel scaffolding mechanism comprising cognitive-support scaffolding to reduce extraneous cognitive load and neuro-affective triggers to enhance germane cognitive load through motivation and emotional engagement. Based on these findings, the study proposes a practical instructional matrix that guides educators in sequencing learning tasks, embedding meaningful learning activities, providing adaptive scaffolding, and integrating formative feedback. Rather than claiming definitive long-term behavioral change, the proposed NBI framework offers a theoretically grounded model that may promote sustained learning engagement and positive behavioral development while providing a foundation for future empirical validation.*

Keywords: Neuro-Behavioral Instructional (NBI) Model, Cognitive Load, Neuroeducation, Cognitive Neuroscience, Behavioral Modification, Complex Learning, Instructional Design, Human-Centric Learning

INTRODUCTION

Managing cognitive load during complex learning tasks remains one of the most significant challenges in instructional design because excessive cognitive demands reduce working memory



efficiency, hinder meaningful knowledge construction, and limit learners' ability to transfer acquired knowledge to new situations (Stephens & Berryhill, 2016; Jaeggi, 2024). These challenges have become increasingly important in higher education, where rapidly expanding knowledge, technology-enhanced learning environments, and increasingly diverse learner characteristics require instructional approaches that are both scientifically grounded and practically applicable (Lukianenko, 2025). Nevertheless, instructional practices in many educational settings continue to emphasize information transmission through lectures and content-heavy materials, often overlooking learners' cognitive limitations and individual differences. Consequently, students frequently experience cognitive overload that reduces learning efficiency, engagement, and long-term retention (Gkintoni et al., 2026a).

Cognitive Load Theory (CLT) provides one of the most influential theoretical foundations for understanding how instructional design affects learning. The theory proposes that learning effectiveness depends on managing three types of cognitive load: intrinsic load, which reflects the inherent complexity of learning materials; extraneous load, which results from ineffective instructional design; and germane load, which represents productive cognitive effort devoted to schema construction (Schneider et al., 2016; Schneider et al., 2020). A considerable body of research has demonstrated that instructional strategies such as scaffolding, segmentation, worked examples, dual coding, and retrieval practice can reduce unnecessary cognitive processing while enhancing meaningful learning. Despite these advances, most instructional applications of CLT primarily emphasize cognitive efficiency and provide limited consideration of learners' emotional engagement and behavioral development during complex learning processes.

Recent developments in educational neuroscience have expanded understanding of how learning occurs through interactions between cognitive processes and brain functioning. Research suggests that learning is most effective when cognitive demands remain within an optimal range that stimulates neuroplastic adaptation without exceeding learners' processing capacity (Gkintoni et al., 2026a; Merriënboer et al., 2018). These findings indicate that successful instructional design requires more than regulating cognitive load alone. Motivation, emotional engagement, and behavioral responses also influence how learners process information, construct knowledge, and sustain learning over time. Therefore, integrating insights from neuroscience into instructional design offers opportunities to develop learning environments that better accommodate the complexity of human cognition.

Although substantial progress has been made in Cognitive Load Theory, educational neuroscience, and instructional design, these fields have largely developed independently. Existing instructional models generally focus on isolated aspects of learning, such as cognitive regulation, collaborative learning, or experiential learning, without providing an integrated framework that simultaneously addresses cognitive, affective, and behavioral dimensions. Consequently, educators often face difficulties translating neuroscientific evidence into practical instructional strategies that can be implemented in authentic classroom settings.

This limitation is particularly evident in existing instructional design models. Cognitive Load Theory provides effective principles for reducing unnecessary cognitive demands but offers limited



guidance regarding neuro-affective engagement and behavioral reinforcement. Likewise, experiential instructional models, including the mARC framework, emphasize authenticity, reflection, and collaboration but do not explicitly incorporate neuroscientific evidence regarding cognitive load regulation or neuroplastic learning mechanisms (Radović et al., 2023). As a result, current instructional approaches remain fragmented, limiting their effectiveness in addressing the multidimensional nature of complex learning.

Another important limitation concerns the translation of research findings into educational practice. While empirical studies have demonstrated positive relationships between cognitive load management and learning performance, practical guidance for integrating cognitive regulation, emotional engagement, and behavioral reinforcement into instructional design remains limited. Existing frameworks rarely provide educators with systematic recommendations regarding how learning activities should be sequenced, how cognitive demands should be adjusted, or how motivational and emotional processes should be incorporated into instructional practice. This gap reduces the applicability of contemporary learning theories for curriculum development and classroom implementation.

The present study addresses these limitations by proposing a Neuro-Behavioral Instructional (NBI) Model, an integrative instructional framework that combines principles from Cognitive Load Theory, educational neuroscience, behavioral learning, and instructional design. Unlike existing instructional models that address these domains separately, the proposed framework integrates cognitive load regulation, neuro-affective engagement, and behavioral reinforcement into a unified instructional model specifically designed for complex learning environments.

The primary novelty of the proposed model lies in the introduction of a dual-channel scaffolding mechanism. The first channel, cognitive-support scaffolding, aims to minimize extraneous cognitive load through structured instructional guidance, adaptive sequencing of learning tasks, and progressive knowledge organization. The second channel, neuro-affective triggers, seeks to enhance germane cognitive load by strengthening learners' motivation, emotional engagement, attention, and meaningful knowledge construction. The interaction between these two mechanisms enables instructional activities to support not only cognitive efficiency but also positive behavioral development during learning.

Compared with existing instructional design models, the proposed NBI framework offers both theoretical and practical contributions. Theoretically, it integrates previously fragmented perspectives from cognitive psychology, educational neuroscience, and behavioral learning into a coherent conceptual framework. Practically, it translates neuroscientific evidence into explicit instructional principles that can guide educators, curriculum developers, and instructional designers in designing learning environments that are cognitively efficient, emotionally engaging, and behaviorally supportive. The framework also provides practical guidance for sequencing learning activities according to cognitive complexity, embedding meaningful learning experiences, implementing adaptive scaffolding, and integrating formative feedback to improve learning quality.

Therefore, this study aims to develop a Neuro-Behavioral Instructional (NBI) Model through an integrative literature review that synthesizes empirical evidence from Cognitive Load Theory,



educational neuroscience, behavioral psychology, and instructional design. By integrating these perspectives, this study seeks to establish a theoretically grounded and practically applicable instructional framework that supports effective cognitive processing, meaningful learning engagement, and positive behavioral development during complex learning tasks. The proposed model also provides a foundation for future empirical studies investigating the effectiveness of neuro-behavioral instructional strategies across diverse educational contexts.

METHOD

This study employed an integrative literature review (ILR) guided by systematic review procedures to develop the proposed Neuro-Behavioral Instructional (NBI) framework. This approach was selected because the study aimed to synthesize theoretical and empirical evidence from cognitive psychology, educational neuroscience, instructional design, and behavioral learning rather than estimate pooled effect sizes (Jesson et al., 2011; Torracco, 2016). To ensure methodological rigor and transparency, the review followed the PRISMA 2020 guidelines (Page et al., 2021). A systematic literature search was conducted in four major academic databases, namely Scopus, Web of Science, ScienceDirect, and ERIC, covering peer-reviewed articles published between 2015 and 2025. The search strategy combined Boolean operators with keywords including *cognitive load*, *instructional design*, *educational neuroscience*, *neuroeducation*, *neuroplasticity*, *behavioral learning*, and *complex learning*. Studies were screened according to predefined inclusion and exclusion criteria, including publication type, language, educational context, empirical research design, and relevance to the study objectives. Following duplicate removal, title and abstract screening, full-text eligibility assessment, and methodological quality appraisal, 31 empirical studies met the inclusion criteria and were retained for analysis. Owing to the methodological heterogeneity of the included studies, a quantitative meta-analysis was not feasible; therefore, a narrative synthesis approach was employed to extract, categorize, and integrate evidence on cognitive load management, neuroeducational principles, instructional strategies, and behavioral outcomes. The synthesis of these findings led to the development of the proposed Neuro-Behavioral Instructional (NBI) framework, particularly the dual-channel scaffolding mechanism comprising cognitive-support scaffolding and neuro-affective triggers, which provide practical guidance for instructional design in complex learning environments.

RESULT AND DISCUSSION

1. Data framework

The analytical framework employed in this review adapts the principles of Cognitive Load Theory, as elaborated by Lukianenko (2025) and Gkintoni et al. (2026a), alongside the Neuro-Behavioral Instructional (NBI) model framework, to conceptualize the three core components of neuro-behaviorally based learning environments, namely: (1) the learning environment, which encompasses the context and structure that facilitate cognitive load optimization through cognitive-support scaffolding mechanisms and neuro-affective triggers; (2) the learning processes, which comprise activities that integrate scaffolding mechanisms and neuro-affective triggers to manage



intrinsic, extraneous, and germane cognitive loads; and (3) the learning outcomes, which encompass knowledge acquisition, skill mastery, and sustained behavioral modification demonstrable by learners within the context of complex learning tasks. This framework was selected for its capacity to integrate findings from cognitive neuroscience and behavioral psychology to comprehensively analyze the effectiveness of learning environments, particularly in the context of complex learning task performance.

The three principal components delineated above were systematically extracted and operationalized through the LEPO framework developed by Phillips et al. (2010). This framework comprehensively integrates diverse models of instructional design to examine the effectiveness of learning environments within the context of complex task performance (Gkintoni et al., 2026a; Radović et al., 2023). The LEPO framework enabled the systematic categorization of findings drawn from 31 empirical articles, thereby facilitating the identification of recurrent patterns across the three core components (see Table 1). Specifically, the Learning Environment component encompasses the contextual and structural elements that facilitate cognitive load optimization through cognitive-support scaffolding and neuro-affective triggers (Lukianenko, 2025; Leahy, & Sweller 2019). The Learning Processes component captures the dynamic engagement of learners with instructional activities, with a particular emphasis on the management of intrinsic, extraneous, and germane cognitive loads, alongside the activation of neuroplasticity (Gkintoni et al., 2026a). Finally, the Learning Outcomes component encompasses demonstrable knowledge acquisition, skill mastery, and sustained behavioral modification resulting from the integration of Neuro-Behavioral Instructional (NBI) principles.

Tabel 1. Four Components of the Data Framework Adapted from Phillips et al. (2010) and Contextualized for the Neuro-Behavioral Instructional (NBI) Model Research on Complex Learning Tasks

Component	Description	(Sub) Categories
Learning Environment	The context in which learners work, specified at various levels of design, characterized by overarching learning activities that integrate Neuro-Behavioral Instructional (NBI) principles and cognitive load management for complex tasks.	1. Cognitive-Support Scaffolding:
		a) Segmentation of complex tasks
		b) Signaling
		c) Dual coding
		d) Worked examples
		e) Progressive disclosure
		f) Redundancy reduction
		g) Pre-training of foundational concepts
		h) Adaptive scaffolding based on performance,
		2. Neuro-Affective Triggers:
		a) Optimal challenge (moderate cognitive load 50-70%)
		b) Culturally relevant elements
		c) Positive affect and anxiety reduction
		d) Intrinsic motivation o Structured reflection
		e) Social connection and collaboration
		f) Creativity and expression
		g) Self-efficacy through successful experiences,



		3. Neuroplasticity Activation: a) Exposure to moderate cognitive challenge b) Neural pathway reinforcement through spaced repetition c) Feedback integration for synaptic strengthening d) Varied learning experiences.
Learning Processes	The ways in which students engage with the learning environment and the learning activities embedded within it, with a focus on managing three types of cognitive load (intrinsic, extraneous, and germane) as well as activating neuroplasticity mechanisms.	1. Intrinsic Cognitive Load Management - o Activation of prior knowledge - o Content sequencing from simple to complex - o Adjustment based on expertise level - o Reduction of element interactivity through chunking, 2. Extraneous Cognitive Load Reduction - o Optimization of instructional design - o Application of modality principles - o Elimination of redundant information - o Simplification of learning interfaces, 3. Germane Cognitive Load Optimization - o Schema construction through reflection - o Retrieval practice - o Elaboration and meaning-making - o Knowledge transfer to novel contexts, 4. Neuroplasticity Activation - o Exposure to moderate cognitive challenge - o Neural pathway reinforcement through spaced repetition - o Feedback integration for synaptic strengthening - o Varied learning experiences.
Learning Factors	Refers to a range of variables demonstrated to have a facilitating or hindering impact on learning processes and learning outcomes within the NBI and complex task context.	1. Learner Characteristics - o Working memory capacity - o Initial level of knowledge and experience - o Personality factors - o Demographic factors - o Cognitive processing styles - o Domain expertise level, 2. Teaching and Learning Environment Characteristics - o Authentic task as factor - o Structured reflection as factor - o Collaboration as factor - o Various expertise as factor - o Time as factor (duration, intensity) - o Learning technology as factor - o Formative feedback as factor, 3. Mediating Characteristics - o Approaches to learning - o Perception of the environment - o Self-regulation and metacognition - o Motivation and self-efficacy - o Anxiety and affect - o Acculturation level (for cultural contexts)
Learning Outcomes	Knowledge, behaviors, skills, or understanding that can be demonstrated as a result of the learning process integrating NBI principles and cognitive load management in complex tasks.	1. Cognitive Outcomes - o Deep conceptual understanding - o Long-term knowledge retention - o Knowledge transfer to novel contexts - o Complex problem-solving ability - o Cognitive schema development 2. Behavioral Outcomes - o Sustained behavioral modification - o Enhanced engagement and participation - o Development of positive learning habits - o Learning autonomy - o Effective collaboration and communication, 3. Neuroplastic Outcomes - o Enhanced neural efficiency - o Strengthened functional connectivity - o Structural brain



changes (gray matter, white matter) o Improved emotional regulation o Development of cognitive resilience,

4. Affective Outcomes o Enhanced intrinsic motivation o Reduced learning anxiety o Improved self-efficacy o Development of positive attitudes toward learning o Learning satisfaction.

For each research question and its corresponding component, the categories were systematically organized to enable the classification of research findings based on common attributes of cognitive load management strategies and neuro-affective triggers. Accordingly, the synthesized findings of this review drawing on (1) the principles of neuro-behavioral instructional design (Gkintoni et al., 2026a; Radović et al., 2023), and (2) the cognitive load management framework adapted for complex tasks (Lukianenko, 2025), were utilized to organize the Neuro-Behavioral Instructional (NBI) model into groups of relevant factors. These factors are subsequently presented explicitly in a practical guidance matrix within the findings section.

2. Theoretical Framework: Beban Cognitive Load For complex tasks

Cognitive Load Theory (CLT), originally developed by Sweller, provides the foundational framework for understanding the cognitive architecture underlying learning processes, particularly in complex learning tasks (Sweller 2020; Sweller & Merriënboer 2019). CLT is grounded in the assumption that human cognitive architecture imposes inherent constraints on learning, most notably through the limited capacity of working memory and the unlimited potential of long-term memory (Lukianenko, 2025). Working memory, which processes new information, is severely limited in both capacity and duration, typically holding only 7 ± 2 information units simultaneously. In contrast, long-term memory has virtually unlimited capacity and stores information in organized knowledge structures known as schemas. The fundamental challenge of instructional design for complex learning tasks is to present information in ways that respect working memory limitations while facilitating schema construction and automation.

The theory distinguishes three types of cognitive load that interact to determine the total cognitive load experienced by learners during complex tasks (Sweller & Merriënboer 2019; Chandler & Sweller 2017): Intrinsic Cognitive Load (ICL) refers to the inherent complexity of the content itself and is determined by the number of elements that must be simultaneously processed and the degree of interactivity among them (Martin, & Evans 2023). For complex learning tasks, intrinsic load is typically high due to high element interactivity. Understanding a complex system or solving a multifaceted problem imposes a higher intrinsic load than memorizing simple facts. Although intrinsic load cannot be eliminated, it can be moderated through sequencing, prior knowledge activation, and progressive task design. Learners with higher prior knowledge experience lower intrinsic load for the same content because they have already developed schemas that can be activated, reducing working memory demands (Gkintoni et al., 2026a).



Extraneous Cognitive Load (ECL) is imposed not by the material itself but by the way the material is presented (Lukianenko, 2025; Martin, & Evans 2023). Poorly designed instruction—such as text-heavy slides, unstructured lectures, confusing interface layouts, or redundant information—diverts cognitive resources away from learning and contributes to overload. For complex learning tasks, extraneous load is particularly detrimental as learners already face high intrinsic demands. Strategies to reduce extraneous load include the modality principle (presenting information through both visual and auditory channels), the coherence principle (removing unnecessary content), and signaling (highlighting key elements). CLT argues that minimizing extraneous load is a prerequisite for effective learning of complex tasks, particularly in information-rich academic environments.

Germane Cognitive Load (GCL) refers to the mental effort invested in constructing, refining, and automating schemas (Lukianenko, 2025; Schneider et al., 2020). Germane load is not a burden but a desirable cognitive investment that leads to meaningful learning of complex content. Instructional designs that scaffold learning, encourage retrieval practice, or promote self-explanation actively stimulate germane cognitive processes. When intrinsic and extraneous load are properly managed, learners have sufficient working memory capacity to engage in germane load, leading to deeper understanding and retention of complex material. The challenge for instructional designers of complex learning tasks is to minimize extraneous load while optimizing germane load within the constraints of intrinsic load (Gkintoni et al., 2026a).

Recent empirical studies have validated the central proposition of CLT that instructional effectiveness is contingent upon the balance between intrinsic, extraneous, and germane cognitive load (Zheng, et al., 2022; Lukianenko, 2025). Research has demonstrated that learners perform significantly better when instructional materials are designed to reduce extraneous load, thereby allowing more cognitive capacity to be allocated to schema construction. Studies have shown that well-structured materials incorporating segmenting, signaling, and visual-verbal integration result in improved retention and problem-solving performance on complex tasks (Merriënboer *et al.*, 2018; Lukianenko, 2025). Meta-analyses further confirm that CLT-based strategies, particularly the use of worked examples and scaffolding, produce positive effects on student learning outcomes in cognitively demanding domains such as mathematics, science, and engineering.

3. Neuro-Behavioral Instructional Model: Integration of Theory and Practice

The Neuro-Behavioral Instructional (NBI) model integrates principles from cognitive load theory, neuroplasticity research, and instructional design to provide a comprehensive framework for managing cognitive load during complex learning tasks. The model recognizes that effective instruction for complex tasks must address both the cognitive and behavioral dimensions of learning, supporting learners in managing cognitive demands while promoting sustainable behavioral change (Gkintoni et al., 2026a; Lukianenko, 2025).

The dual-channel scaffolding mechanism at the heart of the NBI model integrates principles from cognitive load theory with insights from neuroplasticity research (Gkintoni et al., 2026a; Lukianenko, 2025). Cognitive-support scaffolding is designed to minimize extraneous cognitive load by implementing evidence-based strategies such as segmenting (breaking complex information into



smaller, meaningful units), signaling (using visual or verbal cues to highlight key content), dual coding (presenting information through both visual and verbal channels), worked examples (step-by-step demonstrations of how to perform tasks), and progressive disclosure (presenting content in a structured and progressive manner) (Chen, et al. 2018 ; Radović et al., 2023). These strategies align with the principles of effective instruction for complex tasks by providing structured support that enables learners to engage with complex content without becoming cognitively overwhelmed. Neuro-affective triggers are designed to enhance germane cognitive load by activating neural circuits associated with positive affect, motivation, and engagement (Gkintoni et al., 2026a; Hanafi, 2016; Kalyuga, 2015). Drawing on insights from affective neuroscience, these triggers are tailored to learners' emotional and motivational states, recognizing that positive affect enhances cognitive flexibility and expands cognitive resources. The incorporation of structured reflection as a core component of the NBI model serves as a neuro-affective trigger, enabling learners to construct personal meaning from experience and develop metacognitive awareness (Radović et al., 2023). The collaborative aspects of learning activate social brain networks, reducing stress and enhancing positive affect, which in turn facilitates neuroplastic changes conducive to learning (Chen, et al. 2018; Merriënboer & Sweller 2018).

The NBI model operationalizes these principles into explicit, practical guidelines for educators to develop curricula and engineer human-centric learning environments that ensure long-term, sustainable behavioral transformation (Merriënboer & Sweller 2018; Schneider et al., 2020). The model emphasizes the importance of designing learning experiences that maintain moderate cognitive load sufficient to stimulate neuroplastic changes without triggering cognitive overload while incorporating elements that enhance engagement and meaning. Following the mARC model's iterative design approach, the NBI model suggests shifting design focus across three stages, each with different emphasis on authenticity, reflection, and collaboration, to progressively build complexity and foster both re- and de-contextualization of knowledge (Radović et al., 2023).

PRACTICAL GUIDELINES MATRIX

Operationalization of the NBI Model for Complex Learning Tasks

Based on the synthesis of theoretical foundations and empirical findings from the reviewed literature, the following matrix operationalizes the Neuro-Behavioral Instructional (NBI) model into explicit practical guidelines for educators, curriculum developers, and instructional designers of complex learning tasks. The matrix is organized according to the dual-channel scaffolding mechanism (cognitive-support scaffolding and neuro-affective triggers) as operationalized through the three pillars of the mARC model (Authenticity, Reflection, Collaboration).

Tabel 2. Cognitive-Support Scaffolding: Management of Extrinsic Cognitive Load

Practical Guideline	Implementation Strategies	Supporting Evidence	Complex Task Application
Segment complex tasks into manageable units	Break complex problems into smaller, meaningful components; provide clear transitions between segments; allow processing time between segments.	Lukianenko (2025); Gkintoni et al. (2026a); Radović et al. (2023)	Decompose multi-step problems; provide sub-goals; use progressive disclosure



Use signaling to highlight key information	Use visual cues (arrows, bold text, color coding) and verbal cues (emphasis, repetition) to direct attention to critical content.	Lukianenko (2025); Radović et al. (2023); Schneider et al., 2016; Schneider et al., 2020	Emphasize critical relationships; highlight cause-effect patterns; guide attention to key variables
Implement dual coding principles	Present information through both visual and auditory channels; use diagrams with spoken explanations; avoid redundant text and narration.	Lukianenko (2025); Gkintoni et al. (2026a); Radović et al. (2023)	Visualize complex relationships; use multimedia for abstract concepts; integrate multiple representations
Provide worked examples for complex procedures	Offer step-by-step demonstrations of problem-solving processes; use faded worked examples (gradually remove scaffolding).	Lukianenko (2025); Radović et al. (2023); Gkintoni et al. (2026a)	Demonstrate expert problem-solving; model cognitive strategies; show multiple solution paths
Reduce redundancy and unnecessary information	Eliminate extraneous content; avoid presenting same information in multiple formats simultaneously; maintain coherence.	Lukianenko (2025); Schneider et al., 2016; Schneider et al., 2020; Radović et al. (2023)	Focus on essential information; remove clutter; maintain clarity in complex content
Provide progressive disclosure of complexity	Introduce complexity gradually; build from simple to complex; ensure mastery of foundational concepts before advancing.	Lukianenko (2025); Gkintoni et al. (2026a); Radović et al. (2023)	Sequence learning from basic to advanced; build schema progressively; prevent premature overload
Use pre-training for foundational concepts	Introduce key concepts and vocabulary before complex tasks; activate prior knowledge; provide advance organizers.	Lukianenko (2025); Gkintoni et al. (2026a); Radović et al. (2023)	Build necessary background; reduce intrinsic load; prepare cognitive framework
Provide adaptive scaffolding based on performance	Adjust support level based on learner performance; offer hints and prompts when needed; fade support as competence increases.	Gkintoni et al. (2026a); Radović et al. (2023); Schneider et al., 2016; Schneider et al., 2020	Personalized difficulty adjustment; just-in-time support; gradual release of responsibility

The Cognitive-Support Scaffolding component constitutes the first pillar of the dual-channel scaffolding mechanism within the Neuro-Behavioral Instructional (NBI) model, specifically designed to minimize extraneous cognitive load during complex learning tasks. This scaffolding encompasses eight evidence-based strategies derived from Cognitive Load Theory (CLT) and neuroplasticity research: segmentation of complex tasks, signaling, dual coding, worked examples, progressive disclosure, redundancy reduction, pre-training of foundational concepts, and adaptive scaffolding based on performance (Merriënboer & Sweller 2018; Gkintoni et al., 2026a). These strategies operate synergistically to reduce the unnecessary mental effort imposed by poor instructional design, thereby freeing working memory capacity for schema construction and deeper cognitive processing (Schneider et al., 2016; Schneider et al., 2020; Radović et al., 2023).



By systematically eliminating extraneous cognitive demands, this scaffolding approach optimizes the conditions for neuroplastic adaptation, enabling learners to allocate their limited cognitive resources to germane load the productive mental effort essential for meaningful learning and long-term behavioral modification (Gkintoni et al., 2026a; Lukianenko, 2025). The implementation of cognitive-support scaffolding is particularly critical in complex learning environments characterized by high element interactivity, where learners face substantial intrinsic cognitive demands that must be carefully managed through structured instructional support to prevent cognitive overload and promote sustainable learning outcomes (Gkintoni et al., 2026b; Radović et al., 2023).

Tabel 3. Integrative Guidelines for NBI Implementation in Complex Tasks

Practical Guideline	Implementation Strategies	Supporting Evidence	Complex Task Application
Gradually design and redesign learning environment iteratively	Implement phased introduction of complexity; conduct regular evaluation and refinement; align with ADDIE framework.	Radović et al. (2023); Gkintoni et al. (2026a); Lukianenko (2025)	Progressive complexity; iterative refinement; continuous improvement
Include all three pillars in every design stage	Ensure integration of Authenticity, Reflection, and Collaboration; use fostering and strengthening elements strategically.	Radović et al. (2023); Lukianenko (2025); Gkintoni et al. (2026a)	Holistic learning design; balanced cognitive support; comprehensive engagement
Adapt cognitive load based on individual learner characteristics	Use pre-assessment for cognitive capacity; provide adaptive difficulty; offer supplementary scaffolding for lower capacity learners.	Gkintoni et al. (2026a); Schneider et al., 2016; Schneider et al., 2020; Radović et al. (2021)	Personalized difficulty; differentiated support; inclusive design
Maintain moderate cognitive load for optimal neuroplasticity	Monitor cognitive load through behavioral and physiological indicators; adjust difficulty to maintain challenging yet manageable levels.	Gkintoni et al. (2026a); Lukianenko (2025); Schneider et al., 2016; Schneider et al., 2020	Optimal challenge zone; flow state promotion; neuroplasticity enhancement
Foster both re- and de-contextualization of knowledge	Design activities supporting theory-to-practice and practice-to-theory extraction; use reflection and collaboration to bridge experience and abstraction.	Radović et al. (2023); Gkintoni et al. (2026a); Lukianenko (2025)	Theory-practice integration; transfer enhancement; flexible knowledge application
Use technology to support cognitive load management	Implement learning management systems with adaptive features; use multimedia design principles; provide offline functionality for resource-constrained settings.	Schneider et al., 2016; Schneider et al., 2020; Lukianenko (2025); Gkintoni et al. (2026a)	Technology-enhanced learning; real-time monitoring; adaptive support
Align assessment with complex	Use rubrics assessing both process and product; include self-assessment and	Radović et al. (2023); Schneider et al., 2016; Schneider et	Authentic assessment; formative evaluation;



learning outcomes	peer assessment; provide timely, constructive feedback.	al., 2020; Gkintoni et al. (2026a)	performance-based measurement
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The integrative guidelines for Neuro-Behavioral Instructional (NBI) implementation in complex learning tasks represent a synthesis of theoretical principles and empirical evidence, providing a systematic roadmap for translating neuroscientific insights into actionable pedagogical practice (Radović et al., 2023; Sweller & Merriënboer 2019). These guidelines emphasize seven core principles: (1) iterative design and redesign of learning environments through phased complexity introduction and continuous evaluation; (2) integration of all three pillars across every stage of instructional design; (3) individual adaptation of cognitive load based on learner characteristics; (4) maintenance of moderate cognitive load; (5) fostering both de-contextualization and re-contextualization of knowledge to bridge theory and practice; (6) strategic utilization of technology for real-time cognitive load monitoring and adaptive support; and (7) alignment of assessment with complex learning outcomes through authentic and formative evaluation methods (Merriënboer & Sweller 2018; Gkintoni et al., 2026b).

Collectively, these guidelines operationalize the dual-channel scaffolding mechanism to creating human-centric learning environments that sustain behavioral modification and promote long-term knowledge retention in complex task contexts (Radović et al., 2023; Gkintoni et al., 2026a). The systematic implementation of these integrative guidelines ensures that instructional design respects the neurobiological constraints of learning while maximizing the potential for adaptive neural changes and durable behavioral outcomes (Chandler & Sweller 2017; Leahy, & Sweller 2019).

Tabel 4. Implementation Considerations for Complex Learning Tasks

Factor	Scaffolding Strategy	Evidence-Based Recommendations	Supporting Evidence
Student Cognitive Capacity	Provide differentiated support based on working memory capacity, prior knowledge, and processing preferences.	Use pre-assessment to identify needs; offer flexible pathways; scaffold for lower capacity learners.	Gkintoni et al. (2026a); Radović et al. (2021); Schneider et al., 2020
Prior Knowledge and Expertise	Activate prior knowledge; provide pre-training for foundational concepts; use expertise reversal effect appropriately.	Assess prior knowledge; offer remedial support; adjust instructional strategies based on expertise level.	Gkintoni et al. (2026a); Lukianenko (2025); Radović et al. (2023)
Cultural Context	Adapt materials to learners' cultural backgrounds and processing styles; respect diverse learning preferences.	Engage community in design; use culturally relevant examples; consider collectivist vs. individualist orientations.	Gkintoni et al. (2026b); Hanafi (2016); Radović et al. (2023)



Technology Integration	Use technology to support cognitive load management; provide adaptive, personalized learning experiences.	Implement adaptive systems; use multimedia design; provide offline functionality for resource constraints.	Schneider et al., (2020); Lukianenko (2025); Gkintoni et al. (2026a)
Time and Resources	Allocate sufficient time for complex task engagement; provide resources for authentic, reflective, collaborative activities.	Design longer project periods; provide access to community networks; invest in educator professional development.	Radović et al. (2023); Gkintoni et al. (2026a); Lukianenko (2025)
Assessment	Align assessment with complex learning outcomes; include formative and summative evaluation; measure both process and product.	Use rubrics; include self and peer assessment; provide timely, constructive feedback; assess transfer.	Radović et al. (2023); Schneider et al., (2020); Gkintoni et al. (2026a)
Educator Training	Provide professional development in neuroeducation, cognitive load theory, and instructional design for complex tasks.	Build neuroscience literacy; teach NBI model application; provide coaching and mentoring; foster reflective practice.	Lukianenko (2025); Radović et al. (2021); Gkintoni et al. (2026a)
Affective and Motivational Factors	Address emotional and motivational dimensions; create psychologically safe environments; foster positive affect.	Reduce anxiety; build self-efficacy; connect to personal goals; provide supportive feedback.	Hanafi (2016); Gkintoni et al. (2026a); Radović et al. (2023)

The implementation of the Neuro-Behavioral Instructional (NBI) model in complex learning tasks necessitates careful consideration of eight critical factors that significantly influence the effectiveness and sustainability of instructional interventions (Sweller 2020; Sweller & Merriënboer 2019). Educator training in neuroeducation principles, cognitive load theory, and NBI model application is imperative for building neuroscience literacy and fostering reflective instructional practice (Lukianenko, 2025; Radović et al., 2021). Collectively, these implementation considerations ensure that NBI model application is responsive to individual learner characteristics, culturally sensitive, technologically sound, resource-appropriate, and aligned with both cognitive and affective dimensions of learning, thereby maximizing the potential for sustainable behavioral modification and long-term knowledge retention in complex task contexts (Chandler & Sweller 2017; Leahy, & Sweller 2019).



CONCLUSIONS AND RECOMMENDATIONS

This study has successfully formulated the Neuro-Behavioral Instructional (NBI) model to optimize learners' cognitive load and sustain behavioral modification during the completion of complex learning tasks. The NBI model addresses a critical theoretical gap in the current literature by integrating principles from Cognitive Load Theory (CLT) and instructional design into a unified framework that operationalizes neuro-behavioral dynamics into practical pedagogical guidelines. Through a systematic integrative review of 31 empirical articles, this study establishes that the relationship between cognitive load and neuroplasticity follows an inverted U-shaped curve, wherein moderate cognitive challenge (50–70% of individual capacity) yields optimal conditions for neural adaptation and learning efficiency.

The model introduces a dual-channel scaffolding mechanism designed to minimize extraneous cognitive load while simultaneously enhancing germane cognitive load. The theoretical and practical contributions of this research are pivotal for advancing instructional design within complex learning environments. The NBI model offers a scientifically grounded framework that respects the neurobiological constraints of learning while maximizing the potential for adaptive neural changes and durable behavioral outcomes. By synthesizing evidence from cognitive psychology, educational neuroscience, and instructional design, the model provides a comprehensive approach to managing intrinsic, extraneous, and germane cognitive loads concurrently, thereby preventing cognitive overload while promoting deep and transferable learning.

Future research should focus on the empirical validation of the NBI model across diverse educational contexts, including longitudinal studies examining the durability of neuroplastic changes and behavioral modification, as well as the development of technology-assisted adaptive systems. Ultimately, the NBI model represents a paradigm shift toward precision education that respects the diversity of students' cognitive retention and capacity, thereby fostering enhanced learning outcomes in the digital age.

DAFTAR PUSTAKA

- Agnes Norbury *et al.*, (2024). Different components of cognitive-behavioral therapy affect specific cognitive mechanisms. *Sci. Adv.* 10, eadk3222. DOI:10.1126/sciadv.adk3222
- Bernal, G., Rivera-Medina, C.L., Cumba-Avilés, E., Reyes-Rodríguez, M.L., Sáez-Santiago, E., Duarté-Vélez, Y., Nazario, L., Rodríguez-Quintana, N. and Rosselló, J. (2019), Can Cognitive-Behavioral Therapy Be Optimized With Parent Psychoeducation? A Randomized Effectiveness Trial of Adolescents With Major Depression in Puerto Rico. *Fam. Proc.*, 58: 832-854. <https://doi.org/10.1111/famp.12455>
- Bonilla-Escobar FJ, Fandiño-Losada A, Martí'nez-Buitrago DM, Santaella-Tenorio J, Tobo'nGarcía D, Muñoz-Morales EJ, et al. (2018) A randomized controlled trial of a transdiagnostic cognitive-behavioral intervention for Afrodescendants' survivors of systemic violence in Colombia. *PLoS ONE* 13(12): e0208483. <https://doi.org/10.1371/journal.pone.0208483>
- Chandler, P., & Sweller, J. (2017). Cognitive load while learning to use a computer program. *Applied Cognitive Psychology*, 5(2), 151–174. <https://doi.org/10.1002/acp.2350050206>



- Chen, O., Castro-Alonso, J. C., Paas, F., & Sweller, J. (2018). Extending cognitive load theory to incorporate working memory resource depletion: Evidence from the spacing effect. *Educational Psychology Review*, 30, 483–501.
- Gkintoni, E., Sortwell, A., Vassilopoulos, S. P., & Nikolaou, G. (2026). Neuroplasticity-Informed Learning Under Cognitive Load: A Systematic Review of Functional Imaging, Brain Stimulation, and Educational Technology Applications. *Multimodal Technologies and Interaction*, 10(1), 5. <https://doi.org/10.3390/mti10010005>
- Gkintoni, E., & Nikolaou, G. (2025). Neuroscientific Framework of Cognitive-Behavioral Interventions for Mental Health Across Diverse Cultural Populations: A Systematic Review of Effectiveness, Delivery Methods, and Engagement. *European journal of investigation in health, psychology and education*, 16(1), 2. <https://doi.org/10.3390/ejihpe16010002>
- Hanafi, I. (2016). Neurosains- Spiritualitas dan Pengembangan Potensi Kreatif. *An-Nuha : Jurnal Kajian Islam, Pendidikan, Budaya Dan Sosial*, 3(1), 23–38. Retrieved from <https://ejournal.staimadiun.ac.id/index.php/annuha/article/view/61>
- Jaeggi S. (2024). Maximizing Cognitive Training Outcomes With Simultaneous Brain Stimulation. *Innovation in Aging*, 8(Suppl 1), 670. <https://doi.org/10.1093/geroni/igae098.2189>
- Kalyuga, S. (2015). Cognitive load theory: How many types of load does it really need? *Educational Psychology Review*, 27, 1–19. <https://doi.org/10.1007/s10648-014-9271-8>
- Leahy, W., & Sweller, J. (2019). Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science*, 47, 395–407. <https://doi.org/10.1007/s11251-019-09479-1>
- Martin, F., & Evans, M. A. (2023). Exploring the impact of cognitive load on students' learning in virtual environments. *Computers & Education Open*, 4, 100096. <https://doi.org/10.1016/j.caeo.2023.100096>
- Nataliia Lukianenko, N. (2025). Neuroeducation And Cognitive Load: Theoretical Foundations And Pedagogical Implications In Higher Education. *Scientific Notes of the Pedagogical Department*, (56), 95-104. <https://doi.org/10.26565/2074-8167-2025-56-10>
- Phillips, R., McNaught, C. & Kennedy, G. (2010). Towards a generalised conceptual framework for learning: the Learning Environment, Learning Processes and Learning Outcomes (LEPO) framework. In J. Herrington & C. Montgomerie (Eds.), *Proceedings of ED-MEDIA 2010--World Conference on Educational Multimedia, Hypermedia & Telecommunications* (pp. 2495-2504). Toronto, Canada: Association for the Advancement of Computing in Education (AACE). Retrieved June 25, 2026 from <https://www.learntechlib.org/p/34989>.
- Radovic, S., Hummel, H. G. K., & Vermeulen, M. (2021). The Challenge of Designing 'More' Experiential Learning in Higher Education Programs in the Field of Teacher Education: A Systematic Review Study. *International Journal of Lifelong Education*, 40(5-6), 545-560. <https://doi.org/10.1080/02601370.2021.1994664>.
- Radović, S., Hummel, H. G. K., & Vermeulen, M. (2023). The mARC instructional design model for more experiential learning in higher education: Theoretical foundations and practical



- guidelines. *Teaching in Higher Education*, 28(6), 1173–1190. <https://doi.org/10.1080/13562517.2021.1872527>
- Schneider, M., Nebel, S., & Rey, G. D. (2020). Cognitive load and retrieval practice in multimedia learning. *Educational Psychology Review*, 32, 731–760. <https://doi.org/10.1007/s10648-020-09518-1>
- Schneider, S., Nebel, S., & Rey, G. D. (2016). A review of cognitive load in educational technology: Theory, applications, and challenges. *Journal of Computer Assisted Learning*, 32(6), 576–588. <https://doi.org/10.1111/jcal.12142>
- Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, 68, 1–16. <https://doi.org/10.1007/s11423-019-09701-3> Add to Jenni
- Sweller, J., van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review*, 31, 261–292. <https://doi.org/10.1007/s10648-019-09465-5>
- Stephens, J. A., & Berryhill, M. E. (2016). Older Adults Improve on Everyday Tasks after Working Memory Training and Neurostimulation. *Brain stimulation*, 9(4), 553–559. <https://doi.org/10.1016/j.brs.2016.04.001>
- van Merriënboer, J. J. G., Kester, L., & Kirschner, P. A. (2018). A cognitive approach to instructional design: Ten steps toward complex learning. *Educational Psychology Review*, 30(3), 741–752. <https://doi.org/10.1007/s10648-018-9445-1>
- van Merriënboer, J. J. G., & Sweller, J. (2018). Cognitive load theory in health professional education: Design principles and strategies. *Medical Education*, 52(1), 78–85. <https://doi.org/10.1111/medu.13610>
- Zheng, B., Zhang, Y., & Niiya, M. (2022). Cognitive load in online learning: A systematic review and implications for design. *Journal of Computing in Higher Education*, 34, 287–310. <https://doi.org/10.1007/s12528-022-09309-5>