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The cognitive dimensions of digital learning: metacognition and digital literacy in modern education

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Abstract: Although there has been over thirty years of research defining digital tools as learning partners to assist cognition, most classroom use of digital technology remains focused on transmitting content. This article defines the process by which students regulate their own thoughts, metacognition, as an essential part of how they can be digitally literate; and argues that if educators do not provide the metacognitive support necessary for students to utilize the digital tools in a strategic way, then most of what is considered "digital pedagogy" will function more like activity taxonomies. The analysis presents a theoretical interpretation of how Bloom's Digital Taxonomy, SOFLA, and UDL relate to metacognitive processes, positioning these frameworks as illustrative applications of the broader theoretical claim. The study also establishes distinctions between conclusions drawn from existing literature, implications derived from this current analysis, and hypotheses proposed for subsequent empirical testing. It further proposes that inclusive pedagogical practices are more effective at transforming access to actual engagement when students have developed sufficient metacognitive skills to select among multiple modes of representation strategically.

Keywords: digital literacy, inclusive pedagogy, metacognition, self-regulated learning, scaffolding

1 Introduction

The claim that digital technologies should restructure rather than amplify cognition is not novel. Pea (1985) presented that computers could reorganize mental functioning, and Jonassen (1996) framed digital tools as "mindtools." Despite this theoretical framework, educational implementation frequently remains limited to instructional delivery and content distribution. This paper suggests that metacognition is the missing element: the scaffolded abilities to plan, monitor, and evaluate cognitive activity within digitally mediated learning environments (Efklides, 2011; Veenman et al., 2006).

In this paper, the term metacognitive infrastructure is defined to refer to the instructional and technological conditions that externalize, support, and gradually internalize regulatory processes such as planning, monitoring, evaluating, and strategic adjustment. This term does not just relate to individual tools or isolated instructional interventions; it refers to a broader system of scaffolds, reflective prompts, and fading protocols that together guide learners toward a self-regulated interaction with digitally mediated environments.

Three central implications guide this paper's structure. First, digital literacy, defined as the capacity to locate, evaluate, synthesize, and create information within digital platforms in a strategically regulated manner, can be viewed as a context-specific manifestation of metacognitive competence rather than a distinct category set (Spante et al., 2018). Second, pedagogical frameworks including Bloom's Digital Taxonomy and SOFLA are likely to be more pedagogically effective when explicit metacognitive scaffolding is embedded into their implementation. Third, inclusive pedagogy, as operationalized through UDL, is likely to depend on metacognitive infrastructure in order to transform accessibility into active participation. These claims are based on different evidential grounding:

the first relied upon the foundation provided by an established theory, the second is an inference, and the third is a hypothesis requiring empirical testing. Anchored in socio-constructivist theories (Bruner, 1961; Vygotsky, 1978), this paper explores technology as a mediator of both reflective practice and collaborative inquiry (Balgabayeva et al., 2024; Florian & Black-Hawkins, 2011).

2 Digital literacy and metacognition

The socio-constructivist paradigm (Bruner, 1961; Vygotsky, 1978) inserted that knowledge is constructed through mediated activity. Drawing upon this conceptual lens, Jonassen (1996) and Pea (1985) argued that digital tools could externalize cognitive processes, enabling them to function as objects for knowledge construction (Scardamalia & Bereiter, 2006). Such inspectability intersects with metacognition; Flavell (1979) defined it as both cognitive awareness and the regulation of cognitive processes, whereas Efklides (2011) highlighted the dynamic interplay among metacognitive knowledge, experiences, and skills.

Metacognitive experiences, such as perceived difficulty or confidence, influence whether metacognitive knowledge is deployed. This is relevant because learners who possess the knowledge to evaluate online sources may fail to do so when the triggering experience does not arise. Veenman et al. (2006) note that metacognitive skill may be partly domain specific, meaning skill in one technological domain does not automatically transfer.

Spante et al., (2018) mapped digital literacy as encompassing informational, technological, and media competencies. From this analysis' perspective, such mappings treat digital literacy as a skill set rather than a regulated activity. For example, a student may successfully identify a reliable source by following a checklist, yet lack the capacity to judge reliability in unfamiliar contexts where no checklist is available; the difference lies in whether the evaluation was rule-governed or metacognitively regulated. Balgabayeva et al. (2024) argue that digital literacy functions as a metacognitive component of intellectual potential, approaching the position here: digital literacy may depend on metacognitive regulation to a degree that makes the two difficult to treat as independent constructs in practice. Research has identified a positive relationship between self-regulated learning and digital literacy (Rattanapun et al., 2026), consistent with SRL constituting a key regulatory mechanism of which digital literacy is the behavioral surface.

3 Scaffolding metacognitive development

Grounded in Vygotsky's (1978) zone of proximal development, scaffolding provides temporary cognitive support progressively withdrawn as the learner internalizes the regulatory function. van de Pol et al. (2010) identify three features: contingency, fading, and transfer of responsibility, suggesting interventions lacking any one may be closer to structured instruction. Belland et al.'s (2017) conducted a meta-analysis that found variable effect sizes statistics, aligning with the expectation that unfaded scaffolding produces weaker outcomes. Importantly, from the standpoint of Efklides' (2011) framework, effective fading depends on whether learners have developed the metacognitive experiences, such as feelings of knowing or feelings of difficulty, that allow them to detect when they need support and when they can proceed independently. Without these experiences, scaffolding fades arbitrarily rather than because the learner has reached regulatory readiness.

Four modes of scaffolding have been identified by Hannafin et al. (1999): procedural scaffolding, conceptual scaffolding, metacognitive scaffolding, and motivational scaffolding. While these may operate independently, they can be interrelated: procedural difficulties may reduce capacity needed for conceptual work, and without motivational support, learners will not attempt metacognitive monitoring. The progression from external support to internal regulation follows an established pattern: teachers demonstrate model thinking through think-alouds (verbalization), students work with guidance, and eventually regulation is internalized as inner speech (Hartman, 2001). Digital environments frequently implement earlier stages well and later stages inadequately. Sound design should establish conditions under which support is provided, but also the specific conditions that will signal the need for students to begin withdrawing support in order to allow them to develop independent regulation.

4 Revisiting bloom's digital taxonomy

Bloom's Digital Taxonomy (Churches, 2008) maps Krathwohl's (2002) revised taxonomy with digital-based learning activities. Although Churches' work is a widely adopted practitioner resource used by many educators, there are three potential areas for concern related to curriculum development.

First, the empirical basis appears to be restricted; Newton et al. (2020) pointed out that verb lists vary substantially, and Krathwohl (2002) warned against strict sequentiality. Second, the taxonomy describes actions without specifying the regulatory constraints that govern those actions. For instance, a student who bookmarks dozens of articles without planning what to collect, monitoring relevance, or evaluating the emerging structure is performing a digital action but without engaging in a cognitively meaningful remembering process. Furthermore, what Efklides (2011) would consider as a metacognitive experience of difficulty or progress is absent from this activity, which indicates that no regulatory adjustments are made by the learner. Third, cognition is not as hierarchically arranged as the taxonomy suggests. The taxonomy is therefore best viewed as a design heuristic rather than as a cognitive architecture.

5 Digital tools and metacognitive affordances

Digital tools used in education can function as metacognitive infrastructures when they externalize cognitive processes within a sustained regulatory cycle for learners. Four affordances seem significant, though their potential metacognitive functions are proposed interpretations. Structured reflection environments create temporal records of cognitive patterns; Jarvelä et al. (2021) indicated how multimodal analytics capture process data static assessments miss, though unstructured reflection typically results in superficial reflection. Similarly, screen-capture tools produce visual traces of previously invisible planning activities (Azevedo & Gašević, 2019); however, simultaneous verbalization may alter the process, which is consistent with cognitive load theory (Sweller, 2011).

Shared annotation tools externalize coordination between cognitions, though Malmberg et al. (2017) found that in the same space, individuals may be regulating their own thoughts individually instead of coordinating with others. Reversibility can reduce the cost associated with exploratory thinking (Skubik-Peplaski et al., 2022), and tools like Padlet foster digital empathy by providing a safe asynchronous environment for learners' reflection (Terry & Cain, 2016; Nguyen & Pham, 2025). Across these affordances, the tool creates conditions for metacognition but does not perform metacognitive activities.

6 Shared regulation and teaching presence in online settings

Metacognitive regulation is typically higher than individual regulation when individuals are in close proximity with other people. Self-regulation, co-regulation, and socially shared regulation of learning (SSRL) were identified by Jarvelä et al. (2018), with SSRL subsequently conceptualized as a group-level phenomenon (Biasutti & Frate, 2018; Turkmen, 2024). Smaller groups, moderate diversity, and genuine task interdependence appear to create a supportive environment for the emergence of SSRL (Turkmen, 2024). Combining SRL instruction with interactive learning has been associated with strong digital literacy outcomes (Hmelo Silver, 2004; Prince, 2004; Rattanapun et al., 2026).

The Synchronous Online Flipped Learning Approach (SOFLA; Marshall & Kostka, 2020) operationalizes flipped learning (Bergmann & Sams, 2014) through eight phases. Read through a metacognitive lens, each phase can be interpreted as a regulatory episode. In the pre-work phase, tools that embed formative checks prompt learners to monitor their own comprehension in real time; from Efklides's (2011) perspective, this produces the metacognitive experiences of difficulty or confidence that trigger strategic adjustment before the synchronous session begins. The sign-in activity activates prior knowledge as a baseline for monitoring. Whole-group application and breakouts are where SSRL may emerge; in the share-out phase, when feedback protocols require peers to articulate the criteria they are applying, evaluation becomes externalized and therefore inspectable, which is a precondition for internalization. Preview and discovery serves as forward looking goal-setting (Panadero, 2017), without which the flipped cycle may collapse (Talbert, 2017). Assignment instructions may lessen extraneous load, consistent with cognitive load theory (Sweller, 2011). The reflection phase completes the regulatory loop, but only when it is designed to produce specific metacognitive content; a brief confidence rating is not sufficient to perform the evaluative work that a prompt such as "which strategy did you use, what was its outcome, and what will you adjust next time" would elicit. An empirical study of whether or not these phases produce the intended metacognitive effects described would strengthen the framework's applicability across diverse settings. Within the Community of Inquiry framework (Garrison et. al., 2000), teaching presence refers to the design of learning phases as regulatory episodes.

7 Inclusive pedagogy and universal design for learning

Inclusive pedagogy moves beyond the notion of the "average learner" (Booth & Ainscow, 2011; Florian & Black-Hawkins, 2011). UDL offers multiple means of representation, expression, and engagement (Rose & Dalton, 2009). Its effectiveness may rely upon an implicit assumption; students need to have the ability to select among channels in a cognitively informed way. The inability to know whether one type of media will support learning better than another does not allow a student to take full advantage of all of the learning opportunities provided. In Efklides's (2011) terms, for the learners to utilize this process they need to have a metacognitive sense of whether or not the selected medium has helped them; and that the outcomes of their experience are used to select an alternative. This proposed interdependence between UDL and metacognition is the paper's central contribution to the UDL literature, though it remains purely theoretical.

Capp's (2017) meta-analysis reported a mix of positive but heterogeneous effects, consistent with the argument that UDL implementations using metacognitive scaffolding may provide stronger outcomes, though the meta-analysis does not examine this mechanism. The assistive technologies (Rao et al., 2014) and the adaptive platforms (Pane et al., 2017; Walkington, 2013) serve access functions, and these functions are amplified when learners develop metacognitive fluency. Digital empathy (Terry & Cain, 2016) and immersive perspective-taking (Herrera et al., 2018) extend the argument to the affective domain, although technology alone appears insufficient.

8 Conclusion

This paper proposed that metacognitive infrastructure brings together digital literacy, Bloom's Digital Taxonomy, SOFLA, and UDL into a coherent whole. In the absence of this infrastructure, each of these reduces to a less complex form: digital literacy to technical fluency, the taxonomy to an activity catalogue, SOFLA to a scheduling template, and UDL to multiple modes of delivery. Research should be focused on measuring regulatory processes alongside skills; design should begin from the regulatory cycle; and instructors' preparation educational programs should treat metacognitive pedagogy as a core competence.

The emergence of generative AI introduces a new aspect that should be addressed. AI systems may serve as either metacognitive scaffolds that support planning, monitoring, and reflection, or alternatively as substitutes that reduce regulatory engagement through cognitive offloading, this refers to the tendency to direct cognitive effort to external tools rather than performing it internally (Risko & Gilbert, 2016). Ultimately, the degree to which AI strengthens or weakens metacognitive development is likely dependent on instructional design and the extent to which learners remain responsible for evaluation and strategic control. The metacognitive infrastructure framework provides a lens for evaluating AI integration: the question is not whether AI is used, but whether its use places it within a regulatory cycle that preserves and develops learners' agency.

Some limitations must be acknowledged: this is a conceptual paper whose connections are outlined rather than demonstrated through empirical evidence. Future proposed research should present studies manipulating the metacognitive layer while keeping all other elements constant, as well as examining UDL outcomes broken down by metacognitive scaffolding. The argument should be read as a theoretically grounded hypothesis.

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