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Directing the Absent Tool: Friction Embodiment and Competency Progression in AI Assisted Creative Learning

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Abstract: Generative artificial intelligence complicates the relationship between successful creative production and the development of independent disciplinary judgment. Task allocation offers a practical response by identifying operations that learners should protect, perform with support, or delegate, yet the educational value of an allocation depends on conditions that change beyond a single assignment. This article extends a process-centered framework along three connected axes: absence, modality, and time. Constructivist friction describes difficulty encountered when learners must reconstruct judgments previously supplied by an available tool; its educational value depends on subsequent diagnosis, feedback, and transfer rather than difficulty alone. A spatial and embodied extension examines how presence, agency, psychological ownership, and the conditions of verification alter allocation in immersive production. A competency-progression extension treats permission to delegate as a revisable judgment grounded in demonstrated capability across a course. An integrative conceptual analysis connects research on cognitive offloading, learning and performance, scaffolding, immersive learning, and human–AI authorship. Two visualizations of published findings illustrate why assisted achievement and immersive engagement require separate assessment from independent learning. Comparative tables translate the extensions into instructional decisions and measurable constructs. The resulting account positions allocation as a recurring educational judgment: educators revisit assistance when its availability, perceptual context, or relationship to learner competence changes. The article concludes with testable propositions and a longitudinal research design for examining whether adaptive allocation strengthens creative agency, evaluative competence, and durable learning.

Keywords: *generative artificial intelligence, creative agency, constructivist friction, embodied learning, AI literacy, task allocation*.

1. Introduction

Creative education must distinguish the quality of an artifact from the quality of the reasoning through which a learner produces it. A polished image, convincing narrative, or coherent virtual environment can demonstrate successful production while leaving the source of important decisions uncertain. Generative artificial intelligence makes this distinction especially consequential because assistance can supply alternatives, explanations, and revisions that previously required sustained student judgment. The educational question therefore concerns which decisions learners actually exercise and what evidence establishes that exercise. Soderstrom and Bjork (2015) explain why performance during acquisition provides an imperfect basis for inferring durable learning. Applied to creative coursework, this distinction directs attention beyond the finished object toward retention, explanation, and adaptation under changed conditions. It also complicates the assumption that frequent use of sophisticated tools necessarily produces sophisticated understanding. An instructional framework must account for the assistance that contributes to a result and the capabilities that remain available to its maker.

The companion framework developed here addresses this problem through protect, support, and delegate modes. Protection reserves a consequential operation for the learner because performing it serves the learning objective. Support introduces feedback, constraints, or alternatives while retaining the relevant decision with the learner. Delegation permits the tool to perform an operation when the learner can specify an acceptable result and evaluate what returns.

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These modes concern operations within a creative process, rather than permanent categories of students or software. A single assignment can protect interpretive framing, support comparison of alternatives, and delegate a bounded production step. The companion account also treats allocation as provisional within its recursive project phases. A generated alternative may reveal a misconception that requires returning to supported analysis, even when delegation was initially reasonable.

Three conditions require that provisional logic to extend beyond the immediate project. Assistance may become unavailable after learners have incorporated it into their routines. An artifact may move from a flat display into a spatial setting that changes how scale, orientation, and interaction are evaluated. Learners may acquire new capabilities, encounter unfamiliar demands, or revise their understanding of a tool across a semester. Each condition can make an earlier allocation inaccurate without making its original rationale unreasonable. The central issue is the continued validity of the relationship among objective, learner, operation, and available evidence. An allocation remains educationally justified only while that relationship holds. Absence, modality, and time consequently function as reasons to reassess the arrangement under which creative work occurs.

The distinction between assistance and learning has direct empirical relevance, although existing findings require careful transfer across domains. Bastani et al. (2025) report that unrestricted generative AI improved mathematics practice performance while reducing subsequent unaided examination performance relative to a control condition. Creative work introduces additional complications because success often involves defensible interpretation rather than a single correct answer. Doshi and Hauser (2024), for example, found that AI ideas improved evaluations of individual short stories while making stories more similar to one another. Neither result establishes that AI necessarily weakens creative learning. Together, they motivate separate attention to individual product quality, independent capability, and the range of solutions across a class. An assignment could improve one outcome while leaving another unchanged or diminishing it. Allocation must therefore begin with an explicit account of what the course values and what the assessment can establish.

This article argues that adaptive allocation should respond to the removal of assistance, the perceptual conditions of production, and changes in demonstrated competence. Constructivist friction identifies a particular diagnostic event: a learner must reconstruct reasoning that an available tool had previously supplied. The spatial extension asks what counts as adequate evaluation when an artifact is encountered through movement and embodied interaction. The temporal extension asks when accumulated evidence warrants renegotiating the division of work between learner and tool. These extensions preserve the central concern with process ownership and disciplinary agency in the companion framework. They also sharpen its practical implications by specifying triggers for review and evidence for revision. The intended settings are secondary and postsecondary creative courses, including art, design, visual communication, and spatial storytelling. Differences in age, disciplinary preparation, and access remain conditions for local adaptation rather than assumptions of equivalence.

2. Conceptual approach and evidentiary scope

The analysis develops a conceptual extension through a targeted integrative reading of scholarship on learning, human–computer interaction, and creative production. Sources were selected for their relevance to a specific explanatory relationship, such as the distinction between assisted performance and independent learning or the relationship between control and psychological ownership. Foundational learning theory provides definitions and boundary conditions, while recent empirical studies identify observable patterns that the proposed framework should accommodate. This approach does not constitute an exhaustive systematic review or a meta-analysis. The figures re-express selected published results; they do not report observations from a new classroom study. Classroom scenarios specify possible instructional applications and should be read as analytical examples. The article distinguishes direct findings from cross-domain inferences and prospective propositions throughout. Its contribution is an account of when allocation should be reconsidered, together with a research agenda through which that account can be tested.

The conceptual analysis also separates constructs that can appear interchangeable in everyday discussion. Performance concerns achievement under specified conditions, whereas learning concerns a change in capability that persists or transfers beyond those conditions. Agency concerns the exercise of consequential control, while psychological ownership concerns a felt relationship between a person and a process or product. AI literacy supplies conceptual resources for understanding and evaluating systems; demonstrated competence concerns what a learner can accomplish in a particular task. These constructs may influence one another without moving together. A student can feel ownership of an attractive artifact while misunderstanding how its decisive features were produced. Another can demonstrate strong evaluative judgment while reporting limited attachment to a generated result. Maintaining these distinctions allows the three extensions to address educationally different outcomes without collapsing them into a single measure of successful AI integration.

3. Constructivist Friction and the Withdrawal of Assistance

3.1 Defining the withdrawal event

Consider an illustrative visual storytelling assignment in which students use image generation to explore a three-part sequence establishing a location. After an initial period of assisted production, the instructor asks them to construct a comparable sequence without generative suggestions. The compositional objective remains stable, and students retain ordinary drawing materials, reference images, and relevant accessibility supports. Some quickly reconstruct the relations among viewpoint, emphasis, and sequence; others recognize preferred outputs but struggle to explain or reproduce the underlying decisions. The difference becomes visible because the source of ready-made alternatives has changed. This exercise cannot establish a loss of previously mastered skill unless earlier evidence documents that mastery. It can, however, reveal the extent to which successful performance depended on assistance at that point. The instructional value lies in identifying what needs further explanation and practice before the next allocation decision.

Constructivist friction refers here to difficulty that emerges when a learner must reconstruct a consequential judgment previously supplied or materially scaffolded by an available generative tool. The term extends the account, locating the difficulty in a changed relationship between learner and assistance. Three conditions bound the construct: prior access, a meaningful change in that access, and renewed demand for reasoning that the tool had helped perform. Mere inconvenience after losing a fast export function would not qualify if the target judgment remains intact. Neither would difficulty with an entirely new concept that the tool had never supported. Withdrawal can be planned, partial, or accidental, so instructor intention does not define the event. Friction also need not become productive; it may expose insufficient preparation, produce overload, or prompt avoidance. Its constructivist significance arises when learners actively rebuild relations among decisions, reasons, and consequences through an instructional response.

Cognitive offloading offers a useful explanation for why such events occur without requiring a claim that reasoning literally relocates into a machine. Risko and Gilbert (2016) describe offloading as the use of external action to change processing demands and reduce internal cognitive requirements. Their account also connects offloading decisions to metacognitive judgments, which may be inaccurate. In an AI-assisted studio, the corresponding proposal is that students may rely on generated options to accomplish operations they have not yet learned to perform independently. This is a functional redistribution of work across a learner and an external system. It can be beneficial when it frees attention for the intended objective. Problems arise when the redistributed operation is itself the competence that the course expects students to develop. The metaphor of reasoning migrating to the tool should therefore be understood as an allocation hypothesis, not as a demonstrated neurological mechanism or an inevitable consequence of use.

3.2 Relations to established learning constructs

The proposed construct overlaps with established accounts of difficulty while identifying a more specific precipitating condition. Desirable difficulties involve learning conditions that can impede immediate fluency while improving later retention or transfer, provided learners possess the resources to respond productively (Bjork & Bjork, 2011). Productive failure organizes early problem solving and subsequent instruction so that initially unsuccessful attempts can prepare learners for conceptual development (Kapur, 2008). Scaffolding concerns contingent support that changes as learners become able to assume responsibility (van de Pol et al., 2010). Withdrawal of AI assistance can participate in any of these arrangements. A reconstruction task might become a desirable difficulty, or it might expose a failure to fade support appropriately. The additional label is useful only if it identifies the history of prior assistance and the resulting need to reconstruct a particular judgment. Table 1 clarifies these relationships without presenting the constructs as mutually exclusive theories.

Table 1 Constructivist friction in relation to established learning constructs

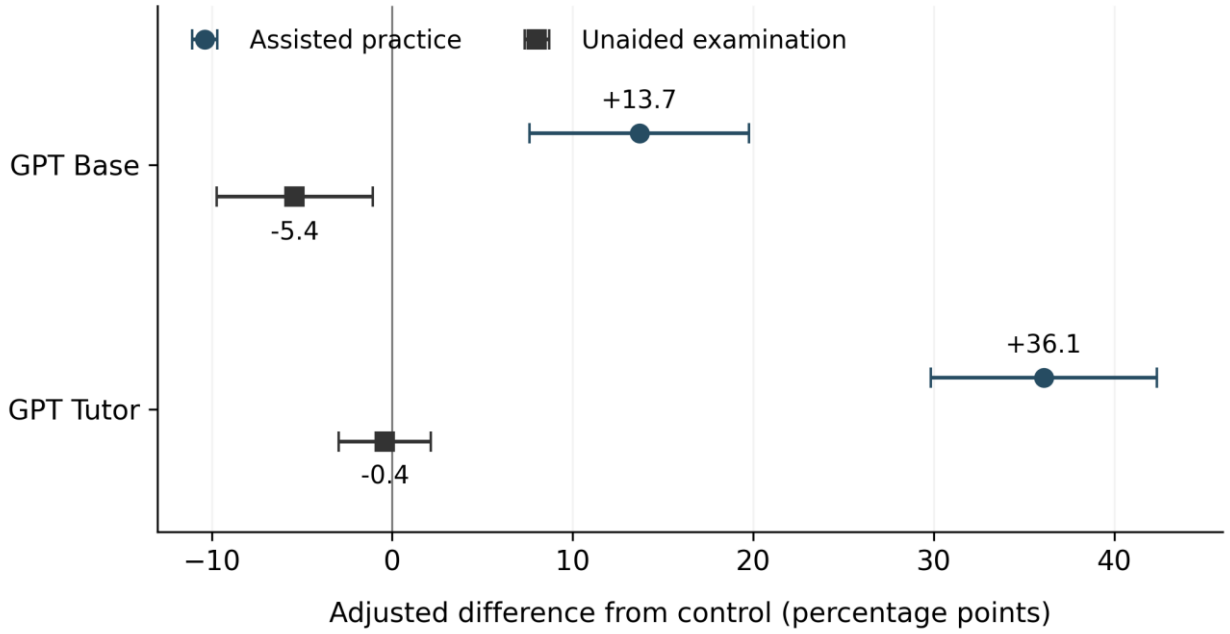
Construct	Defining condition	Relevant evidence	Relation to withdrawal
Desirable difficulties	Challenge that can strengthen later retention or transfer	Delayed benefit despite reduced immediate fluency	Withdrawal may qualify if it improves subsequent learning.
Productive failure	Problem solving before instructional consolidation	Conceptual learning after unsuccessful initial attempts	A reconstruction attempt can precede consolidation.
Cognitive offloading	External action changes internal processing demands	Which operations rely on external resources	Describes the distribution of work before removal.
Scaffolding and fading	Contingent support with transfer of responsibility	Performance as support is adjusted	Planned withdrawal can be part of fading.
Constructivist friction	Prior assistance changes and judgment must be reconstructed	Difficulty linked to an identifiable assisted operation	Names the proposed diagnostic event; benefit is conditional.

A well-designed scaffold is contingent on need and organized around eventual learner responsibility, whereas a generative system can remain immediately available without any educational plan for transfer. In that situation, removal exposes a dependency that was never deliberately constructed as a scaffold. The timing and intensity of the resulting difficulty may therefore differ from a gradual reduction of teacher guidance. Conversely, when AI support is already contingent and deliberately faded, an additional construct may explain little beyond existing theory. Empirical work should test that possibility rather than assume conceptual distinctiveness from the outset. The proposed contribution is a diagnostic specification within a broader family of mediated learning processes. Its value will depend on whether documenting prior assistance improves explanations of reconstruction difficulty beyond prior knowledge, task difficulty, and the amount of support removed.

3.3 Published evidence and its limits

Bastani et al. (2025) provide an empirical anchor for separating assisted performance from unaided learning. Their classroom-randomized study compared standard GPT access, a tutor with teacher-informed safeguards, and a control condition. Table 1 of the study reports practice effects of 13.7 and 36.1 percentage points for the two AI conditions, followed by examination effects of −5.4 and −0.4 points, respectively. Figure 1 displays these estimates with approximate normal confidence intervals calculated from the published standard errors. The guarded tutor's examination estimate was not statistically distinguishable from the control. These findings concern high school mathematics and do not demonstrate the proposed reconstruction mechanism in creative education.

Figure 1 Assisted practice and subsequent unaided examination performance



The interpretation of withdrawal requires separating several possible causes of a performance difference. A learner may never have acquired the target skill, may have acquired it but struggle to retrieve it in a changed setting, or may be unable to express it through the required production method. Anxiety, unfamiliar interfaces, and time restrictions can create further differences. A finished image and a timed hand sketch also sample different motor demands, so their quality cannot be subtracted as though they were equivalent tests. Kovari (2026) emphasizes the importance of specifying assessment conditions and checking whether compared outcomes represent commensurable constructs. That methodological concern is central here because an observed decline alone cannot identify the effect of assistance removal. Researchers need comparable judgments, baseline capability, and evidence about what learners actually delegated. The proposed mechanism becomes more credible when those observations converge with explanations of the reconstruction process.

3.4 Making reconstruction instructionally productive

A diagnostic withdrawal should target a bounded judgment and establish its evidentiary purpose before assistance changes. For a sequence about a location, the instructor might ask students to justify how a change in viewpoint alters narrative emphasis. Students could respond through rough diagrams, an oral explanation, or manipulation of prepared shapes, depending on which method best isolates compositional reasoning. The task would hold the learning objective constant while limiting the particular generative function under examination. Students would first predict

where they expect difficulty, making their expectations available for comparison with observed performance. The instructor would then examine whether problems involve concept knowledge, evaluation, execution, or uncertainty about the task. These distinctions matter because they call for different responses. More independent practice addresses a different need from a worked example, a clarification of criteria, or a change in response format.

Reconstruction becomes educationally useful through feedback and an opportunity to apply the reconstructed principle. After an initial attempt, students can compare their sequence with the earlier generated alternatives and identify a decision they had accepted without understanding. The instructor can model how that decision follows from a criterion, then ask students to revise a new example. This sequence connects diagnostic evidence to subsequent learning rather than treating exposure of difficulty as an instructional achievement. Chi and Wylie (2014) distinguish levels of engagement in ways that support attention to explanatory and constructive activity. A student who changes surface features without articulating a reason provides different evidence from one who develops and tests an alternative account. Peer critique can make those accounts explicit, provided the student must still explain the final choice. The assessment should then examine whether the principle remains available on a later, comparable task.

The timing of withdrawal also determines what can reasonably be inferred. A brief interruption during practice can reveal immediate reliance, while a delayed task can examine whether understanding persists after the original production context has receded. Neither replaces the other. Immediate success may depend on memory for a recently discussed example, and delayed difficulty may reflect forgetting common to all conditions. A useful sequence samples a small set of consequential operations rather than repeatedly removing every form of assistance. The aim is to learn whether students can resume responsibility for judgments central to the course. Once they can, routine production support may remain appropriate. This approach treats independent reconstruction as one source of evidence within creative education, rather than making tool absence the universal definition of authentic work.

Withdrawal must also preserve access to the capabilities that allow students to participate in the assessment. Removing a generative composition function differs educationally from removing speech input, magnification, captions, or another support that enables expression. The target is the decision being assessed, not an idealized picture of unaided manual production. Instructors should specify which supports remain available and why they do not supply the judgment under examination. Equivalent response options can help separate disciplinary understanding from motor speed, sensory tolerance, or language production. Students should know that a diagnostic difficulty creates an opportunity for instruction and revision. When a task carries substantial grading consequences, its conditions should align with prior teaching and practice. These design choices strengthen the validity of the evidence because they reduce competing explanations for apparent dependency.

4. Extending Allocation to Spatial and Immersive Production

4.1 Modality changes the conditions of judgment

Spatial production changes the conditions under which creative judgments can be made and checked. In a flat composition, a viewer usually encounters relations within a bounded visual field whose scale can be adjusted on a screen. A spatial environment organizes attention across distances, directions, and possible movements, often allowing important features to fall outside the current field of view. An arrangement that appears coherent in an overhead plan may become confusing when experienced at bodily scale. A sign that seems legible in a render may be too distant or poorly oriented during navigation. These differences make modality relevant to the allocation of evaluative work. Hutson (2024) situates immersion, presence, and interactivity within the broader development of digital cultural experience. The instructional extension asks how those properties alter the evidence needed to justify a student's decisions about an artifact.

An illustrative assignment can make this change concrete without attributing learning outcomes to a particular event or platform. Students might design a small virtual exhibition around a historical theme using either a desktop interface or a headset. In both versions, they must explain how sequence and juxtaposition support interpretation. In the spatial version, they must also consider the route through the exhibition, the visibility of interpretive labels, and the relationship between an object and the visitor's viewpoint. A generator can propose an arrangement, but the student still needs to determine whether that arrangement communicates the intended relationships. Testing only an overhead screenshot would leave some of those judgments unexamined. An instructor may therefore permit generation while requiring embodied inspection and a documented revision. The resulting allocation depends on how the artifact will be encountered, even when the thematic objective remains unchanged.

4.2 Presence embodiment and ownership

Presence and embodiment supply related but distinct concepts for interpreting spatial experience. Slater (2018) distinguishes the technical characteristics of immersion from the subjective illusion of being in a represented place. Kilteni et al. (2012) describe embodiment through self-location, agency, and body ownership. Self-location concerns where one experiences oneself to be, agency concerns the relation between action and experienced

consequences, and body ownership concerns the felt status of a body as one's own. These concepts should not be transferred without qualification to ownership of a designed object. Feeling that a virtual hand belongs to oneself differs from feeling that an exhibition layout expresses one's authorship. Desktop environments can also support agency and self-relevant engagement, so the difference is not an absolute division between embodied and disembodied media. The pertinent question is which perceptual and action relationships become available and how they affect judgment in the specific assignment.

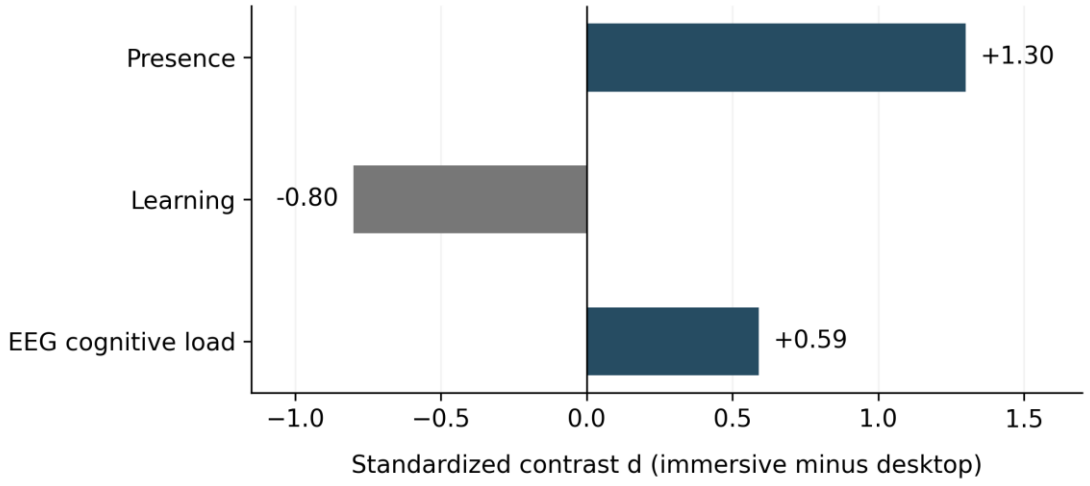
Psychological ownership provides a complementary account of the relationship between a maker and a digital artifact. Belk (2013) examines how digital possessions and practices participate in an extended sense of self. Atasoy and Morewedge (2018) found weaker valuation of digital than physical goods, with psychological ownership helping explain that difference. Research on interactive virtual objects further connects ownership to the circumstances of interaction and control (Krauss & Wienrich, 2025). Poretski et al. (2019) studied engagement with a virtual dog across augmented and fully virtual settings, finding that the surrounding physical or virtual context mattered for relatedness and ownership. These studies justify examining how an artifact is encountered, although they do not establish stronger educational ownership whenever a headset is used. In a classroom, attachment may follow time investment, control, recognition, or the opportunity to alter an object. The framework therefore treats modality as a condition to investigate, with psychological ownership measured separately from technical immersion and learning.

More direct evidence from human–AI writing demonstrates why ownership and authorship require separate measures. Draxler et al. (2024) found a discrepancy between participants' felt ownership of AI-generated text and their public attribution of authorship, while greater influence over the text increased ownership. Pennanen et al. (2026), in a preregistered experiment with 273 online participants, found that editing increased ownership and that iterative prompting helped when editing was unavailable. Fully manual writing nevertheless produced higher ownership than all AI-assisted conditions in that study. These were writing experiments, not demonstrations of semester-long student development or spatial learning. Their relevance is a proposed mechanism of control and self-investment that might also operate in creative environments. A student who merely accepts a generated room may experience a different relationship to it from one who tests and revises the visitor route. That analogy generates a research question rather than establishing an equivalent effect across media.

4.3 Engagement and learning can diverge

Immersive learning research cautions against using vivid experience as a substitute for evidence of understanding. Makransky and Petersen (2021) propose a model in which presence and agency influence learning through affective and cognitive processes, including interest, cognitive load, and self-regulation. Those pathways allow positive and negative consequences to coexist. In a study of 52 university students, Makransky et al. (2019) found greater presence in an immersive science simulation alongside lower learning and higher EEG-based cognitive load than in the desktop condition. Figure 2 presents the reported standardized contrasts with direction expressed as immersive relative to desktop. The study concerned learning within a simulation rather than authoring a creative environment. Its role in the present argument is to demonstrate the need for distinct measures, not to predict that spatial creative assignments will produce the same pattern.

Figure 2 Presence learning and cognitive load in an immersive science simulation



For creative allocation, this distinction makes the cost of verification particularly important. A student may be able to generate a visually impressive environment more quickly than they can inspect its navigational consequences. Some errors become apparent only after movement, interaction, or testing from a different height and orientation. Others concern interpretation and can be detected through discussion without prolonged immersion. Adequate verification therefore combines methods appropriate to the possible error. A spatial walkthrough can examine visibility and sequence, while a plan can reveal overall relations that are difficult to hold in memory during navigation. A brief peer task can test whether the intended action is understandable. Delegation remains justified only when the student can perform or arrange checks that are sufficient for the educational and experiential stakes of the operation.

4.4 Allocating spatial operations

Protected work in spatial production should concentrate on judgments whose exercise constitutes the learning objective. If students are studying the relationship between scale and authority in exhibition design, they should formulate and defend that relationship before asking a tool to generate a layout. Support can then supply alternative viewpoints or flag potential problems without resolving the interpretation. Delegation might handle a repetitive transformation after the student has specified acceptance criteria and shown that they can inspect its effects. Even a seemingly mechanical conversion can alter silhouette, texture, legibility, or performance, so no operation is inherently free of disciplinary consequences. The relevant issue is whether those consequences matter to the current objective and whether they can be checked. Table 2 compares how the same allocation logic operates in flat and spatial assignments. The comparison retains the original three modes while changing the evidence through which each mode is justified.

Table 2 Allocation modes across flat and spatial creative assignments

Mode	Flat production example	Spatial production example	Evidence for allocation
Protect	Student frames the interpretation and explains compositional emphasis.	Student plans sequence, scale, and visitor viewpoint.	The judgment is a central learning objective requiring direct exercise.
Support	AI proposes alternatives; student compares them against stated criteria.	A tool flags occlusion or offers viewpoints; student decides how to revise.	Student uses feedback while retaining responsibility for the decision.
Delegate	A specified export or transformation is automated and inspected.	A bounded asset conversion is automated and tested in context.	Student specifies an acceptable result, detects consequential errors, and corrects or escalates them.

Tool capability introduces a further reason to revisit spatial allocation without assuming that all technical changes constitute progress. A revised generator may produce cleaner assets but introduce a different set of errors in scale, interaction, or semantic interpretation. A workflow that becomes easier to inspect can make delegation more feasible, while a more opaque pipeline may make it less defensible. The instructor therefore needs a local account of the errors that matter and the checks students can conduct. A modest benchmark set of representative tasks can reveal whether the same acceptance criteria still discriminate useful from problematic results. Students can contribute to that evaluation by documenting failures and successful corrections. The resulting record belongs to the instructional context rather than to a universal ranking of software. Allocation can then respond to observed verification demands instead of relying on the reputation or novelty of a tool.

Spatial tasks also require equivalence of educational opportunity across different ways of encountering the work. Headset use may impose sensory, motor, or fatigue demands that do not correspond to the intended creative competence. An alternative inspection method should therefore preserve the judgment being assessed as closely as possible. A desktop walkthrough, multiple perspective views, a physical model, or a peer-guided examination may reveal relevant relationships, although these methods do not automatically offer identical perceptual information. Instructors should identify the remaining differences and avoid treating a preferred device as a proxy for achievement. Students can document decisions through annotated plans and structured explanations in addition to experiential testing. This combination makes the process inspectable for peers and instructors who do not share the same access conditions. It also prevents the spatial extension from reducing creative agency to a particular hardware configuration.

5. Dynamic Competency Progression and the Renegotiation of Allocation

5.1 Competence as a changing basis for permission

An allocation that is appropriate at the beginning of a course can become restrictive or insufficient as students develop. Consider an instructor who initially protects storyboarding because students cannot yet explain how compositional relations support meaning. Several weeks later, some students consistently identify weak alternatives, defend revisions, and transfer their criteria to unfamiliar examples. Continuing the original restriction may then devote substantial time to a judgment already demonstrated. Other students may produce fluent artifacts while still needing support with evaluation, even after equally frequent tool use. A single calendar-based relaxation would treat these different trajectories as equivalent. The temporal extension instead makes review predictable while leaving the resulting allocation dependent on evidence. The question becomes what this learner can responsibly specify, evaluate, and reconstruct for this operation at this point in the course.

AI literacy provides an important foundation for such judgments but should not function as a general license to delegate. Long and Magerko (2020) conceptualize literacy through competencies for understanding, evaluating, and interacting with AI. Chiu (2025) further foregrounds the relationship between literacy and competency in educational framework development. The UNESCO student framework organizes development across understand, apply, and create levels within several dimensions, including ethics and system design (Miao et al., 2024). These contributions support a developmental account broader than prompt fluency. A learner may understand model limitations yet lack the art historical knowledge needed to assess a generated interpretation. Another may be an accomplished designer while misunderstanding the provenance or constraints of a generative system. Allocation should respond to this uneven profile through task-specific evidence rather than a single designation of AI proficiency.

Longitudinal evidence supports repeated assessment while also showing why development should not be described as an automatic consequence of tool exposure. Li et al. (2026) examined two waves of questionnaire data from 216 undergraduates and reported increases in computational thinking and AI literacy. Their structural models showed positive concurrent relationships, but computational thinking at the first wave did not significantly predict later AI literacy in the reported longitudinal path. This distinction limits a simple causal reading of the study. It also means that change in questionnaire scores should not be treated as demonstrated improvement in creative verification. The instructional inference is that capabilities warrant reassessment over time, with measures matched to the relevant operations. Repeated performance tasks can complement self-reports by showing whether students actually identify problems and justify alternatives. Development should be established through converging evidence rather than inferred from the passage of a semester.

The theory of scaffolding supplies a rationale for changing support as competence develops. Wood et al. (1976) described tutoring as assistance that enables learners to engage in problem solving beyond their initial unaided capability. Later review work identifies contingency, fading, and transfer of responsibility as central features of scaffolding (van de Pol et al., 2010). The expertise reversal effect further indicates that instructional techniques useful for novices can become less useful as relevant knowledge increases (Kalyuga et al., 2003). These findings do not prescribe a universal sequence from protection to complete automation. In the present framework, growing competence may justify delegating a familiar operation while protecting a newly introduced judgment. A student can thus move in different directions across operations within the same project. The educational goal is a better fit between support and current need, not a continually increasing proportion of work performed by AI.

5.2 Evidence for revising an allocation

Evidence for delegation should demonstrate both the ability to recognize an acceptable result and the ability to respond when the result fails. An instructor might ask a student to state criteria before generation, compare alternatives containing plausible defects, and explain a correction. The student should also identify circumstances in which their own judgment is insufficient and further consultation is necessary. These performances are more informative than a polished example selected after many undocumented attempts. Brief reconstruction tasks can examine whether the underlying principle remains available when the generator is absent. Repetition across a familiar and a moderately changed task can reveal whether competence is narrowly tied to one workflow. The required level should reflect the consequence of an error and the instructional purpose of the operation. A low-stakes formatting task and the interpretation of a culturally sensitive object do not require identical evidence of readiness.

Confidence deserves attention because it can influence both willingness to delegate and willingness to inspect. Lee et al. (2025) surveyed 319 knowledge workers, finding that greater confidence in generative AI was associated with less reported critical thinking, whereas higher task-specific self-confidence was associated with more. Their study concerns self-reported work practices and does not establish causal skill loss. It nevertheless motivates examining whether students calibrate confidence to observable performance. Before reviewing an output, learners can predict which criteria they expect it to satisfy and indicate where uncertainty remains. After checking, they can compare those predictions with the problems identified. The purpose is to

make verification selective and reasoned rather than ceremonial. A student who confidently accepts every suggestion needs different support from one who detects errors accurately but remains unable to act without repeated reassurance.

Scheduled review points make adaptive allocation feasible without requiring continuous individual surveillance. An illustrative fifteen-week course might gather baseline evidence in the opening weeks, revisit allocation after a first complete project, and review again when the work changes modality or introduces a new disciplinary demand. A final delayed task could examine whether selected judgments remain available beyond the original production sequence. These times are examples of instructional organization, not validated thresholds. At each review, students would submit a small set of decisions with explanations of what was protected, supported, or delegated. The instructor would retain the current allocation, widen delegation, or restore support for a named operation. Students should receive the reason for that decision and an attainable route to reconsideration. Predictable review combined with evidence-sensitive outcomes makes adaptation more transparent than informal permission granted according to apparent technical confidence.

Process documentation should be proportionate to the inference an instructor needs to make. Requiring every prompt and every intermediate output can generate extensive records while obscuring the decisions that matter. A compact portfolio can instead retain an initial criterion, a consequential alternative, a rejected suggestion, and a revision that shows the criterion in use. The student can explain how assistance affected the decision and what they would do if that assistance changed. These selected records should be sampled against classroom performance so that retrospective narration does not become the sole evidence of agency. Peer critique and brief oral defense can supply additional perspectives without treating articulate presentation as equivalent to understanding. Documentation becomes educational when it supports comparison across attempts and informs the next decision about assistance. Its value should be judged by the insight it provides, not by the volume of activity it captures.

Ownership should remain a separate outcome as competency develops. Greater skill in prompting or editing may enable more control, but a learner can become highly effective while feeling detached from an AI-assisted product. Conversely, emotional attachment can grow through effort even when technical judgment remains weak. Process ownership can be explored through students' accounts of which consequential choices they regard as their own, while product ownership concerns their felt relationship to the resulting artifact. These reports should be interpreted alongside evidence of actual contribution rather than substituted for it. The distinction also protects against using an ownership score as a moral assessment of legitimate AI use. Students may responsibly delegate peripheral work and still exercise substantial disciplinary agency. A developmental account should describe these relationships empirically instead of assuming that competence, ownership, and achievement rise together.

Competency progression must also accommodate interruptions and reversals. A student who evaluates generated images well may struggle when moving to an unfamiliar three-dimensional environment. Changes in tool behavior can invalidate a previously reliable checking routine. Fatigue, uneven access, and differences in prior disciplinary preparation can alter what a student can demonstrate in a particular session. An allocation review should therefore ask what changed before attributing difficulty to declining ability or inadequate effort. Returning an operation to support mode can be a reasonable adjustment that enables continued progress. The learner's contribution to this diagnosis matters because they often know which part of the workflow became uncertain. Temporal adaptation consequently includes the capacity to reopen earlier judgments, as well as the opportunity to recognize newly demonstrated competence.

6. Discussion of the Three Axes of Adaptation

6.1 A unified account of revisable allocation

Absence, modality, and time describe three ways an allocation can cease to fit the conditions for which it was made. Absence changes which resources participate in performance. Modality changes how relevant properties become perceptible and how an acceptable result can be checked. Time changes the evidence available about the learner and, often, the capabilities of the tool. Their common consequence is uncertainty about whether an earlier division of work still serves the learning objective. The framework therefore treats review as a normal part of creative instruction. It does not require every change to trigger a new policy for the entire course. Instead, the instructor identifies the affected operation and asks whether the evidence supporting its current mode remains adequate.

An allocation review can be organized around a concise set of educational questions. What judgment is the learner expected to develop, and which portion of that judgment does the tool currently perform? What evidence shows that the learner can specify, evaluate, and reconstruct the relevant operation? How will the artifact be encountered, and can the available checking process detect the errors that matter? Has assistance, task context, or demonstrated capability changed enough to invalidate an earlier answer? These questions extend the companion framework without replacing its project phases or adding a fourth allocation mode. They also make the rationale for a decision visible to students. A defensible allocation records both its purpose and the conditions under which it should be reconsidered.

The three axes may interact, so evaluating them in isolation could conceal the mechanism of an instructional effect. A student who has practiced independent explanation may experience less disruptive friction when a familiar tool becomes unavailable. The same student may still encounter substantial difficulty when the judgment must be exercised in an unfamiliar spatial setting. Conversely, moving an artifact into a bodily encounter might reveal a problem that remained invisible on screen, producing useful reconsideration while assistance remains available. Greater tool familiarity might reduce production effort but increase reliance if the course never requires evaluation. These possibilities make a simple monotonic model of improvement implausible. The proposed framework instead anticipates context-sensitive relations among prior knowledge, verification demands, and the history of assistance. Empirical studies should test those relations directly and retain outcomes that challenge the proposed explanation.

6.2 Testable propositions and measurement

Four propositions organize an initial research agenda while preserving the distinction between explanation and evidence. First, the need to reconstruct a previously assisted judgment should depend on the extent and character of earlier delegation, after accounting for baseline knowledge and task demands. Second, reconstruction followed by targeted feedback should improve later performance more than exposure of difficulty alone, when the relevant learning conditions are comparable. Third, the effect of spatial modality on allocation should depend partly on whether the verification method samples the properties that matter in the encountered environment. Fourth, allocation revised through demonstrated competence should produce different learning trajectories from a fixed policy, although the direction and magnitude remain empirical questions. These propositions concern relations among observable conditions rather than an assumed benefit of every adaptive practice. Each requires measures capable of distinguishing competing explanations. Table 3 identifies candidate observations and the inferences they can and cannot support.

Table 3 Candidate measures for testing adaptive allocation

Construct	Candidate observation	Interpretive boundary
Assisted performance	Artifact quality under documented tool access	Does not establish independent learning.
Independent capability	Comparable reconstruction and delayed transfer tasks	Requires comparable criteria and preserved access supports.
Constructivist friction	Errors, latency, hint requests, and explanations after changed assistance	A decline alone does not identify the cause or show skill loss.
Verification competence	Detection and correction of plausible defects with reasons	Requires disciplinary criteria and representative errors.
Presence and embodiment	Separate reports of presence, self-location, agency, and body ownership	Should not substitute for learning or product ownership.
Process and product ownership	Separate reports linked to documented consequential choices	Felt ownership does not establish authorship or competence.
Competency progression	Repeated performance tasks and confidence calibration	Growth must be distinguished from task familiarity and tool change.

Constructivist friction requires especially careful operationalization because a single difference score is insufficient. Researchers could record errors on a comparable reconstruction task, time spent identifying a criterion, requests for hints, and the quality of a subsequent explanation. These measures sample different aspects of difficulty and should initially be analyzed separately. A student who works slowly but accurately differs from one who produces an immediate unsupported answer. Retrospective interviews can examine which operation students believed the tool had been supplying, but such reports require comparison with process records. Pre-assistance baseline tasks help distinguish failure to learn from deterioration in previously demonstrated performance. Delayed tasks indicate whether feedback produces a persistent change rather than a temporary response to

coaching. Evidence for the proposed construct would be stronger if its indicators explain outcomes beyond established measures of task difficulty, prior knowledge, and support withdrawal.

6.3 A longitudinal design for creative courses

A feasible initial study could follow multiple creative course sections across a semester while comparing a fixed allocation policy with scheduled evidence-based review. Sections would use a common set of learning objectives and comparable assignments, with instructor preparation designed to reduce unintended differences in feedback. Random assignment at section level would strengthen causal inference if enough sections were available; otherwise, a matched design would require explicit adjustment for baseline differences and more cautious conclusions. All students would complete baseline assessments of the selected disciplinary judgments and relevant AI understanding. Researchers would sample assisted production, a comparable reconstruction task, and delayed transfer at several points. The design would document actual assistance as well as assigned policy because permitted use and enacted use may differ. Tool versions and consequential changes would be recorded. This approach tests adaptation as an instructional practice while retaining evidence about the mechanism through which it might operate.

The modality extension could be examined through matched flat and spatial tasks that share an interpretive objective while making their differences explicit. For example, both conditions might organize the same objects around a historical argument, with one presented as a screen-based composition and the other as a navigable environment. Common criteria would assess the quality of interpretation, selection, and justification. Modality-specific criteria would assess properties such as navigation and embodied scale without pretending that they have identical counterparts in a flat artifact. Counterbalancing task order could reduce practice effects, although learning from the first task may still influence the second. Researchers would collect experience, workload, and access information to interpret differences in performance. A common transfer task could then examine whether a principle learned in one setting remains available elsewhere. The study would distinguish the effects of encountering a spatial artifact from the separate demands of authoring it.

Analysis should respect the nested and repeated structure of classroom evidence. Observations arise within learners, assignments, and course sections, so a model should account for dependence where the number of units supports it. The primary outcome and contrasts should be specified before inspecting the results, with effect estimates and uncertainty reported alongside significance tests. A pilot can inform a defensible sample-size plan, especially when section-level variation or attrition may be substantial. Independent raters should evaluate artifacts and explanations against shared criteria, with reliability assessed before interpreting differences as learning effects. Missing observations should be described by condition and reason because absence from a withdrawal task may relate to the phenomenon under study. Qualitative analysis can trace how students interpret and correct consequential decisions, including cases that contradict aggregate trends. Mixed evidence is most useful when it explains a specific discrepancy rather than merely adding favorable quotations to numerical findings.

6.4 Implications for teaching and institutional practice

The framework asks educators to make assessment conditions explicit enough that a result has an interpretable meaning. A portfolio can communicate strong assisted production, while a reconstruction task can communicate a different dimension of capability. Neither should silently stand in for the other. Course descriptions can identify which judgments require independent demonstration and where supported or delegated work serves the curriculum. Students then know why assistance differs across operations and what evidence can change that arrangement. Departments can compare rubrics and examples to reduce inconsistent expectations across sections. Shared planning can also distribute the work of developing verification tasks for emerging tools. This institutional contribution concerns the quality of educational judgment rather than the adoption of a single platform or a uniform percentage of permitted AI involvement.

Adaptive allocation also has consequences for the distribution of opportunity. Students with extensive prior access may initially demonstrate more efficient workflows, while others may possess strong disciplinary understanding without comparable technical experience. Treating speed or fluency as the main evidence for delegation could amplify that difference. Common access to practice, explicit instruction in evaluation, and multiple ways to demonstrate reasoning can make the review process more informative. The framework also requires an attainable route from a protected operation to a revised allocation, so early difficulty does not become a lasting classification. At the same time, offering delegation before a learner can check consequential results may conceal a need for instruction. Equity therefore depends on the relationship between access, support, and valid evidence of learning. The appropriate response can include more assistance, a different kind of assistance, or a better assessment of an existing capability.

The conceptual contribution remains bounded by several unresolved issues. Evidence from mathematics, writing, consumer behavior, and science simulations provides relevant mechanisms and contrasts, but transfer to creative classrooms requires direct investigation. The distinctions among process ownership, product ownership, agency, and independent capability also need discriminant validation within the same study. Instructors may find adaptive review

difficult to sustain when class sizes are large or tool behavior changes rapidly. Students may alter their visible behavior because they know a review determines permission to delegate. A framework that encourages documentation can also privilege those who explain their process fluently unless the assessment includes other evidence. These limitations identify design requirements for implementation and research. They do not invalidate the central premise that allocation should be reconsidered when the conditions supporting it change.

7. Conclusion

AI-assisted creative learning requires an allocation model that remains responsive to the conditions under which students exercise judgment. Protection, support, and delegation offer a useful account of how work can be distributed, but that distribution acquires educational meaning through its relationship to an objective and evidence of learner capability. Constructivist friction identifies the diagnostic possibilities and risks that appear when an available source of assistance is removed. Spatial production changes what students need to perceive, test, and explain before they can responsibly accept a result. Competency progression changes the evidence on which an allocation rests across assignments and courses. These extensions preserve the original concern with creative agency while making its provisional character operational. The instructional task is to revisit consequential decisions at moments when the learner, the assistance, or the conditions of evaluation have changed. Doing so makes it possible to identify when a productive workflow is also supporting the intended learning.

The proposed research agenda places independent reconstruction, assisted performance, psychological ownership, and verification competence in a shared design without treating them as equivalent outcomes. Published findings demonstrate why those distinctions matter, while the classroom applications specify how educators might obtain the necessary evidence. What remains to be established is whether scheduled, evidence-sensitive allocation improves durable creative capability and under which conditions it does so. The strongest test will examine both successful adaptations and cases in which additional review adds burden without educational benefit. It will also assess whether the proposed construct of friction contributes explanatory value beyond established theories of scaffolding and cognitive offloading. Creative education can then develop guidance grounded in the operations students need to understand, rather than in a general presumption for or against automation. Directing the absent tool ultimately means designing learning so that a change in assistance reveals something interpretable and leads to an appropriate instructional response. A framework that revisits its own decisions makes that response possible across changing technologies, environments, and learners.

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