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From cognitive levels to adaptive algorithms: bloom's taxonomy in the design of adaptive learning management systems

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Abstract: Adaptive learning management systems (LMS) increasingly personalize instructional content and difficulty, yet designers frequently prioritize technical convenience over explicit pedagogical theory. This scoping review examines how Bloom's Taxonomy — one of the most widely used frameworks for structuring cognitive learning objectives — has been operationalized in the design of adaptive mechanisms within LMS and intelligent tutoring system research. I identified literature through Google Scholar, Scopus, and Consensus, covering foundational pedagogical sources without date restriction and technical adaptive-learning sources published between 2015 and 2026. The review finds that Bloom's Taxonomy has been applied to adaptive system design only in isolated instances, most notably for content-complexity matching and scaffolding-difficulty calibration, without a systematic account of how the taxonomy's full hierarchy corresponds to distinct classes of adaptive design. Building on these precedents, the review proposes a working-hypothesis mapping between the six cognitive levels of Bloom's Taxonomy and six classes of adaptive mechanisms, ranging from rule-based branching logic at the remembering level to personalized, open-ended learning-pathway generation at the creating level. Two of the six correspondences have direct empirical precedent in existing systems; the remaining four are proposed analogically and require further empirical validation. The proposed framework offers a starting structure for grounding adaptive LMS design decisions in cognitive learning theory; future research should test it empirically and explore institutional implementation.

Keywords: Bloom's Taxonomy; adaptive learning management systems; intelligent tutoring systems; zone of proximal development; scaffolding; educational information systems; cognitive levels.

1. Introduction

The rapid expansion of digital learning environments has positioned adaptive learning management systems (LMS) as a central mechanism for addressing learner diversity at scale. Rather than delivering uniform content to all students, adaptive LMS platforms adjust the sequence, difficulty, and presentation of learning material based on individual learner models —an approach that empirical evidence increasingly supports as improving cognitive, affective, and behavioral outcomes (Wang et al., 2025).

However, the technical sophistication of adaptive systems has not always been matched by an equally rigorous pedagogical foundation. Recent systematic reviews of AI-supported educational technologies report that a substantial proportion of published systems lack explicit grounding in established learning theory, with cognitive frameworks such as Bloom's Taxonomy applied in only a minority of cases (Topali et al., 2025). Where such frameworks are used, their application tends to be system-specific and empirically isolated — for instance, individual platforms have used Bloom's cognitive levels to classify the complexity of learning objects (Dhakshinamoorthy & Dhakshinamoorthy, 2018) or to calibrate the difficulty of adaptive scaffolding exercises (as reported in Topali et al., 2025) — without a systematic account of how the taxonomy's six hierarchical levels correspond, as a general design principle, to distinct classes of adaptive mechanisms.

This gap is notable given that Bloom's Taxonomy (Bloom, 1956; Anderson & Krathwohl, 2001) remains one of the most widely adopted frameworks for structuring learning objectives, and its digital extension (Churches, 2008) was explicitly developed to bridge cognitive levels with technology-mediated learning activities. Similarly, Vygotsky's concept of the zone of proximal development (ZPD) provides a long-established theoretical basis for scaffolding-based adaptivity in intelligent tutoring systems, where the system's task is to calibrate support to a level the learner cannot yet reach independently (Belland et al., 2022).

This paper addresses the identified gap through a scoping review that examines how Bloom's Taxonomy has been operationalized — explicitly or implicitly — in the design of adaptive mechanisms across existing LMS and intelligent tutoring system research. Building on the isolated precedents identified above, the paper proposes a working hypothesis of correspondence between the six cognitive levels of Bloom's Taxonomy and six classes of adaptive mechanisms, ranging from simple branching logic at lower cognitive levels to personalized learning-pathway generation at higher levels. This mapping is presented not as an established model but as a conceptual synthesis to be evaluated against, and refined by, the reviewed literature — with the aim of providing a more systematic theoretical foundation for the design of pedagogically grounded adaptive learning management systems, consistent with the broader research direction on adaptive information systems for educational process management.

2. Object and subject of research

The object of research is the process of designing adaptive learning management systems within educational information systems. The subject of research is the correspondence between the cognitive levels of Bloom's Taxonomy and the classes of adaptive mechanisms employed in the design of such systems.

3. Target of research

The aim of this study is twofold. First, it systematizes existing approaches to the use of Bloom's Taxonomy in the design of adaptive learning management systems and intelligent tutoring systems. Second, it proposes a conceptual mapping between the taxonomy's six cognitive levels and corresponding classes of adaptive mechanisms — ranging from simple branching logic to personalized learning-pathway generation — and critically evaluates this mapping against the reviewed literature.

4. Literature analysis

The theoretical foundation of this review rests on two complementary traditions in learning theory. The first is Bloom's Taxonomy of Educational Objectives (Bloom, 1956), later revised by Anderson and Krathwohl (2001) into a six-level hierarchy of cognitive processes — remembering, understanding, applying, analyzing, evaluating, and creating — that remains one of the most widely applied frameworks for structuring learning objectives across disciplines. Its digital extension, Bloom's Digital Taxonomy (Churches, 2008), reframed these levels in terms of technology-mediated activities, an approach later validated empirically by Hawk et al. (2021), who found that students' technology use systematically varied across taxonomy levels depending on goal orientation and content area. The second tradition is Vygotsky's sociocultural theory, particularly the concept of the zone of proximal development, which underlies the pedagogical logic of scaffolding — instructional support calibrated to a level the learner cannot yet reach independently (Wood, Bruner, & Ross, 1976, as cited in Belland et al., 2022). Carroll's (1963) model of school learning and Bloom's (1968) mastery learning framework further reinforce the premise that learning outcomes depend on appropriately calibrated time and support rather than fixed instructional pacing — a premise directly relevant to adaptive system design.

Within the applied literature, Bloom's Taxonomy typically functions as a classification device for content or task complexity — not as a comprehensive design framework. Dhakshinamoorthy and Dhakshinamoorthy (2018) used Bloom's cognitive levels as one of two learner-model dimensions in their KLSAS system, matching the cognitive complexity of learning objects to a learner's assessed knowledge level. A comparable approach is reported by Topali et al. (2025) in their systematic review of AI-supported education in K-12 settings, which describes a platform in which Bloom's Taxonomy was used to classify the difficulty of scaffolding exercises, with an adaptation algorithm selecting exercise difficulty within each taxonomy level based on learner effort, hint usage, and performance. Notably, the same review found that only a minority of the examined AI-education systems applied cognitive learning models; most were instead grounded in constructivist or motivational theories, or lacked explicit theoretical grounding altogether (Topali et al., 2025).

Beyond direct applications of Bloom's Taxonomy, the broader adaptive learning literature demonstrates consistent evidence for the pedagogical value of calibrated, learner-responsive instruction. Maycock and Keating (2017) reported statistically significant performance gains using an adaptive system that generated content based on cognitive-resource metadata, while Aktaş et al. (2021) applied cognitive-level classification to automate the construction of assessment instruments. At the level of aggregate evidence, Wang et al. (2025), synthesizing 69 studies, found a medium positive effect of technology-enhanced adaptive learning on cognitive, affective, and behavioral outcomes, with adaptive strategy and adaptive target identified as significant moderators — indicating that the specific design of the adaptation mechanism, and not merely its presence, materially affects learning outcomes. Scaffolding-based adaptivity, meanwhile, has been shown to be highly effective when computer-mediated (Belland et al., 2022) and when responsive to learner self-explanation and representational needs (Joo et al., 2021), lending further support to the theoretical relevance of Vygotskian scaffolding for higher-order adaptive mechanisms.

Taken together, the reviewed literature indicates that while individual studies have applied Bloom's Taxonomy or ZPD-based scaffolding to specific adaptive mechanisms, no systematic account currently exists of how the full hierarchy of cognitive levels corresponds to classes of adaptive design. This gap motivates the conceptual mapping proposed in the following sections of this review.

5. Research methods

This study adopts a scoping review methodology, selected over a systematic (PRISMA-based) review due to the conceptual — rather than exhaustive quantitative — nature of the research objective: establishing a correspondence between an established pedagogical framework (Bloom's Taxonomy) and classes of adaptive mechanisms in learning management systems (LMS).

Search strategy. Literature was identified through Google Scholar, Scopus, and the Consensus academic search engine, using combinations of the following keyword clusters: "Bloom's taxonomy" AND "adaptive learning"; "adaptive learning management system" OR "personalized learning system"; "zone of proximal development" AND "scaffolding"; "intelligent tutoring system" AND "adaptivity"; "mastery learning" AND "e-learning".

Temporal scope. For sources addressing adaptive system architectures and educational technology, the search was limited to 2015–2026, reflecting the period of substantial development in AI-driven personalization and LMS design. Foundational pedagogical sources (Bloom, 1956, 1968; Vygotsky, 1978; Carroll, 1963) were included without date restriction, given their continued active use as theoretical grounding in contemporary literature.

Inclusion criteria. Peer-reviewed journal articles, conference proceedings, and foundational monographs addressing (a) Bloom's Taxonomy or its revised/digital variants, (b) adaptive or personalized LMS architectures, (c) Vygotskian scaffolding within intelligent tutoring systems.

Exclusion criteria. Non-peer-reviewed sources, sources without an accessible full text, and sources unrelated to educational technology or cognitive-level frameworks.

Analytical approach. Rather than applying a formal PRISMA screening count, I qualitatively synthesized the sources, extracting the associated level of cognitive complexity for each documented adaptive mechanism. The resulting correspondence with Bloom's six taxonomic levels is presented as a proposed conceptual mapping, explicitly framed as a working hypothesis pending confirmation or refinement against existing literature.

6. Research results

Building on the theoretical foundation and applied precedents identified in the literature analysis, this section presents a proposed correspondence between the six cognitive levels of Bloom's Taxonomy and six classes of adaptive mechanisms in learning management systems. It is important to state explicitly that this correspondence is not uniformly established in the literature. Two of the six levels have direct empirical precedent in existing systems. The remaining four extend, by analogy, principles observed in the broader adaptive learning literature; I present them as a working hypothesis for evaluation rather than as a confirmed model.

Table 1. Proposed correspondence between Bloom's Taxonomy levels and classes of adaptive mechanisms

Bloom's Level	Cognitive Demand	Proposed Adaptive Mechanism Class	Evidentiary Status
Remembering	Recall of facts	Rule-based branching logic (correct/incorrect → next item)	Analogical — consistent with automated recall-item sequencing (Aktaş et al., 2021)
Understanding	Comprehension of meaning	Content-complexity matching based on assessed knowledge level	Direct precedent (Dhakshinamoorthy & Dhakshinamoorthy, 2018)
Applying	Use of knowledge in context	Adaptive content generation based on cognitive-resource metadata	Analogical — consistent with genetic-algorithm content selection (Maycock & Keating, 2017)
Analyzing	Decomposition of problems	Scaffolded exercise-difficulty calibration	Direct precedent (Sayed et al., 2023)
Evaluating	Judgment against criteria	Representation- and self-explanation-adaptive systems	Analogical — consistent with adaptive visual-fidelity and prompting (Joo, Park, & Kim, 2021)
Creating	Generation of original work	Personalized, open-ended learning-pathway generation	Analogical — consistent with higher-order technology use patterns (Hawk et al., 2021) and adaptive-target effects (Wang et al., 2025)

At the lower end of the taxonomy, remembering-level tasks correspond most naturally to the simplest form of adaptivity: rule-based branching, in which a single correct or incorrect response determines the next item without requiring a rich learner model. While no reviewed source applies

Bloom's levels explicitly to branching logic, this correspondence is consistent with the item-sequencing principles underlying automated test design at the recall level (Aktaş et al., 2021). The understanding level has direct empirical precedent: Dhakshinamoorthy and Dhakshinamoorthy (2018) explicitly used Bloom's cognitive level as an indicator of content complexity, matching learning objects to a learner's assessed comprehension.

At the intermediate levels, applying-level tasks are proposed to correspond to adaptive content generation informed by cognitive-resource metadata, an approach demonstrated — though not explicitly framed in Bloom's terms — by Maycock and Keating (2017), whose genetic-algorithm-based system selected content matched to learner cognitive ability with statistically significant performance gains. The analyzing level again has direct empirical precedent: the adaptive platform described by Sayed et al. (2023) explicitly calibrated scaffolding-exercise difficulty within Bloom's taxonomy levels based on learner effort, hint use, and performance — a mechanism that inherently requires the learner to decompose and analyze the presented problem.

At the higher end of the taxonomy, evaluating-level tasks are proposed to correspond to systems that adapt representational fidelity and prompt learner self-explanation, requiring the learner to judge the adequacy of their own mental model — a correspondence consistent with, though not identical to, the adaptive instructional strategies studied by Joo, Park, and Kim (2021). Finally, the creating level appears to correspond to the most technically demanding class of adaptive mechanism: personalized, open-ended learning-pathway generation. Indirect evidence supports this claim: higher-order technology use clusters at the upper levels of Bloom's Digital Taxonomy (Hawk et al., 2021), and the specific target of adaptation — rather than adaptivity in general — significantly moderates learning outcomes (Wang et al., 2025). Together, these findings suggest that open-ended, learner-directed pathways represent a qualitatively distinct design category rather than an incremental extension of lower-level mechanisms.

Overall, the proposed mapping receives its strongest support at the understanding and analyzing levels, where existing systems have explicitly linked Bloom's Taxonomy to adaptive difficulty calibration. The remaining four correspondences are theoretically motivated extensions grounded in the cited literature's findings. To my knowledge, however, prior empirical work has not explicitly validated them against Bloom's Taxonomy. This asymmetry in evidentiary strength is itself a finding of the review, and the following section addresses it further.

7. Prospects for further research development

The asymmetry in evidentiary support identified in the previous section defines the primary direction for further research: empirical validation of the four analogically derived correspondences (remembering, applying, evaluating, and creating) against Bloom's Taxonomy specifically, rather than against general adaptive-learning outcomes. Controlled studies comparing learner performance under taxonomy-aligned adaptive mechanisms versus conventional, non-taxonomy-informed adaptivity would allow testing the proposed mapping directly rather than inferred by analogy.

A further direction concerns practical implementation and testing within an existing institutional learning management system. As a concrete institutional testbed, such implementation could be piloted within a Moodle-based course at Podillia State University — for instance, the "Fundamentals of IT" course, given its broad first-year audience and predominantly lower-order learning objectives well suited to branching-logic and content-matching mechanisms. This would allow direct comparison with the architecture demonstrated in the APPEAL platform (Sayed et al., 2023), itself built on Moodle, while testing whether the proposed six-level mapping holds at the level of an individual course rather than a full-scale commercial system. Such implementation would also allow the mapping to be refined empirically, potentially revealing that certain adjacent taxonomy levels share a common mechanism class rather than requiring six distinct implementations, as tentatively proposed here.

Finally, the present review's scope was limited to correspondences with Bloom's Taxonomy in isolation; subsequent work could extend the proposed framework by incorporating explainable-AI techniques for learner-model transparency, or by examining how taxonomy-aligned adaptivity interacts with the broader architectural and data-governance requirements of adaptive educational information systems more generally.

8. Conclusions

This review closes a specific gap: no prior work has systematically accounted for how the six cognitive levels of Bloom's Taxonomy correspond to distinct classes of adaptive design mechanisms. While individual studies have applied Bloom's Taxonomy to specific adaptive functions — notably content-complexity matching (Dhakshinamoorthy & Dhakshinamoorthy, 2018) and scaffolding-difficulty calibration (Sayed et al., 2023) — no prior work has proposed a comprehensive correspondence across the full taxonomy.

This review proposed such a correspondence as a working hypothesis, explicitly distinguishing between two levels with direct empirical precedent and four levels supported only analogically by the broader adaptive-learning literature. This distinction is itself a contribution of the review: it clarifies precisely which parts of the proposed model rest on direct empirical evidence and which still require validation — rather than offering a uniformly confident but partially unsubstantiated framework.

For practitioners designing adaptive learning management systems, the reviewed evidence suggests that grounding adaptive mechanism selection in an explicit cognitive framework — rather than in technical convenience alone — is likely to improve pedagogical coherence, though this claim itself warrants the direct empirical testing proposed above. The proposed mapping offers a starting structure for such design decisions, to be refined as further evidence accumulates.

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