Viewpoint: Generative Traversal Learning: Toward Creativity Through Meta-Space Navigation

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Abstract

The rapid advancement of artificial intelligence is reshaping both the production of knowledge and the meaning of learning, raising renewed questions about which forms of cognition remain distinctly human. Creativity has increasingly been positioned as a central educational objective; however, its theoretical grounding and pedagogical articulation remain incomplete. Existing approaches often encourage exploration within established representational structures, while offering limited accounts of how learners might move across such structures.

This viewpoint introduces Generative Traversal Learning (GTL) as a conceptual framework for understanding creativity as an iterative movement between structured knowledge and a generative meta-space. GTL describes a learning process in which individuals depart from a given knowledge structure, engage a more abstract representational space from which multiple structures are possible, and return with reorganized understanding. Within this perspective, creative potential emerges through structured departure and return rather than unbounded exploration, positioning learning as a dynamic navigation across levels of representation.

The paper advances a conceptual lens intended to help reorient discussions of creativity in AI-mediated education and to support future theoretical and empirical inquiry into traversal-based models of learning.

Keywords: Creativity, Generative Traversal Learning, Meta-Representation, Conceptual Learning, Learning Sciences

1 Introduction

The rapid advancement of artificial intelligence is transforming not only how knowledge is produced but also what it means to learn. As AI systems increasingly perform tasks once associated with human expertise, education faces a pressing question: what forms of learning remain uniquely human? Among the proposed answers, creativity has emerged as a central educational objective. Preparing learners for an AI-mediated world requires moving beyond the transmission of established knowledge toward cultivating the capacity to generate new understanding.

Despite widespread recognition of its importance, creativity remains difficult to operationalize in educational practice. Existing approaches often emphasize divergent thinking, problem-based learning, exploratory inquiry, or the recombination of prior knowledge. While these methods have demonstrated value, they frequently operate within existing representational structures. Learners are encouraged to explore a space of possibilities, yet the structure of that space itself is rarely questioned. As a result, creativity is often treated as variation within a framework rather than movement beyond it.

This limitation points to a deeper challenge: creative cognition may require the ability to temporarily suspend structured knowledge, access a more generative representational space, and subsequently return with newly organized understanding. However, educational theory has only partially articulated such processes, and current pedagogical models provide limited guidance on how this movement might be cultivated.

In this viewpoint, we propose *Generative Traversal Learning* (GTL) as a conceptual framework for understanding creativity as an iterative movement between structured knowledge and a generative meta-space. Intuitively, GTL describes a learning process in which a learner departs from a specific knowledge structure, returns to a more abstract generative space from which multiple structures are possible, and then reconstructs the original knowledge. Crucially, this traversal extends beyond reconstruction, specifically, the round-trip may yield insights that reframe the initial domain. Rather than positioning creativity solely as the production of novelty, GTL reframes it as the capacity to navigate levels of representation. The generative potential emerges not from unbounded exploration but from structured departure and return. In this sense, learning becomes a dynamic process of movement across representational strata rather than a linear accumulation of information.

We emphasize that this paper is intentionally conceptual and exploratory. Our aim is to articulate a perspective that may help reorient discussions of creativity in the age of AI. By introducing GTL, we hope to stimulate dialogue across learning sciences, cognitive science, and AI-informed education, and to encourage future empirical and theoretical work investigating traversal-based models of learning.

2 Literature Review

Beyond long-standing academic interest, fostering creativity has become an explicit policy priority in the context of rapid advances in artificial intelligence (AI). UNESCO

has issued guidance on generative AI in education and research, emphasizing governance that protects human agency and seeks to ensure that the use of GenAI in educational settings genuinely benefits learners and teachers [1]. At the regional level, the European Union's 2018 Council Recommendation on key competences for lifelong learning foregrounds creativity as a competence embedded across its framework for education and training [2]. In parallel, the OECD's Future of Education and Skills 2030 agenda highlights "creating new value" as a transformative competence, positioning creative capability as central to navigating uncertainty and social transformation [3]. Taken together, these agendas suggest a shared educational challenge in the AI era: not merely acquiring information efficiently, but cultivating generative capacities that support original problem framing, re-representation, and knowledge creation.

Creativity has long been a central concern across educational psychology, cognitive science, and the learning sciences. Early work frequently framed creativity as a function of divergent thinking, emphasizing the generation of multiple responses to open-ended problems [4, 5]. While influential, this perspective largely treats creativity as variation within an existing representational structure rather than as a transformation of that structure itself.

2.1 Abstraction and Representational Change in Learning

Constructivist traditions shifted attention from idea production to knowledge construction. Piaget conceptualized learning as an active process in which individuals reorganize cognitive schemas through assimilation and accommodation [6]. Central to Piaget's theory is the notion of *reflective abstraction* (réflexion réfléchissante), through which learners construct higher-order cognitive structures by coordinating and abstracting from lower-level operations. This process describes how concrete experiences give rise to increasingly abstract forms of knowledge.

Building on similar insights, Sfard's theory of *reification* examines how mathematical learners transition between viewing concepts as processes (dynamic operations) and objects (manipulable entities) [7]. For instance, a function initially understood as a computational procedure may become reified as a mathematical object that itself can participate in higher-order operations. This vertical movement between representational levels suggests that mathematical understanding involves navigating a hierarchy of abstraction.

From a different pedagogical tradition, Davydov proposed that learning should proceed by *ascending from the abstract to the concrete* [8]. Rather than inductively generalizing from multiple examples, Davydov argued that students should first grasp abstract, general relationships and then descend to rich concrete instantiations. This approach positions abstract knowledge as generative: capable of producing multiple concrete understandings.

These perspectives converge on a shared recognition: learning often involves movement across levels of abstraction. However, they differ in emphasis. Specifically, Piaget focuses on developmental construction, Sfard on representational duality in mathematics, and Davydov on pedagogical sequencing, and none fully theorizes the bidirectional traversal as a unified mechanism for creativity.

2.2 Productive Destabilization and Preparatory Learning

More recent research has examined the productive role of cognitive destabilization. Kapur's theory of Productive Failure demonstrates that unsuccessful problem-solving attempts can prepare learners for deeper conceptual understanding [9]. Schwartz and Bransford likewise show that preparatory activities enhance subsequent instruction by increasing learners' sensitivity to structural features of the domain [10]. Such work highlights the importance of transitional cognitive states; however, it does not fully theorize the nature of the representational space into which learners transition during these moments of restructuring.

Research on transfer further gestures toward movement across levels of abstraction. Traditional distinctions between near and far transfer emphasize the difficulty of applying knowledge across contexts [11]. Later interpretations suggest that successful transfer depends on recognizing deep structural similarities rather than surface features. Yet transfer theories typically assume stable underlying structures, rather than considering the generative potential that may emerge when those structures are temporarily suspended.

Parallel discussions appear in the literature on metacognition, which describes learners' capacity to reflect upon and regulate their own cognitive processes [12]. Metacognitive awareness enables a form of epistemic distancing from immediate problem representations. Nevertheless, it is commonly framed as a monitoring mechanism rather than as entry into a generative meta-representational space.

2.3 Computational Perspectives on Generative Processes

Beyond education, developments in cognitive science and artificial intelligence offer conceptual tools that further motivate the present work. Representation learning research suggests that complex structures can emerge from compressed latent spaces capable of supporting generative reconstruction [13]. Although primarily computational in orientation, such perspectives imply that creativity may involve navigation within and re-expansion from high-dimensional representational spaces.

Recent advances in generative artificial intelligence further illuminate this perspective. Diffusion models [14, 15], for example, generate structured outputs by first progressively corrupting data into noise and then learning to reverse this process through iterative denoising. Conceptually, this forward–reverse dynamic suggests that complex structures may be reconstructed from highly entropic states when guided by learned transformations.

While diffusion models are computational in nature, they offer a compelling epistemic metaphor: movement toward an unstructured space does not necessarily imply informational loss, but may instead enable the reorganization of representations. Such processes hint at a broader principle in which generativity emerges not only from structured reasoning but also from the capacity to traverse between structure and indeterminacy.

2.4 Synthesis and Motivation for GTL

Taken together, these traditions converge on a shared insight: meaningful learning often involves moments of destabilization, abstraction, or representational shift. However, existing frameworks rarely articulate the full round-trip movement through which learners depart from structured knowledge, access a generative space, and return with reorganized understanding.

Piaget, Sfard, and Davydov each describe aspects of this movement—upward abstraction, representational transformation, or downward instantiation, but do not theorize the complete traversal cycle as a unified pedagogical mechanism. Productive failure and preparatory learning emphasize transitional states but leave the generative structure of those states underspecified. Computational models demonstrate forward-reverse dynamics but remain disconnected from learning theory.

This conceptual gap motivates the introduction of *Generative Traversal Learning* as a lens for interpreting creativity as structured movement across representational levels. GTL synthesizes these insights by centering the bidirectional traversal itself from concrete knowledge through generative abstraction and back, as the core mechanism enabling creative reorganization of understanding.

3 Generative Traversal Learning

We propose *Generative Traversal Learning* (GTL) as a pedagogical scheme designed to enhance creativity through structured movement across levels of knowledge abstraction. Rather than remaining within a single representational level, GTL guides learners to: (1) collect related concrete knowledge instances, (2) abstract toward generative organizing principles, and (3) return to generate new concrete understandings. We argue this bidirectional traversal may constitute an underutilized pathway to creative insight.

At its core, GTL foregrounds the importance of meta-knowledge: the capacity to engage with highly abstract structures from which multiple forms of concrete knowledge may be generated. Creativity, from this perspective, is grounded less in the modification of existing representations than in access to generative levels of organization.

This proposal is motivated by (1) observations of learners temporarily stepping beyond structured knowledge, and more important, (2) fundamentally by the recognition that deep understanding often involves grasping principles capable of organizing knowledge itself. Such moments suggest that learning may depend on an ability to navigate between levels of abstraction rather than remaining confined within a single representational regime.

This intuition finds partial resonance in recent advances in generative artificial intelligence. Diffusion-based models demonstrate that coherent structure can be reconstructed through guided transitions from highly entropic states, suggesting that high generativity can emerge from dynamics from apparent disorder. While computational in nature, these processes point toward a broader epistemic possibility: traversal between details to abstract levels may help us learn generativity.

A related insight appears in classical philosophical traditions. The Yijing (Book of Changes) characterizes transformation through the expression "reversal is the movement of the Dao" (fan zhe dao zhi dong), suggesting that generative change often arises through dynamic return. Invoked here as an interpretive parallel rather than a theoretical foundation, this perspective echoes the idea that movement away from fixed structure may constitute a condition for renewed organization.

GTL extends these converging intuitions into a learning-theoretic context, framing creativity as emerging from the capacity to traverse generative levels of representation.

3.1 Conceptual Grounding

Learning involves the accumulation and refinement of knowledge. At the same time, knowledge itself possesses a hierarchical structure in terms of generative potential. Some forms of knowledge are concrete and specific, while others operate at a higher level of abstraction, capable of generating multiple instantiations of more concrete knowledge.

GTL is grounded in the recognition that learners can navigate this generative hierarchy bidirectionally. From a specific piece of knowledge, one may ascend to a higher-level form that possesses greater generative capacity, which is a meta-knowledge from which the original, along with related variants, can be derived. Conversely, from such generative knowledge, learners can descend to produce new concrete understandings that were previously inaccessible.

Learners may engage in this upward movement for various reasons: to seek organizing principles underlying scattered observations, to recognize structural similarities across seemingly disparate cases, to gain flexibility in applying knowledge to new situations, or to access a perspective from which existing understanding can be reorganized. The ascent to a more generative level enables a form of knowledge reorganization that proceeds through reconstruction from a more fundamental source.

GTL therefore proposes a learning scheme as a traversal process: a dynamic passage from structured knowledge toward a generative meta-level and back again. Creativity, in this view, emerges from the capacity to move between levels of generative abstraction. The meta-level functions as a field of organizational potential from which multiple knowledge structures may be instantiated.

3.2 Definition and Core Mechanism

Generative Traversal Learning refers to a learning process in which a learner temporarily departs from an established representational structure, accesses a generative meta-space that loosens prior constraints, and subsequently returns with reorganized understanding.

The mechanism is characterized by a round-trip dynamic comprising three epistemic moments. The first is *structural immersion*, in which the learner operates within a stable representational framework. The second is *reduction of structures*, marked by abstraction, uncertainty, or conceptual suspension, where existing schemas no longer fully determine the space of reasoning. The third is *reconstructive generation*, through which knowledge is reconfigured, often revealing relations that were previously inaccessible.

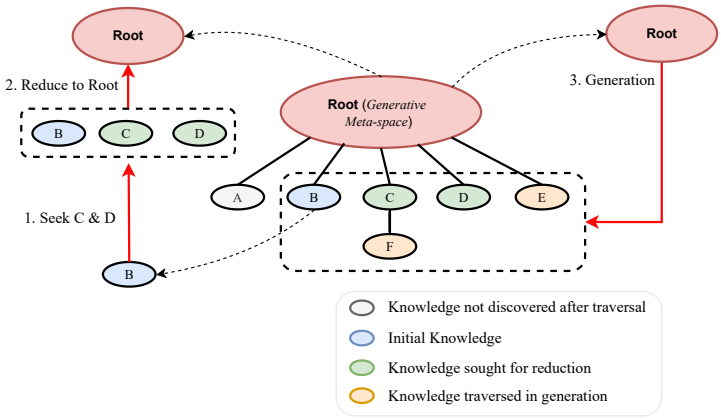

Fig. 1 An analogy between traversal in an abstract syntax tree (AST) and generative learning dynamics. Starting from the initial knowledge A, the learner seeks related knowledge to reduce it toward a more abstract meta-level representation. Through this reduction process, nodes such as B and C are integrated into the root (the generative meta-space). From the root, the learner then engages in a generative process, producing new knowledge structures; for example, knowledge E may emerge directly from the root, while F may arise as a descendant of C, reflecting hierarchical expansion rather than independent generation. Dotted lines indicate that connected nodes correspond to the same knowledge state across phases. Different colors represent distinct types of knowledge.

Crucially, in the return for reconstructing knowledge, this traversal process may produces surplus organization: insights, cross-domain analogies, or newly available conceptual pathways. Creativity, in this sense, emerges less from novelty alone than from the reorganization enabled by movement across representational regimes.

4 An AST Analogy

Abstract Syntax Trees (ASTs), widely used in generative grammar and programming language theory, provide a formal representation of hierarchical structure and the processes through which complex expressions are constructed from simpler elements. While GTL is not proposed as a computational model, the structural clarity of ASTs offers an intuitive analogy for understanding traversal-based learning dynamics.

Figure 1 illustrates this analogy. On the left side, the learner begins from a specific knowledge component and moves upward toward a more abstract generative root. On the right side, knowledge is re-instantiated through a downward generative process. Importantly, these movements need not be perfectly symmetric nor logically exhaustive.

4.1 Reduction Toward a Generative Root

Within an AST, multiple terminal nodes may correspond to a shared higher-order structure. Analogously, learners often start with partial knowledge fragments rather than a complete representation of the conceptual system. Suppose a learner encounters a knowledge element that can be situated within a broader structure denoted

as $A \rightarrow BCDEF$. Possessing only B does not immediately reveal the full generative rule. However, the attempt to situate B within a larger structure may prompt the learner to seek related components such as C or D, thereby increasing the likelihood of reconstructing the organizing principle.

Crucially, this upward movement does not require recovering every constituent element. The generative root functions less as a logical totality than as an orienting abstraction that stabilizes understanding. Once such a root is approximated, the learner gains access to a space from which multiple structural relations become intelligible.

4.2 Generative Return

From the reconstructed root, the learner may subsequently generate new knowledge configurations. Returning from abstraction often enables the emergence of previously unconsidered relations. For instance, recognizing connections to E or F that were not initially encountered.

After generative returning, some knowledge may still not be discovered, e.g., A in Figure 1.

This bidirectional movement highlights a central intuition of GTL: generativity is not confined to expansion from existing knowledge but is frequently enabled by temporary abstraction away from it. The root, therefore, should not be interpreted as a summary of prior knowledge but as a meta-representational space capable of supporting further conceptual differentiation.

4.3 Interpretive Scope

The AST analogy is intended as a heuristic. Learning does not follow deterministic production rules, nor does conceptual reconstruction proceed with the precision of symbolic grammars. Nevertheless, the analogy clarifies an important feature of traversal-based learning: understanding may deepen when learners move between local knowledge elements and higher-order organizing structures.

Seen in this light, creativity emerges from the capacity to navigate the space that relates knowledge elements and different generativity levels of knowledges. GTL therefore invites educators and researchers to attend to what learners know and to how they traverse the structures within which knowledge becomes generative.

4.4 Pedagogical Instantiation

Although GTL is proposed primarily as a conceptual account of learning, it can be illustrated through examples from advanced learning contexts. Consider a student encountering multiple mathematical proofs that share certain structural features. It is perhaps several proofs by contradiction, or proofs relying on symmetry arguments. Initially, each proof may be understood in isolation as a sequence of logical steps specific to its own problem.

As the learner accumulates experience with these related examples, they may begin to notice commonalities: recurring patterns of reasoning, shared structural moves, or similar ways of establishing necessity. This collection of observations provides the

material for an upward movement. Rather than continuing to engage with each proof as a separate procedural sequence, the learner may abstract toward a more generative level to seek the meta-mathematical principle or structural invariant that organizes this family of proofs.

This ascent involves temporarily suspending attention to the specifics of individual proofs to access a higher-order organizing structure. From this more abstract level, the learner can reconstruct understanding: individual proofs become visible as instantiations of a deeper principle. Moreover, this generative knowledge may enable the learner to recognize similar structures in distant mathematical domains, or to construct new proofs by applying the same organizing principle to different problems.

Similar patterns appear in philosophical inquiry, theoretical modeling in physics, and other domains where learners move from accumulating specific cases to grasping generative principles, and then apply those principles to generate new understanding. GTL offers a framework for recognizing such movements as central to creative learning.

4.5 Distinction from Existing Paradigms

GTL offers a distinct perspective on how transformative learning occurs. Traditional learning theories often emphasize the gradual building or refining of knowledge structures: adding new concepts to existing schemas, correcting misconceptions, or adapting prior knowledge to new contexts. While such processes are undoubtedly important, they typically assume learning operates within a relatively stable representational framework.

GTL, by contrast, foregrounds a different dynamic: the epistemic significance of temporarily moving beyond established structures altogether. Rather than remaining within a fixed knowledge system and refining it, learners may access a more abstract generative space from which multiple organizational possibilities emerge.

This differs from metacognitive approaches, which describe learners reflecting on their thinking but typically remain oriented toward regulation within a task space: monitoring comprehension, planning strategies, or evaluating progress against goals. GTL describes something more fundamental: traversal across levels of abstraction, where the very organizing principles of knowledge become fluid and subject to reconstruction.

It also differs from productive failure frameworks, which emphasize learning through unsuccessful problem-solving attempts. In productive failure, initial struggles reveal knowledge gaps that subsequent instruction can address. The failure makes learners ready to receive new information. GTL, however, is not primarily about identifying what is missing, but about accessing a generative meta-level from which existing knowledge can be fundamentally reorganized. The movement is not from ignorance to knowledge acquisition, but from structured knowledge to generative abstraction and back.

The capacity to enter and return from such meta-representational spaces may constitute a foundational condition for creativity, particularly in intellectual environments increasingly shaped by artificial intelligence, where the ability to reorganize knowledge may become as important as acquiring it.

5 Discussion and Conclusion

This paper proposes Generative Traversal Learning as a conceptual framework for structuring learning experiences around bidirectional movement between concrete knowledge and generative abstractions. By drawing an analogy with traversal in abstract syntax trees, we suggest that explicitly guiding learners through cycles of reduction and regeneration may support creative reorganization of knowledge.

This proposal remains speculative and untested. We advance it as a lens for examining certain features of advanced learning rather than as a validated instructional method. Several questions must be addressed before GTL could inform actual pedagogical practice.

GTL appears most suited to domains with clear hierarchical knowledge structure, such as mathematics, formal sciences, systematic philosophy, programming. Whether it applies to domains with less hierarchical organization (e.g., history, literature, practical skills) remains unclear. The framework may describe what already occurs implicitly in effective advanced instruction rather than proposing something genuinely novel.

The framework assumes learners can be guided through abstraction levels, but provides no specific techniques for doing so. Critical questions include: How do instructors identify when learners have collected sufficient concrete instances? What scaffolding helps learners abstract toward generative principles without losing grounding? How can generative return be structured to avoid aimless exploration? These operational details require empirical investigation.

While elements of GTL may appear in advanced instruction, the framework distinguishes itself through its explicit focus on traversal across generative levels as a unified mechanism. Traditional pedagogy may use multiple examples before discussing principles, but typically does not theorize the upward movement as access to higher generative potential, nor does it explicitly structure the downward return as regeneration rather than mere application. GTL reconceptualizes these familiar moves as a coherent cycle centered on generative abstraction, offering educators a deliberate framework for structuring learning sequences.

If learning can be interpreted as movement within structured conceptual space, it becomes meaningful to ask how such movement might be evaluated. Possible approaches include measuring structural coherence of learner representations, tracking transitions between knowledge states, or assessing generative capacity of abstracted principles. Such formalization could enable more rigorous investigation of GTL's claims.

We suggest three productive research paths:

First, case study analysis of existing advanced instruction where GTL-like patterns may already occur. Examining graduate seminars, mathematics tutorials, or theoretical physics pedagogy could reveal whether expert instructors implicitly structure learning this way.

Second, design-based research implementing GTL in controlled settings. Small-scale studies could test whether explicit reduction-generation cycles improve learning outcomes compared to standard approaches, and identify implementation challenges.

Third, computational modeling of GTL dynamics. Representing knowledge states and abstraction levels formally could clarify the framework's mechanisms and generate testable predictions.

In summary, this paper advances Generative Traversal Learning as a conceptual proposal rather than an established theory. Its core claim is that creativity may be enhanced through structured movement across levels of generative abstraction requires empirical validation. We offer it as a framework for examining certain learning dynamics and as an invitation for further investigation.

6 Ethical Use of Artificial Intelligence

Artificial intelligence tools were employed in a supportive role during the preparation of this manuscript. The substantive intellectual contributions, including the development of concepts, theoretical arguments, and interpretations, remain the sole responsibility of the author.

The use of such tools was guided by a commitment to academic integrity, transparency, and responsible scholarship.

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