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Cognitive Science in Educational Design: Challenges and Prospects for the Development of Transversal Skills

Mohammed LAHLOU [1], Karima LAAMIRI[2], Jaouad EL GUENNOUNi[3]

1 PhD Student in Educational Sciences. Laboratory: Literature, Humanities, Art, and Educational Sciences, ENS Téouane, lahlou.mohammed.ens@gmail.com
2 Research Professor, (FSJEST, UAE), k.laamiri@uae.ac.ma
3 Research Professor, Taza Multidisciplinary Faculty / USMBA, jawadelguennouni@gmail.com

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ABSTRACT

This article examines the effect of a pedagogical approach grounded in cognitive science on the development of transferable skills among students. Drawing on a literature review, it highlights the main cognitive mechanisms involved in learning including attention, memory, executive functions, and metacognition and their role in the acquisition of complex skills such as critical thinking, collaboration, and problem-solving.

The study emphasizes that integrating principles from cognitive science such as cognitive load management, active learning, and consideration of emotional dimensions enables the design of instructional approaches that are more effective and better tailored to learners' needs. From this perspective, instructional design emerges as a key lever for operationalizing these theoretical insights and fostering deep cognitive engagement.

The findings of this analysis, however, reveal a gap between theoretical advances and current instructional practices, where transferable skills are often addressed implicitly and in an unstructured manner. This research therefore proposes rethinking the design of learning environments within an integrated framework that combines cognitive science and instructional design, in order to explicitly support the development of behavioral skills.

Keywords: Cognitive sciences; Instructional design; Transversal skills; Higher education

1. INTRODUCTION

Over the past few decades, the field of education has undergone a major shift influenced by advances in cognitive science. These advances have led to a better understanding of the fundamental mechanisms of learning, particularly the processes related to attention, memory, motivation, and cognitive regulation (Calas, 2018) . In this context, instructional design can no longer be limited to the mere transmission of content but must now be based on scientifically grounded models that consider how the human brain functions.

At the same time, contemporary educational systems are placing increasing emphasis on the development of soft skills, such as critical thinking, collaboration, creativity, and problem-solving (Abderrahim, 2026; Albandea & Giret, 2016; Aziz & Zaidoune, 2025) . These skills are now considered essential for meeting the demands of a changing professional world characterized by complexity, uncertainty, and digital transformation.

Consequently, a central question arises: To what extent can instructional design informed by cognitive science foster the effective development of these transferable skills? This paper addresses this question by exploring the links between instructional design, cognitive science, and the development of soft skills.

Despite the importance placed on soft skills in institutional and academic discourse, their effective development among students remains limited (Duru-Bellat, 2015; Hasna & Fatine, 2025) . This situation can be explained in part by a mismatch between stated objectives and the instructional practices implemented.

Indeed, instructional approaches are rarely designed based on a detailed understanding of the cognitive processes involved in learning. As a result, they struggle to create conditions conducive to deep cognitive engagement, the activation of executive functions, and the development of complex skills.

In this context, the research question can be formulated as follows:

To what extent can an instructional design ground in the contributions of cognitive science contribute to the development of transferable skills among college students?

For this research, a documentary methodology was adopted, based on an in-depth review of scientific literature on cognitive science, instructional design, and transferable skills. This approach involves analyzing, comparing, and synthesizing academic works (articles, books, institutional reports) to identify the key concepts, theoretical models, and empirical findings relevant to the subject of study. The objective is not to produce field data, but to construct a rigorous analytical framework that enables an understanding of the connections between the contributions of cognitive science and their application in instructional design to foster the development of cross-disciplinary skills. This approach thus makes it possible to identify theoretical convergences, pinpoint the limitations of existing practices, and propose avenues for reflection toward instructional design that is better informed by scientific knowledge about learning.

2. THEORETICAL FRAMEWORK COGNITIVE SCIENCES: DEFINITION

Cognitive science refers to an interdisciplinary field that studies the mechanisms of human thought, particularly how humans perceive, process, store, and use information *(Allix et al., 2023; Calas, 2018)* . It draws on several disciplines, such as cognitive psychology, neuroscience, linguistics, artificial intelligence, and philosophy, to understand how the brain functions and how mental processes such as learning, attention, memory, and decision-making work *(Friedenberg & Silverman, 2006)* . In the field of education, these disciplines provide an essential foundation for designing more effective instructional approaches that consider learners' cognitive abilities and limitations.

3. THE CONTRIBUTIONS OF COGNITIVE SCIENCE TO LEARNING THE COGNITIVE LEAD THEORY (JOHN SWELLER)

It posits that working memory capacity is limited (Chanquoy et al., 2007; Tricot, 1998) , which implies that instructional strategies must be designed to avoid cognitive overload. Clear structuring of content, the use of multimodal media, and the progressive nature of tasks are essential. Cognitive Load Theory (CLT), developed by John Sweller in the 1980s, falls within the framework of cognitive science as applied to learning. It is based on the idea that human working memory

is limited in both capacity and duration, which directly influences the effectiveness of learning processes.

Sweller distinguishes three types of cognitive load:

- **Intrinsic load:** related to the inherent complexity of the content to be learned and the learner's skill level.

- **Extrinsic load**: generated by the way information is presented (often unnecessary or poorly designed).

- **Relevant (or pertinent) cognitive load** corresponds to the cognitive resources mobilized to construct lasting mental schemas.

We can summarize these three types of cognitive load as follows:

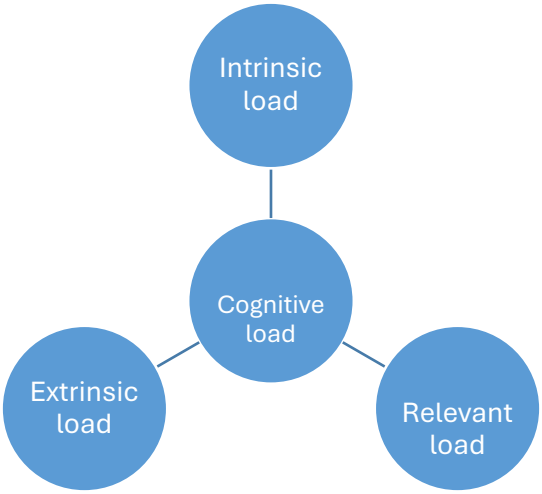


Figure 1: Types of Cognitive Load

Source: Memory processes (Baddeley, Ebbinghaus)

Learning relies on the interaction between working memory and long-term memory. The consolidation of knowledge requires strategies such as spaced repetition, elaboration, and active retrieval (Olive & Piolat, 2005) . Memory processes are often described based on two major theoretical contributions: first, Hermann Ebbinghaus's characterization of the fundamental stages of encoding, storage, and retrieval in the late 19th century; and second, Alan Baddeley and Graham Hitch's modular model of working memory in the 20th century. Ebbinghaus demonstrated that information is first encoded from environmental stimuli and then stored in various memory systems, where spaced repetition limits the loss described by his famous "forgetting curve" (Murre & Dros, 2015) .

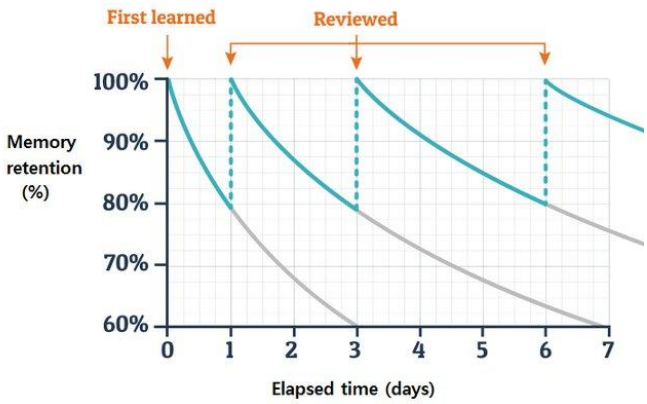


Figure 2 : Ebbinghaus's forgetting curve

Source: (Chun & Heo, 2018)

For his part, Baddeley models working memory as an active system composed of a central administrator coordinating at least two specialized subsystems (the phonological loop and the visuospatial sketchpad), and, in an expanded version, an episodic buffer that integrates information from long-term memory. Collectively, these studies help us understand that memory is not merely passive storage but relies on dynamic processes of encoding, active maintenance, and retrieval (Mujawar et al., 2021) , the effectiveness of which depends on the information modality, cognitive load, and organized repetition.

4. ATTENTION AND COGNITIVE ENGAGEMENT

Attention is a prerequisite for all learning, insofar as it enables the learner to select relevant information from among all the stimuli to which they are exposed (Léger, 2026) . It can be defined as the ability to direct, sustain, and control cognitive resources toward a given piece of information, task, or goal, while inhibiting or filtering out irrelevant information. In an educational context, this function is particularly important, since the quality of attention directly influences the processes of encoding, processing, and memorizing information. Thus, a learner who is distracted or subjected to information overload risks devoting part of their cognitive resources to peripheral elements, to the detriment of information that is essential to understand and memorize. Educational environments must therefore be designed to promote sustained attention, particularly through clear organization of content, a reduction in distractions, and the alternation of learning modalities (Kessous et al., 2010) . However, attention alone is not enough to guarantee effective learning: it must be accompanied by genuine cognitive engagement on the part of the learner. This refers to the degree of intellectual investment mobilized in carrying out a learning task (Lepage & Leduc,

2019) . It manifests itself, in particular, using sophisticated cognitive and metacognitive strategies, the establishment of connections between new and prior knowledge, problem-solving, self-regulation of effort, and the ability to monitor one's own understanding. High cognitive engagement thus implies that the learner does not merely receive or reproduce information, but actively processes it, questions it, organizes it, and applies it to new situations. From this perspective, attention serves as a gateway to learning, while cognitive engagement largely determines its depth. Instructional design must therefore seek not only to capture learners' attention but also to transform it into productive cognitive activity by offering problem-based scenarios, authentic tasks, and activities that foster reflection, collaboration, and metacognition.

5. THE ROLE OF EMOTIONS (DAMASIO)

Emotions play a fundamental role in cognitive processes and cannot be viewed as a peripheral phenomenon or as a disruption of rationality. Research in affective neuroscience shows, on the contrary, that emotional and cognitive processes are in constant interaction and that they jointly contribute to behavioral orientation, decision-making, attention, and memory. From this perspective, Antonio Damasio's work has profoundly challenged the traditional view of a separation between reason and emotion (Patterson & Mastracci, 2019) . Drawing in particular on studies of patients with lesions of the ventromedial prefrontal cortex, Damasio demonstrates that impairments in emotional mechanisms can lead to significant difficulties in decision-making, even while certain intellectual abilities and logical reasoning remain intact. His somatic marker hypothesis proposes that past emotional experiences leave traces associated with bodily and affective states that can then rapidly guide choices and behaviors in new situations (Damasio, 1996) . Emotion thus appears not as the opposite of reason, but as a mechanism that helps select and prioritize relevant information (Damásio, 1999) . This interaction is particularly important in the field of education: a learning experience associated with interest, curiosity, or a sense of competence can promote attentional engagement and facilitate the encoding and retrieval of information, whereas a sustained negative emotional state—particularly excessive anxiety or a sense of insecurity—can divert some cognitive resources away from the learning task. Subsequent research in cognitive and affective neuroscience has also shown that emotions are closely linked to attention and memory, particularly through the systems involved in salience processing and memory consolidation (Immordino-Yang & Damasio, 2007; Pessoa, 2008) . From this perspective, Immordino-Yang and Damasio (2007) emphasize that truly meaningful learning is difficult to separate from emotional processes: what the learner feels in a given situation helps determine what they pay attention to, what they consider relevant, and what they are likely to retain. However, we should avoid a simplistic interpretation suggesting that positive emotions automatically lead to better learning (Tyng et al., 2017) . The influence of emotions depends on their nature, intensity, duration, and the educational context. The challenge for instructional design, therefore, lies less in constantly seeking a "positive emotional state" than in designing a safe, stimulating, and cognitively engaging environment in which emotions can support attention, motivation, effort regulation, and meaning making. Thus, from a perspective inspired by cognitive science, the learner can be viewed as a cognitive, affective, and social being, which implies designing instructional situations that go beyond the mere transmission of knowledge.

6. THE INTERSECTION BETWEEN COGNITIVE SCIENCE AND INSTRUCTIONAL DESIGN

The intersection between cognitive science (memory, attention, cognitive engagement, and emotions as defined by Damasio) and instructional design opens up a fundamental perspective for rethinking the design of teaching and learning systems—no longer based on intuitive conventions, but rather on how the brain and human cognition actually process information. This interface makes it possible to transform findings from cognitive science research into operational principles of instructional design by linking internal processes (working memory, attention, emotions) with the structure of learning situations, materials, and activities.

- ***Memory, Cognitive Load, and the Microstructuring of Content***

Baddeley's work on working memory (phonological loop, visuospatial sketchpad, central administrator) shows that cognitive resources are limited and selective (Tricot, 1998) , which requires instructional designers to structure content in order to reduce unnecessary cognitive load. This involves, for example, breaking down learning into small units (microlearning), simplifying interfaces, avoiding sensory overload, and implementing coherent multimodal materials that engage both channels (visual and verbal) without overloading working memory. Instructional design can thus draw on these memory models to design progressive learning paths, where each micro-module is conceived as an "operating block" that activates and consolidates encoding, and is then reinforced through spaced recall exercises, in line with the principles of spaced repetition and progressive consolidation (Chun & Heo, 2018) .

- ***Attention, Cognitive Engagement, and Activity Models (ICAP)***

Models of attention and cognitive engagement emphasize that learning depends less on simple passive exposure to information than on how that information captures and directs attention, and then truly engages the learner. From this perspective, the ICAP model (Chi & Wytranslie) proposes a continuum of cognitive engagement (passive, active, constructive, interactive), where each level corresponds to a more or less deep type of learning. Instructional design can therefore use this continuum as a framework: by increasing the number of activities that require learners to rephrase, explain, argue, respond to others, or collaborate, it promotes the constructive and interactive modes, which are recognized as generating more lasting and transferable learning. In practice, this translates into instructional scenarios that alternate between brief directive presentations, targeted questions, written or oral production tasks, and forums or synchronous discussions, in order to optimize attention regulation and maintain a high level of cognitive engagement.

- ***Emotions, Somatic Markers, and Intrinsic Motivation***

Antonio Damasio's work on the modulatory role of emotions shows that cognition is neither a cold nor an autonomous process, but functions in close interaction with emotional signals, particularly through "somatic markers" that guide decisions and choices (Immordino-Yang & Damasio, 2007) . Applied to instructional design, this means that managing emotions (psychological safety, enjoyment of learning, reduction of excessive anxiety, and recognition of achievements) is not merely a peripheral "affective" aspect, but a central driver of cognition and memory. Well-designed interventions therefore incorporate narrative elements, authentic contexts, meaningful challenges, and positive affective feedback, which generate motivating emotions and transform certain experiences into memorable "markers" that will subsequently guide learning behaviors.

We synthesize intersections for instructional design

At the intersection of these theories, modern instructional design can be summarized as a discipline that optimizes: the structure of content and materials based on the limitations of working memory and the principles of cognitive load; the sequence of activities to capture attention and promote high levels of cognitive engagement (ICAP models); learning contexts and interactions to harness the role of emotions as modulators of cognition and motivation, in accordance with Damasio's hypotheses.

In other words, the cognitive sciences provide instructional designers with a genuine "model of how learners function," which enables the design of systems that are not only didactically coherent but also neuro- and cognitively plausible, in accordance with the natural mechanisms of memory, attention, engagement, and emotions.

The intersection between cognitive science, instructional design, and transferable skills is based on a functional link between understanding learning mechanisms, designing educational programs, and developing complex human skills. Indeed, cognitive science sheds essential light on the mental processes involved in the acquisition of knowledge and behaviors (attention, memory, executive functions, metacognition) (, which helps guide instructional design toward more effective and scientifically grounded pedagogical choices. Instructional design, as a structured approach to designing and regulating learning situations, transforms these theoretical insights into concrete practices (scenario planning, active learning activities, feedback, cognitive regulation).

In this context, cross-cutting competencies such as collaboration, communication, emotional regulation, and critical thinking are no longer viewed as implicit skills but as progressive constructs supported by educational environments intentionally designed to engage and reinforce cognitive and socio-emotional processes. Thus, this intersection facilitates a shift from a transmissive pedagogy to an integrated pedagogy, where the development of soft skills is directly grounded in the scientific foundations of learning and operationalized through appropriate instructional design.

7. DISCUSSION

The results of the literature review highlight a strong theoretical convergence between the contributions of cognitive science, the principles of instructional design, and the requirements for developing cross-disciplinary skills. Indeed, the studies reviewed confirm that fundamental cognitive processes such as attention, memory, executive functions, and metacognition form the foundation upon which not only academic learning but also cross-disciplinary skills are built (Olive & Piolat, 2005) . Thus, skills such as critical thinking, problem-solving, and collaboration engage complex cognitive mechanisms that can be stimulated and strengthened through appropriately designed instructional strategies.

From this perspective, instructional design emerges as a strategic lever for putting the findings of cognitive science into practice. Instructional models that incorporate active learning approaches (problem-based learning, project-based learning,

case studies) foster deep cognitive engagement and provide authentic contexts conducive to the development of cross-disciplinary skills. Furthermore, incorporating principles from cognitive load theory, memory consolidation, and the role of emotions helps optimize the effectiveness of learning strategies.

However, the analysis also highlights a persistent gap between theoretical advances and actual pedagogical practices, particularly in the university setting. Transversal skills are often integrated implicitly or declaratively, without being truly supported by structured approaches or rigorously assessed (Duru-Bellat, 2015) . Furthermore, teachers' adoption of insights from cognitive science remains limited due to a lack of specific training and a gap in the transfer of knowledge between research and practice (Perrin, 2019) .

Furthermore, certain limitations must be highlighted. On the one hand, existing research sometimes exhibits conceptual fragmentation, making it difficult to develop integrated models. On the other hand, the predominance of theoretical or experimental studies in controlled settings raises questions about the transferability of results to real-world educational environments. Finally, the very complexity of cross-curricular competencies which encompass cognitive, social, and emotional dimensions require holistic pedagogical approaches that have not yet been sufficiently developed.

Thus, this discussion highlights the need to rethink instructional design from a systemic perspective, coherently integrating insights from cognitive science to foster the effective and measurable development of cross-curricular competencies.

CONCLUSION

This research aimed to analyze the extent to which pedagogical design grounded in cognitive science can contribute to the development of cross-curricular competencies. Through a literature review, it highlighted the existence of a robust theoretical framework supporting the idea of complementarity among these three dimensions: cognitive science, instructional design, and cross-curricular competencies.

The results show that cognitive science provides essential foundations for understanding learning mechanisms and guiding the design of more effective instructional approaches. When integrated into instructional design, these insights enable the creation of learning environments that foster not only the acquisition of knowledge but also the development of key cross-disciplinary skills, which are indispensable in contemporary professional contexts.

Nevertheless, the research also highlights significant challenges, particularly regarding instructional implementation, teacher training, and the assessment of cross-curricular skills. These findings call for a renewal of educational practices, based on a stronger link between research and practice, as well as a more integrated and contextualized approach to instructional design.

Looking ahead, it appears necessary to extend this discussion through empirical studies that test and validate pedagogical models inspired by cognitive science in real-world teaching contexts. Furthermore, the integration of educational technologies, particularly artificial intelligence, could offer a promising avenue for personalizing learning and enhancing the development of cross-disciplinary skills.

In summary, this research contributes to the debate on the evolution of instructional practices in the era of cognitive and digital transformations by highlighting the need for scientifically informed instructional design geared toward the learner's holistic development.

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