GENERATIVE AI AND COGNITIVE ACTIVITY IN PRIMARY EDUCATION: THE BOUNDARY BETWEEN SUPPORTING AND REPLACING STUDENT THINKING

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Abstract: The rapid integration of generative artificial intelligence into educational environments is transforming the ways in which learners access information, receive feedback, and engage with learning content. However, in primary education, where cognitive, metacognitive, and self-regulatory abilities are still developing, the pedagogical value of generative AI cannot be determined solely by its capacity to provide rapid and personalized assistance. The central issue concerns the boundary between using AI as a cognitive and pedagogical scaffold and allowing it to substitute for the learner's own intellectual activity. This conceptual paper examines this boundary through the relationship between generative AI, teacher mediation, and students' cognitive engagement in primary education. Drawing on recent research on AI in primary and K–12 education, the paper argues that effective integration of generative AI requires a shift from answer-oriented use toward process-oriented learning, in which AI supports questioning, comparison, explanation, reflection, and independent reasoning rather than producing completed solutions. Particular attention is given to the risk of excessive cognitive offloading, whereby learners transfer essential elements of problem-solving and knowledge construction to AI systems. The paper proposes a pedagogical principle according to which the educational value of generative AI should be assessed not by the amount of assistance provided, but by its capacity to preserve and strengthen learner agency, cognitive engagement, and independent thinking. Consequently, teacher mediation remains essential for determining when, why, and to what extent AI assistance should be introduced into primary learning activities.

Keywords: generative artificial intelligence, primary education, cognitive activity, independent thinking, cognitive offloading, learner agency, teacher mediation, AI in education, pedagogical integration, critical thinking.

Generative artificial intelligence (GenAI) has introduced a qualitatively different form of technological assistance into educational practice. Unlike earlier digital learning tools that primarily provided access to predefined instructional materials or programmed feedback, generative AI can produce explanations, examples, questions, summaries, narratives, images, and problem-solving suggestions in response to individual prompts. This capacity creates new

possibilities for personalization and adaptive learning, but it simultaneously raises a fundamental pedagogical question: **at what point does assistance cease to support learning and begin to replace the cognitive activity through which learning occurs?**

This question becomes particularly significant in primary education. Children at this educational stage are developing foundational abilities in reasoning, problem-solving, self-regulation, metacognition, and independent decision-making. Consequently, the pedagogical consequences of AI use cannot be evaluated only through efficiency, accuracy, or immediate task performance. The more fundamental issue is whether AI-mediated learning environments create conditions in which learners remain intellectually engaged with the learning process.

Recent systematic research confirms that AI applications in primary education have been associated with individualized learning, instructional support, and diverse pedagogical approaches, while simultaneously raising concerns related to students 'individual needs, data, ethics, and the conditions of implementation. A systematic review of 35 Scopus-indexed empirical studies focusing on children aged 4–12 demonstrates that AI in primary education represents a developing but still insufficiently consolidated research field.

At the same time, broader research on GenAI in education indicates a significant gap in K–12 research. A systematic mapping review of 407 publications identified major research themes around pedagogical enhancement, performance, adoption, ethical implications, and risks, but emphasized the relative scarcity of research specifically addressing K–12 contexts and the limited number of experimental investigations into GenAI's educational impact.

These observations lead to the central problem of the present paper: **how can generative AI be integrated into primary education without transferring the learner's essential cognitive work to the technology?**

The paper therefore focuses not on whether generative AI should be used in primary education, but on **how the boundary between cognitive support and cognitive substitution can be pedagogically defined and maintained**.

The pedagogical value of generative AI should first be distinguished from its technological capability. The fact that an AI system can generate an answer does not necessarily mean that providing that answer contributes to learning. In educational contexts, learning is not reducible to the acquisition of a correct response; it involves processes of questioning, interpretation, comparison, reasoning, error recognition, and meaning construction.

From this perspective, GenAI can perform two fundamentally different pedagogical functions.

In the first case, AI acts as a **cognitive scaffold**. It provides hints, alternative explanations, examples, guiding questions, feedback, or progressively structured assistance while leaving the learner responsible for the essential reasoning process.

In the second case, AI becomes a **cognitive substitute**. It generates the answer, solves the problem, constructs the explanation, or produces the final product, while the learner merely accepts and reproduces the output.

The distinction is therefore not determined by whether AI is present in the learning process, but by **which cognitive functions remain with the learner after AI has been introduced**.

This distinction is particularly important because the same technological capability can produce opposite pedagogical outcomes. A generated explanation may help a child understand a difficult concept when it is used as a starting point for discussion. The same explanation may inhibit learning when it eliminates the need for the child to formulate a hypothesis or construct an explanation independently.

Consequently, the pedagogical question should shift from:

“Can AI provide the correct answer?”

to:

“What part of the thinking process should remain with the learner?”

This shift provides the conceptual basis for defining responsible GenAI integration in primary education.

One of the central challenges associated with GenAI is **cognitive offloading**—the transfer of cognitive operations from the learner to an external technological system.

Cognitive offloading itself is not inherently negative. External tools have always been used to reduce unnecessary cognitive demands and allow individuals to concentrate on more complex tasks. The pedagogical problem emerges when AI does not merely reduce peripheral cognitive load but assumes responsibility for the **core intellectual operation through which learning is expected to occur**.

For example, using AI to generate several examples of a mathematical concept may support learning. However, asking AI to solve the problem and then

copying the solution removes the very reasoning activity through which mathematical understanding is constructed.

The distinction can therefore be represented as follows:

AI assistance

→ provides prompts
→ offers alternatives
→ gives feedback
→ visualizes concepts
→ stimulates questioning

versus

AI substitution

→ produces the answer
→ solves the problem
→ writes the explanation
→ makes the decision
→ completes the task.

The first model preserves learner agency; the second risks reducing it.

Recent research on GenAI and cognitive offloading demonstrates that the relationship is not necessarily linear or uniformly negative: AI-supported offloading can sometimes facilitate performance when it is accompanied by metacognitive regulation. This suggests that the critical issue is not simply **whether cognitive offloading occurs**, but **what is being offloaded, why it is being offloaded, and whether the learner remains cognitively responsible for the central learning objective**.

For primary education, this distinction is particularly important because children may not yet possess sufficiently developed metacognitive abilities to evaluate when technological assistance is beneficial and when it becomes excessive.

If the distinction between assistance and substitution cannot be determined solely by the technology itself, the role of the teacher becomes central.

The teacher functions as the **pedagogical mediator** who determines the purpose, timing, intensity, and form of AI assistance. Rather than simply introducing an AI tool into classroom practice, the teacher must design learning situations in which the technology supports specific cognitive processes.

For instance, instead of asking an AI system:

“Solve this problem for the student,”

the teacher can formulate the activity as:

"Give the student three possible strategies for approaching the problem, but do not provide the final answer."

Such a prompt changes the pedagogical function of AI. The technology no longer completes the cognitive task; it creates conditions under which the learner must perform it.

The same principle can be applied to reading, writing, mathematics, and science. AI may generate questions, alternative interpretations, examples, or counterarguments, while the learner remains responsible for selecting, evaluating, explaining, and defending a position.

Thus, **teacher mediation transforms AI from an answer-generating technology into a learning-support technology**.

This is particularly consistent with contemporary research emphasizing that effective AI integration depends not simply on access to technological tools but on pedagogical design and teacher competence. Research on AI in primary education similarly indicates that implementation involves pedagogical, ethical, and individual considerations rather than technological adoption alone.

The distinction between supporting and replacing student thinking suggests the need to reconsider how AI-supported tasks are designed.

A **result-oriented model** can be represented as:

Question → AI → Answer → Student

Here, the learner's cognitive participation is potentially minimized.

A **process-oriented model**, by contrast, can be represented as:

Question → Student hypothesis → AI support → Comparison → Evaluation → Revision → Independent conclusion

In the second model, AI becomes part of the learner's cognitive environment without becoming the primary source of intellectual decision-making.

This distinction is particularly relevant for primary education because learning activities should gradually develop the learner's capacity to formulate questions, tolerate uncertainty, test alternatives, recognize errors, and justify conclusions.

Therefore, effective GenAI integration should prioritize **Socratic questioning, guided prompting, comparative tasks, error analysis, explanation generation, reflection, and self-assessment** rather than unrestricted answer generation.

The goal is not to minimize AI use. The goal is to **design AI use so that greater technological assistance does not automatically mean less cognitive participation**.

Based on the preceding analysis, the boundary between supporting and replacing student thinking can be conceptualized through four interconnected dimensions:

1. **Purpose of AI use**
   Is AI being used to facilitate learning or merely to complete a task?
2. **Distribution of cognitive responsibility**
   Which elements of reasoning remain the learner's responsibility?
3. **Degree of teacher mediation**

How actively does the teacher regulate the type and intensity of AI assistance?

4. **Evidence of learner agency**
   Does the learner question, evaluate, modify, justify, and independently reproduce the reasoning?

Accordingly, the pedagogical effectiveness of GenAI can be conceptualized as:

Pedagogical purpose + teacher mediation + learner agency + controlled AI assistance → meaningful cognitive engagement

rather than:

More AI assistance → better learning.

This distinction is important because recent reviews identify both pedagogical enhancement and ethical/risk dimensions as major themes in GenAI research, while primary-school research remains comparatively underdeveloped.

The analysis suggests that the central problem in primary education is not the presence of GenAI itself but the **redistribution of cognitive responsibility** that occurs when the technology becomes part of the learning process.

If AI assumes peripheral and repetitive cognitive operations, it can potentially free learners and teachers to focus on higher-order activities. However, when AI assumes the central processes of reasoning, explanation, decision-making, or problem construction, technological efficiency may be achieved at the expense of learning itself.

This creates a pedagogical paradox: **the more effectively AI performs a learning task, the greater the need to ask whether the learner still performs the cognitive work that the task was originally designed to develop.**

Therefore, the success of GenAI in primary education should not be evaluated exclusively through speed, accuracy, personalization, or task completion. These indicators describe technological performance, but they do not necessarily demonstrate learning.

A more meaningful criterion is whether AI-supported learning increases the learner's capacity to **question, reason, evaluate, explain, and act independently**.

This position also implies that the role of the teacher becomes more—not less—important in AI-mediated education. As generative systems become increasingly capable of producing instructional content, the teacher's distinctive contribution shifts toward pedagogical judgment: deciding what should be generated, what should remain cognitively difficult, what requires human interaction, and where technological assistance should deliberately be limited.

Generative AI creates significant opportunities for primary education, particularly through personalization, adaptive support, content generation, visualization, and immediate feedback. However, these opportunities do not automatically translate into meaningful learning.

The central pedagogical challenge lies in maintaining a productive boundary between **supporting cognitive activity and replacing it**.

The analysis demonstrates that AI should be designed and implemented as a **cognitive scaffold rather than a cognitive substitute**. Its educational value depends not on the amount of assistance it provides but on whether that assistance preserves learner agency and sustains the intellectual processes through which knowledge is constructed.

For primary education, this principle is especially important because independent reasoning, metacognition, and self-regulation are still developing. Consequently, the teacher must remain responsible for regulating the purpose, level, and form of AI assistance, while learners must retain responsibility for the essential cognitive operations underlying the learning objective.

Thus, the appropriate pedagogical model can be summarized as:

AI should make learning more supported, not thinking less necessary.

In this sense, the ultimate goal of GenAI integration is not to produce learners who can obtain answers more efficiently, but to develop learners who can **ask better questions, evaluate information more critically, reason more independently, and use AI without surrendering responsibility for their own thinking**.

This conclusion is particularly significant given that systematic research continues to identify substantial gaps in K–12 and primary-school GenAI research.

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