

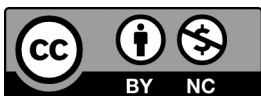
Reconstruction of the Performance Standards in the Transition from 7 to 14 Grades from the Perspective of Generative AI: Concrete Path from “Hierarchical Linearity” to “Instantaneous Generation”

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Abstract: Generative AI tech is racing ahead, and it's greatly changing the ecosystem and scenes of secondary maths education. This has brought about unprecedented challenges of adaptability and a crisis of explanatory power for the traditional “hierarchically linear” math literacy standards that stem from the cognitive logic of “static knowledge accumulation.” Using a theoretical speculation research paradigm, the thesis systematically conceptually decomposes, rigorously propositionally deduces, and deeply conducts theoretical dialogues to investigate the generative mechanism of such dilemmas, as well as to systematically propose pathways for solving them. The research concludes the shortcoming of traditional standards is the inability to recognize the difference between two distinct mathematical practice fields - “static foundational context” and “dynamic generative context”, and the lack of understanding that both foundational and generative competencies have an inherent dialectic “means/ends” relationship such as a student being able to perform computations, make reasoned argumentations, contextualize problems and dynamic model tasks together. Based on this, the study originally proposes the theoretical framework of “Context-Competency-Synergy Three-Dimensional integration”, which not only clarifies the internal logic of the adaptive transformation from “hierarchical linearity” to “instantaneous generation” theoretically, but also provides a solid theoretical foundation and action guidance for the reconstruction of the secondary school mathematical literacy standards and the innovation of teaching practice in the intelligent era.

Keywords: Generative AI; Secondary school mathematical literacy; Literacy performance standards; Hierarchical linearity; Instantaneous generation; Theoretical reconstruction



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1 Introduction: Problems in Research and Intention

The theoretical construction and evolution of mathematical literacy performance standards are deeply rooted in the intersecting contexts of competency-based educational trends and modern educational evaluation systems (Chen et al., 2024). From the continuous attention of the OECD's PISA research program on "an individual's capacity to formulate, employ, and interpret mathematics in a variety of contexts" (Čižmar, 2023), to the systematic, step-by-step classification of the "cognitive process hierarchy" in Bloom's classic taxonomy of educational objectives (Chen et al., 2024), to the clear definition and emphasis on the connotation and denotation of "core competencies" (such as mathematical abstraction, logical reasoning, mathematical modeling) in China's "Compulsory Education Mathematics Curriculum Standards (2022 Edition)" (Cao & Wu, 2024), there have gradually emerged two interrelated yet inherently tense theoretical divisions and practical paths globally: "fine-grained ability hierarchies" and "holistic competency integration" (Liu, 2022; Lu et al., 2021). When generative AI, with its inherent technical characteristics such as "instantaneous content generation" and "human-machine collaborative cognition", embeds itself forcefully and profoundly transforms the core field of secondary mathematics education (DeCarlo et al., 2024; Pratschke, 2024), the latent theoretical tension between the traditionally constructed "hierarchically linear" literacy performance standards characterized by linear progression and gradient Design from "remembering" "understanding" to "applying" "analyzing" and even to "synthesizing" and "creating", and the intrinsic learning needs catalyzed by the AI era such as "instantaneous generation" in highly dynamic and uncertain problem contexts, and "constructing complex models in close human-machine collaboration" becomes increasingly prominent and transforms into an unavoidable practical dilemma (Wang & Li, 2024; Lin & Jiang, 2025). The former is basically based on the static logic presupposition of knowledge as a fixed object to be accumulated gradually, while the latter clearly points to the dynamic logic of knowledge being continuously generated and evolving through interaction and practice (Zhang, 2025). The profound conflict between these two logics not only challenges our existing understanding of the traditional conceptual boundaries of mathematical literacy performance standards but also triggers ongoing debate and deep reflection within the academic community. At the original theoretical level on "how the nature of mathematical literacy in the intelligent era should be redefined and characterized" (Li, 2024).

At present, the theoretical debates on the core issue of "how secondary school mathematical literacy performance standards should respond to the challenges of the intelligent era" have formed a "binary opposition" dead end (Liu & Wang, 2024). Among them, the "hierarchical conservatives" mainly relying on the established framework of Bloom's taxonomy, strongly hold that literacy standards must follow a gradient Design of cognitive difficulty to ensure the solidity and sequentiality of students' acquisition of basic mathematical skills (Chen et al., 2024). They are cautious or even critical of the possible tendency towards "de-hierarchization" in the AI era and firmly believe that any form of "generative ability" must be based on a systematic and solid hierarchy of knowledge accumulation (Liu, 2022). In contrast, the "generative radicalism" advocates gain more support from cutting-edge human-machine collaborative cognition theories such as distributed cognition and situated learning (Zhao et al., 2025). They argue that generative AI technology has fundamentally changed the inherent way of human knowledge creation and application; Therefore, the development of literacy standards should be directed to cultivating and testing "the individual's ability to problem-solve in real-time in specific scenarios" (Walkington et al., 2024). They advocate that in the face of dynamic and unpredictable complex situations, students' core ability to integrate multidimensional knowledge and ingeniously develop strategies should have a much higher value priority than the mastery of static, closed hierarchical knowledge systems (Santika, 2024). The deep root of this seemingly sharp opposition lies in the fact that both sides, to some extent, neglect the

dialectical relationship that should be present between the dual missions of “foundational” and “generative” embedded in the specific context of “secondary mathematics education” (Huang & Yang, 2025), simply placing “foundation” and “generation” at two irreconcilable ends, and failing to give effective philosophical guidance for theoretical breakthroughs and practical innovation.

Therefore, the main study question of this paper is: How can we transcend the simplistic binary opposition of “hierarchical conservatism” versus “generative radicalism” from the perspective of theory, and through penetratingly exploring the internal logic and transformation mechanism between the “hierarchically linear” logic and the “instantaneous generation” needs, seek and map out an integrated path for the systematic secondary school mathematical literacy performance standard reconstruction in the intelligent age, which is both theoretically self-consistent and practically feasible? The special value of this study is precisely here, from a theoretical level, on one hand, we will carefully analyze the philosophical roots, technical preconditions, and concrete manifestations of these two logics, on this kind of careful analysis, profoundly expound their dialectical unity, and then bridge, in fact, the extremely large gap in thinking between old literacy theory and new logical technology like cutting-edge AI technology; and perhaps provide some strong theoretical supports for the great era and epoch shift of mathematical literacy standards and the great innovation to its paradigm; at the same time, from a practical level, also hope to give us an advanced view, systematic, and operational theoretical and analytic framework and action guide that will solve a group of urgent practical issues, such as “how can we scientifically and successfully implement AI tools into the literacy evaluation system? And what is the way to obtain the dynamic balance among students’ foundational ability and generative ability in a certain teaching practice?” (Zhang, 2025)

In order to achieve the above research objectives, the main text will strictly follow the internal logic of “Deconstruction of Conceptual System - Analysis of Core Contradictions - Reconstruction of Theoretical Path - Elucidation of Practical Implications” to unfold the discussion step by step and ultimately strive to form a system of theoretical conclusions that can systematically and completely respond to the above core questions.

2 Core Ideas Deconstruction and Theoretical Dilemma Exploration

The secondary school mathematical literacy performance standard, as the key link connecting abstract, high-level mathematics education goals with concrete, vivid teaching practices, becomes the logical starting point of all arguments in this study (Chen et al., 2024). The deep excavation of its essence must be conducted from the three interrelated yet distinct dimensions of its inherent essential nature, its external functional characteristics, and its deep-seated value orientation. Only by resorting to this route can we hope to accurately pinpoint and deeply reveal its deep-rooted adaptability difficulties amidst the influence of generative AI tech (Wang & Li, 2024).

2.1 Examining from a Perspective of the Important Qualities

From the dimension of essential attributes, the secondary school mathematics literacy performance standard is not a simple, mechanical “collection of evaluation indicators”, but rather essentially is a concrete and operable normative system and action guide for the national mathematics curriculum core competencies (Cao & Wu, 2024). Its core function lies in transforming relatively abstract core competency elements such as “mathematical modeling” “logical reasoning”, and “mathematical operation” into a series of specific behavioral performance indicators and competency dimensions

that can be observed, measured and evaluated in the classroom environment (Liu, 2022). Take the “mathematical modeling” competency as an example, it can be further divided into several concrete, operational, and assessable specific steps that are easier to grasp, like “identify key mathematical relationships in real-world situations” “create basic mathematical models based on mathematical rules” “solve and check these models using math tools”, and “interpret the model results and think about them critically” (Chen et al., 204.02.08). The purpose of this refined “concretization” process is to translate the grand goal of “what to teach for” into micro-level practical strategies of “how to teach” and “how to assess” based on the intrinsic cognitive laws of mathematics learning activities, and to truly play the role of the “core bridge” connecting educational ideals and teaching reality (Lu et al., 2021).

2.2 Examining from the Perspective of Function Characteristics

From the dimension of functional characteristics, the traditional secondary school mathematical literacy performance standard shows extremely distinct hierarchical linearity in its internal structure logic (Chen et al., 2024). This structural logic originates directly from the “cognitive hierarchy theory” systematically proposed by Benjamin Bloom and his colleagues in “Taxonomy of Educational Objectives” (1956). This theory takes the complexity and difficulty level of individual cognitive processes as the core basis for classification, presupposing that the development of human learning ability is in a linear, step-like sequence from “remembering” to “understanding” “applying” “analyzing” “synthesizing,” and “evaluating” (Liu, 2022). From this theoretical perspective, the acquisition and demonstration of each higher-level ability are strictly regarded as being necessarily built upon the full mastery of the preceding lower-level abilities. For instance, in the setting of standards for the specific teaching content of “factorization”, the traditional approach generally first requires students to “accurately master the basic formulas and rules” (remembering level), then asks students to “understand the derivation process and applicable conditions of the formulas” (understanding level), further requires students to “skillfully apply the formulas to factorize polynomials of a simple structure” (applying level), and finally may expect students to reach “creatively apply or combine multiple methods to solve complex factorization problems” (synthesizing/creating level) (Chen et al., 2024). The significant advantage of this design model lies in its high degree of standardization and operability: it enables teachers to systematically plan teaching progress and design teaching links according to a clear hierarchical gradient; it also enables evaluators to uniformly and objectively measure the literacy development levels of different students with the help of a relatively quantifiable indicator system, thereby maintaining the order and efficiency of large-scale mathematics teaching and assessment activities to a large extent (Lu et al., 2021). However, the inherent limitations of such a “hierarchically linear” structure have become increasingly obvious as educational practice and technological innovation unfold it essentially makes students’ mathematical literacy into a static inevitable result of “hierarchical knowledge accumulation”, completely ignoring the inherent contextual dependency, process dynamics and individual constructiveness of mathematics learning activities themselves (Zhang, 2025; Lin & Jiang, 2025).

3 The Core of Propositional Deduction and the Theoretical Construction of Dialectical Relationships

To systematically analyze the above theoretical dilemmas at a deep theoretical level and find a path beyond it, this

study breaks away from the superficial narrative of phenomenological description and instead is based on the rigorous method of propositional deduction. It is to reveal the nature of the problem, by means of four linked and progressively advancing core propositions, as a whole, to construct dialectical relationships that resolve these problems.

3.1 Proposition 1: The Structural Premise of “Hierarchically Linear” Standards is Rooted in the Traditional Epistemology of “Knowledge as a Static Object”

The hierarchical linear structure exhibited by traditional secondary school mathematics literacy performance standards is not an accidental or arbitrary design choice; It fundamentally originates from the “static view of knowledge” and “linear view of cognitive development” contained in Bloom’s taxonomy of educational objectives (Chen et al., 2024). The core assumption of this theoretical system is that mathematical knowledge is an object outside the learner, stable and well-structured. The development of students’ cognitive abilities must follow a strictly irreversible linear progression path from “remembering” specific facts, to “understanding” meaning, to “applying” in new situations, and even to “analyzing” structural elements, “synthesizing” knowledge systems, and ultimately “evaluating” value (Liu, 2022). This logic of “hierarchical dependency” highly aligns with the “static transmission” scenario of traditional secondary mathematics education: knowledge is regarded as certain and unquestionable theorems and formulas, learning is planned as a sequential linear process, and assessment relies on standardized measurement of the mastery of fixed knowledge nodes (Lu et al., 2021). Therefore, the “hierarchically linear” norm can be essentially regarded as the operational manifestation of cognitive hierarchy theory in the field of mathematical literacy evaluation, and its effectiveness is strictly derived from the premise of the “static nature and cumulative nature of knowledge” (Chen et al., 2024). For example, in the setting of literacy standards for “quadratic functions”, the gradient design from “remembrance of the general form” to “understanding the graphical properties”, to “application for finding the maximum/minimum value”, and even to “synthesis for solving practical problems”, all reflect the linear accumulation process of knowledge from simple to complex, from isolated to interconnected, with the aim of ensuring the solidity and stability of students’ basic mathematical capabilities through such a structured path (Cao & Wu, 2024).

3.2 Proposition 2: The “Dynamic Knowledge Production” Logic of Generative AI at the Epistemological Level, at Bottom Fundamentally Shakes the Epistemological Foundation of “Hierarchically Linear” Standards Generation AI and its Application Scenarios are Strictly Limited to Closed Contexts

The core technical feature of generative artificial intelligence is its ability to dynamically and non-deterministically generate unprecedented problem contexts, knowledge representations, and even solutions based on instantly input complex instructions and data streams (Čižmar, 2023; DeCarlo et al., 2024). This “dynamic knowledge production” logic means that knowledge no longer exists as a static object to be passed down and accumulated. Still, it has become a cognitive tool and creative product that can be “generated instantly and continuously updated” through human-machine interaction and collaboration (Zhang, 2025). Consequently, the two basic assumptions of “fixed knowledge” and “pre-determined path” in traditional learning scenarios are simultaneously shattered (Walkington et al., 2024). For example, in a generative AI-driven mathematical modeling task such as “dynamic scheduling optimization for urban shared bikes”, students are confronted with a complex system that is generated in real time by artificial intelligence, which contains multiple dynamic variables such as “time-varying data on regional population density” “impact factors of sudden weather changes”, and “random simulation of vehicle failure rates” (Zhao et al., 2025). In this context,

students' problem-solving process inevitably shows highly nonlinear and cross-hierarchical characteristics: they first need to directly “apply” statistical methods to analyze data distribution (skipping the staged mechanical memorization of formulas), then “understand” the mathematical relationships hidden in the preliminary demand curve generated by AI, then subsequently need to creatively combine optimization models with stochastic processes, and continuously “analyze” and “evaluate” the intermediate results provided by AI to revise their own strategies during this process (Lin & Jiang, 2025). This cognitive process, which deals with the complexity of real-world problems - “reverse-hierarchical” or “networked”, completely dismantles the strict linear sequence of “remember before understanding, understand before applying”, and the static epistemological premise based on “hierarchically linear” standards became invalid in the open, human-machine collaborative “dynamic generative context”, thus strictly restricting the explanatory power and guidance to those relatively well-structured “static foundational contexts” (Liu & Wang, 2024).

3.3 Proposition 3: Foundational Abilities and Generative Abilities, they're not Opposites, but there is a Deep Dialectical Unity, an “Instrument as Prerequisite” and “Worthwhile Manifestation” Relationship

When the powerful capabilities of generative AI externalize and take on some higher-order thinking processes (such as information retrieval, preliminary pattern exploration, solution generation), there is a theoretical and practical misconception to guard against, which is the belief that traditional foundational mathematical abilities (such as precise computation, rigorous deductive reasoning, accurate mathematical abstraction) are already outdated (Li, 2024). On the contrary, the core assertion of this study is to explain the “instrumental prerequisite, valuable realization” dialectical relationship between the fundamental capability and the generative capability (Cao & Wu, 2024); Foundational skills, such as proficient algebraic operations and rigorous logical thinking, are the indelible instrumental prerequisites and cognitive “interface” for people to interact well, make precise decisions and perform key checks in the human-machine collaborative cognitive system (Chen et al., 2024). If students lack solid computational skills, they will be unable to quickly check the key parameters in the “cost-benefit model” generated by AI without rigorous logical reasoning ability, and they will be unable to identify and correct potential logical leaps or factual fallacies that AI may introduce when performing “geometry proof assistance” (Lin & Jiang, 2025). Contrary to this is the generative ability of contextualized problem solving, construction of dynamic mathematical models, and the critical application of AI tools, which allows the foundational abilities to have a “meaningful realization” field that provides value (Zhang, 2025). Computation is no longer a mechanical operation for repeated practice but serves as a means to support decision-making in a dynamic process of optimization; Reasoning is no longer for the purpose of completing a formalized proof exercise, but to ensure the internal logical self-consistency and reliability within complex system modeling (Zhao et al., 2025). From this perspective, basic abilities are the “soil” on which generative abilities take root, sprout and grow, while generative abilities are the “fruit” grown from basic abilities; In the intelligent era, the two sides of mathematical literacy cannot be separated from each other (Huang & Yang, 2025).

3.4 Proposition 4: In order to Achieve Such a Transformation of the Literacy Standards, it is Necessary to Establish the Practical Principle of Dynamic Balance Based on the Context of Foundation and Generating

Based on the previous propositions, the transformation from “hierarchical linearity” to “instantaneous generation”

should by no means be a simple replacement of paradigms or wholesale negation, but rather a dialectical sublation and structural expansion based on the principle of contextual sensitivity (Liu & Wang, 2024). The particular stage at which individual cognition develops and socializes within secondary mathematics education, and the “founding” mission it carries, make systematic instruction on foundational abilities and core ideas, basic concepts and key methodological ideas indispensable (Chen et al., 2024). At the same time, the “generative” core literacy requirements brought by the intelligent era to the members of society force education to respond with the cultivation of students’ ability to adapt to change, integrate knowledge and generate new value (Walkington et al., 2024). Thus, the core principle of the reconstructed literacy standards should be to dynamically and organically balance “foundational” and “generative” depending on different mathematical practice situations, while also accepting and upholding the two value demands of these two terms (Zhang, 2025). This means that in “static foundational contexts” (such as the introduction of core concepts, the training of basic skills, the proof of theorems and formulas), the design of “hierarchically linear” standards should be retained and optimized to ensure a solid and firm mathematical foundation; Whereas in “dynamic generative contexts” (such as interdisciplinary project-based learning, inquiry-based modeling with real data, solving open-ended problems), the logic of “instantaneous generation” should be boldly introduced and advocated, with the focus on students’ ability to mobilize resources, collaborate with humans and machines, and solve problems creatively in complex and uncertain environments (Zhao et al., 2025). The principle of differentiated positioning and dynamic balance according to context is a logical boundary and practical wisdom that the process of change in literacy standards must be scientific and realistic (Santika, 2024).

4 Theoretical Construction and Transcendence: The “Context - Competency - Synergy” Three-Dimensional Integration Framework

Having completed the core propositional deduction and clarified the internal dialectical relationship. In response to the theoretical challenges brought by generative AI and overcoming the limitations of existing research paradigms, this study builds a new “Context-Competency-Synergy” three-dimensional integration framework (Liu & Wang, 2024). This framework is not only a description of the constituent elements of the literacy standards, but also a system of theoretical models and practical guides for their systematic reconstruction (Zhao et al., 2025).

4.1 Context Dimension: Deciding on Differentiated Zones of Literacy Accomplishment and Boundaries of Logic Application

The context dimension should be placed first for this framework. It is fine-classifying on the fields where mathematical practice activities occur, thus establishing the boundaries for different literacy logics’ fields (Zhang, 2025). It clearly separates “static foundational contexts” from “dynamic generative contexts”. The former corresponds to traditional, well-structured and goal-stated fields of knowledge transmission and skill training, such as memorizing formulas, proving theorems, and mastering fixed algorithms (Chen et al., 2024). Here, even the “hierarchically linear” logic retains some rationality and effect, which becomes indispensable for mastering the mathematical knowledge system properly in a structured manner and achieving automation of basic skill (Liu, 2022). The latter corresponds to complex problem-solving fields that are supported by technologies such as generative AI or inherent in the real world, characterized by ill-structuredness, open goals, and dynamically changing conditions (Walkington et al., 2024). In this

context, the “instantaneous generation” logic becomes dominant, which focuses on the ability to define problems in the midst of uncertainty, integrate resources and iteratively optimize solutions (Lin & Jiang, 2025). The addition of the context dimension essentially breaks down the contradiction between “hierarchy” and “generation”, converting them from competing dimensions in practice into demands at different levels in different fields of practice, so that they can be inclusive when explaining theory and clear when providing guidance (Huang& Yang, 2025).

4.2 Competency Dimension: List out the Perpetual Spectrum of the Connotation of Literacy and the Internal Change Mechanism:

In terms of the competency dimension, the framework gives up static and list-like thinking that divides “foundational” and “generative” as two ends, instead depicting them as a continuous spectrum of interdependent and mutually reinforcing literacy (Cao & Wu, 2024). One end of this spectrum is “basic skills”, which include mathematical operations, logical reasoning, spatial imagination, mathematical abstraction, etc., and are the cornerstones and tools of mathematical thinking (Chen et al., 2024). The other end of the spectrum is “generative abilities”, which involves contextualized problem posing and solving, construction and evaluation of dynamic mathematical models, strategic selection and critical use of AI tools, etc., and is manifested as the emergence and embodiment of mathematical wisdom in complex contexts (Zhao et al., 2025). the main idea about the framework is to no longer regard these two sorts of skills as separate points for evaluation but rather profoundly reveals the “cause-effect” connection: the core abilities are stimulated, organized, and perfected under the impetus of generative tasks, transforming potential tools into actuality; at the same time, the repeated practice of generative abilities, in turn, solidifies, strengthens, and broadens the mastery and applications scope of fundamental skills, even spurring the need for new types of fundamental tools. (Zhang, 2025).

4.3 Synergy Dimension: Answer to the New Literacy Meaning of Reshaped Human-Machine Relations in the Smart Age

The synergy dimension is the key theoretical innovation of this framework in the face of the main characteristics of the intelligent era (Liu & Wang, 2024). It explicitly includes the quality of the “human-machine synergy” interaction in the core consideration of literacy performance and refines the requirements for the synergy according to the differences in the context (Santika, 2024). In “static basic settings”, synergy mainly manifests as a deep dialogue between the “individual and the mathematical knowledge object”, with characteristics such as independent thinking, autonomous exploration and the creation of an internal knowledge system (Chen et al., 2024). In the “dynamic generative context”, synergy upgrades to effective interaction within the cognitive ecosystem composed of “individual-generative AI-problem context” (Zhao et al., 2025). It involves both the technical operational aspects of “using AI”, as well as the critical thinking aspects of “questioning AI’s generated results” “analyzing AI’s decision-making logic”, “creatively guiding AI’s exploration direction”, and the ethical responsibility aspect of “analyzing AI’s social impact”. (Wang & Li, 2024) The synergy dimension gets established, literacy standards start being able to test students’ all-around cognitive literacy and ability to adapt by working with, competing against, and even working alongside intelligent agents (Li, 2024).

To sum up, the main value of the “Context-Competency-Integration” is that the Three-Dimension Integration Framework is the inheritance and transcending integration of existing frameworks such as the Cognitive Hierarchy Theory (Zhang, 2025) and the Distributed Cognition Theory (DCT) (Zhang, 2025). It neither entirely rejects the

historical contribution of hierarchical logic nor blindly follows generative logic without regard for the educational foundation. Instead, it clarifies the respective “domains of validity” of both in terms of the dimension of context, and then organically connects and unifies them at the practice level through the dimensions of competence and synergy (Huang & Yang, 2025). It provides a novel, systematic, and applicable theoretical view that is applicable for analysis and promotion of the overall reshape of secondary school mathematical literacy performance standards in the future Smart Age (Wang & Li, 2024).

5 Conclusion and Outlook: Sublimations & Paths of Practice

Through systematic theoretical speculation on the performance standards of secondary school mathematical literacy from the perspective of generative artificial intelligence, this study has achieved a full logical cycle of “problem diagnosis” - “theoretical construction” and then into “path guidance” (Čižmar, 2023). The core conclusion is that the adaptability dilemmas between traditional “hierarchically linear” standards and the intelligent era are essentially the result of the structural conflict between the cognitive logic of “static knowledge accumulation” and the technology logic of “dynamic knowledge production” (DeCarlo et al., 2024). The fundamental path to resolving this conflict is not a simple either/or substitution, but rather a dialectical sublation and structural expansion from “hierarchical linearity” to “instantaneous generation” through the establishment of the “Context-Competency-Synergy Three-Dimensional Integration” framework (Zhang, 2025). This framework uses the context dimension to define the applicable boundaries of different logics, the competency dimension to connect the literacy spectrum of “instrumental foundation” and “valuable generation”, and the synergy dimension to respond to the new cognitive requirements of the human-machine symbiosis era, thereby providing a systematic solution for the reconstruction of literacy standards in the intelligent era that has both theoretical self-consistency and practical feasibility (Zhao et al., 2025).

5.1 Theoretical Value - Deep Condensation

The theoretical contributions of this paper can be summarized as follows.

First, to achieve the contextualized expansion and epochal revision of cognitive hierarchy theory (Chen et al., 2024). This study does not completely negate the historical value of Bloom’s taxonomy. Still, by introducing the key variable of “context”, it precisely anchors its validity to “static foundational contexts”, while providing a clear theoretical explanation and solution for its limitations in “dynamic generative contexts”, thus finding a new, reasonable position for it within the educational theory system of the intelligent era (Liu, 2022).

Second, completing the operational implementation and disciplinary concretization of human-machine collaboration theory (Liu & Wang, 2024). It incorporates the basic principles of “Human + Tool + Task Context of Interaction” as indicated in theories such as distributed cognition. It transforms them into concrete, perceptible, testable, and testable “Synergy Dimension” and “Generates Abilities” dimensions under secondary school Mathematical Literacy standards into concrete requirements of courses, teaching and assessment reforms. To promote deeper exploration of the way “the theories” get translated practically (Santika, 2024).

Third, to have an integrative framework for the fundamental issues of local mathematics education (Cao & Wu, 2024). The three-dimensional model put forward in this paper gives researchers an advanced theoretical means to

solve the problem of integrating “Shuang Ji” (fundamental knowledge, fundamental skills) and “core competencies” thoroughly in China’s new curriculum reform, especially in relation to the new challenges presented by generative AI (Lu et al., 2021). It clearly shows that “Shuang Ji” is the indispensable “instrumental foundation” in the literacy spectrum. Still, the deepening of “core competencies” in the intelligent era must integrate and emphasize the new connotations of “generative ability” and “human-machine synergy” (Huang & Yang, 2025).

5.2 Multidimensional Explanation

Based on the above theoretical framework, this study provides the following concrete suggestions for secondary school mathematics education practice (Wang & Li, 2024).

At the level of curriculum standards and textbook development, it is suggested to re-categorize and classify learning content and activities based on the “context dimension” (Chen et al., 2024). In the clearly categorized “static foundational context” sections, retain and optimize the content sequence and training system in accordance with hierarchical logic; In the “dynamic generative context” sections, boldly Design learning tasks based on project, inquiry and human-machine collaboration, and set clear and graded achievement standards for the “generative ability” and “synergy ability” (Zhao et al., 2025).

At the level of classroom teaching and evaluation, teachers need to have the teaching ability of “dual-track Design” (Zhang, 2025). On the one hand, they should be able to efficiently organize the teaching of basic knowledge and the training of key skills; On the other hand, they should be good at creating and using dynamic learning environments based on generative AI, guide students to use basic abilities as tools to solve complex problems, and develop higher-order literacy of cooperatively exploring with AI and being able to critically construct new knowledge (Lin & Jiang, 2025). The corresponding evaluation system should move beyond the single paper-and-pencil examination and incorporate various evaluation methods according to the process, reflecting collaboration and creativity (Walkington et al., 2024).

At the level of professional development of teachers, the role of teachers should shift from “authoritative transmitters of knowledge” to “designers of learning Environment, guides of human-machine collaboration, and facilitators of thinking deepening” (Li, 2024). Professional development programs should pay more attention to developing a new generation of teaching abilities to design differentiated contexts, design AI tools, assess generative abilities, and guide relevant ethical discussions (Liu & Wang, 2024).

5.3 Research Limitations and Future Prospects

As a theoretical speculation, the “Three-Dimensional Integration Framework” proposed in this study still needs to be tested, revised and improved through subsequent empirical research (Čižmar, 2023). Future work can be done in the following ways.

First, conduct design-based research and action research (Cao & Wu, 2024). Apply the above framework specifically to the revision of local or school curriculum standards, unit teaching plan design, and assessment scheme development. Test its effectiveness through iterative cycles of “design-implementation-evaluation-revision” and extract specific models and typical cases for implementation under different cultural contexts and school conditions (Santika, 2024).

Second, conduct targeted empirical investigations (Lin & Jiang, 2025). For example, use strict experimental designs

to compare the differential impacts on students' mastery of basic knowledge, development of generative ability, learning interest, and belief when teaching is based on traditional standard benchmarks versus new framework standards in different contexts (static basic vs. dynamic generative) (Zhang, 2025).

Third, deepen the research on the micro-mechanisms of "human-machine synergy" literacy (Zhao et al., 2025). Future research should further explore what exactly those cognitive and metacognitive strategies are in effective human-machine synergy when doing math problems. How can teachers develop them, recognize them, and what could it be when facing potential threats like mental lassitude brought about by too much reliance on AI? (Huang & Yang, 2025)

Finally, the ultimate significance of this research is to call on education of new era intelligence (Liu & Wang, 2024): transforming opposition to dialectics. It states that educational progress does not rely on a complete rejection of tradition but on creating value through the innovative transformation and development of tradition (Chen et al., 2024). Faced with the great tide of technology, the essence of reconstructing secondary school mathematical literacy standards is to find and hold on to a good dynamic balance between what is essential and what is generative (Zhang, 2025). This path of balance is both the core of this study's theory-building way and may provide a valuable perspective for examining broader educational transformation (Lu et al., 2021).

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