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FROM CREATIVE IDEAS TO SCIENTIFIC ACTION: RETHINKING BRAINSTORMING AND CASE-BASED LEARNING IN JUNIOR SECONDARY SCIENCE

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Abstract

Students can suggest original solutions to science problems without being able to explain whether those solutions would work. Yet classroom discussions and assessments often treat the generation of ideas, scientific reasoning and innovation as though they were the same achievement. This article asks what kinds of learning experiences can help students move from an imaginative possibility to a claim that is supported by evidence and realistic in its setting. Through a critical synthesis of research on creativity, scientific argumentation, case-based learning and culturally responsive science education, it proposes the Epistemically Warranted Idea-to-Action (EWIA) framework. EWIA brings together five connected teaching functions: framing a meaningful problem, generating alternatives, examining evidence, adapting ideas to local constraints, and communicating or acting responsibly. Two examples from junior secondary Basic Science, flood-related water safety and soil erosion, illustrate how teachers might use the framework without expensive digital resources. An analytic assessment rubric and five propositions indicate how the proposal could be tested in future research. The argument is that originality, scientific justification, practical feasibility and actual implementation should be recognised as related but distinct educational outcomes. The framework is conceptual and has not yet been tested in classrooms.

Keywords: Scientific Creativity; Brainstorming; Case-Based Learning; Evidence-Based Reasoning; Basic Science; Instructional Design.

Introduction

What should count as creativity in a science classroom? A learner may offer an unusual explanation for a familiar phenomenon, sketch an imaginative device or suggest a new way to solve a local problem. Each response may be worth discussing. But science education must also teach learners to ask whether an explanation is supported by evidence, whether a proposed test is fair and whether a suggested action could have unintended consequences. Encouraging original thinking without developing these habits risks confusing imagination with scientific understanding.

Brainstorming and case-based learning appear frequently in recommendations for more active science teaching. Brainstorming gives pupils room to explore alternatives before they are judged; a carefully chosen case makes them confront the details and constraints of a particular situation (Allchin, 2013). Both can make lessons more engaging. Neither guarantees that an interesting suggestion will become a well-supported conclusion. A student might propose that a home-made filter makes floodwater safe to drink. The idea is concrete and apparently useful, but it would be irresponsible to accept the claim without evidence about microbiological safety. The teaching challenge lies in helping learners identify that gap, not merely in eliciting more suggestions.

Such questions are especially pressing in classrooms where books, laboratory equipment, internet access and instructional time are limited. Learners may also have relevant knowledge that is difficult to express in the language of formal science teaching. These conditions influence which problems can be investigated and whose contributions receive attention. They do not make scientific standards less important. Nor should material deprivation be celebrated as though scarcity automatically produces creativity. Research on community knowledge and multiple ways of knowing suggests a more constructive response: take learners' experiences seriously, while making the evidence used to evaluate claims explicit (Bang & Medin, 2010; Moll et al., 1992).

The argument is not that science education has overlooked the need to evaluate ideas. The OECD (2023, 2024) already describes creative thinking in terms of generating, evaluating and improving ideas. Measures of scientific creativity likewise attend to more than fluency or originality (Hu & Adey, 2002; Xu et al., 2025). Research on scientific explanation shows the difficulty students face when connecting observations and scientific ideas to support a claim (Novak & Treagust, 2026). The more specific gap concerns the relationships among these achievements. How does a teacher distinguish a promising possibility from a justified scientific response, and a justified response from one that can safely be put into practice? How should those differences shape classroom activities and assessment?

This article responds by developing an Epistemically Warranted Idea-to-Action (EWIA) framework. The name is technical, but the central proposition is straightforward: creative science teaching should make visible what learners imagine, what they can justify, what is feasible, and what they should communicate or do. The model brings brainstorming and case-based inquiry into the same conversation without assuming that combining them will always improve learning. It adds attention to whose ideas enter the discussion, how evidence changes those ideas, and why deciding not to act can sometimes demonstrate sound scientific judgement. Although the examples are drawn from junior secondary Basic Science, the distinctions may be useful in other school science contexts.

Conceptual approach

This article develops a conceptual model; it does not report an intervention, reanalyse the results of a thesis or claim to be a systematic literature review. The aim is to bring together strands of scholarship that address different parts of one teaching problem. Jaakkola (2020) identifies theory synthesis and model building as legitimate routes to conceptual contribution when authors make the relationships among existing concepts explicit and develop propositions that can be challenged.

The discussion draws on five bodies of scholarship: definitions of creativity; assessment of scientific creativity; brainstorming and group ideation; case-based inquiry and scientific argumentation; and work on language, culture and resources in science classrooms. Foundational accounts are read alongside contemporary contributions, including the OECD's creative-thinking framework (2023, 2024), a review of case-based learning in sciecccxnce education (Dewi & Rahayu, 2023), a meta-analysis of brainstorming (Çelik & Akay, 2025), and recent assessment research (Xu et al., 2025). Sources were selected for their relevance to the conceptual problem and the alternative explanations they raise. The article does not claim an exhaustive database search, systematic screening process or numerical evidence saturation.

The synthesis proceeds in three stages. It first distinguishes processes commonly grouped together under creativity or innovation: producing ideas, judging their scientific support, revising them in response to practical constraints and putting them into use. It then examines what brainstorming, case-based learning, scientific argumentation and community-grounded pedagogy can contribute to those processes. Finally, it develops a model, classroom examples and research propositions. These propositions are reasoned expectations, not findings from the framework's implementation.

Three questions guided the reading: What does each body of work explain well? What does it leave unclear about the passage from an idea to a defensible scientific response? Where might its assumptions fail in a crowded, multilingual or poorly resourced classroom? Taking rival explanations seriously matters because a framework that only gathers supportive citations may be rhetorically attractive but difficult to test.

Conceptual Foundations and Competing Explanations

Creative Thinking Is Not the Same as Scientific Justification

Creativity is generally understood to involve novelty and usefulness or appropriateness, not novelty in isolation (Runco & Jaeger, 2012). The scientific domain adds constraints: an unusual claim should be open to disciplined questioning, coherent with available evidence and corrigible when testing fails. Hu and Adey (2002) constructed a scientific-creativity instrument involving open-ended scientific tasks and attention to multiple features of creative response. Their work helped make pupils' scientific imagination assessable but does not imply that every unusual answer represents a tested invention. Indeed, a response may be personally new and educationally important without being historically unprecedented. Beghetto and Kaufman's (2007) account of *mini-c* creativity is valuable here because learners can generate meaningful new understandings for themselves before producing outcomes judged original by others.

A productive difficulty emerges between general criteria of originality and usefulness and the specific epistemic obligations of school science. In writing or imaginative design, subjective novelty may be sufficient for some instructional purposes. In a science investigation, however, what matters is not simply whether a learner proposes a different explanation but whether the explanation can withstand relevant counter-evidence, articulate assumptions and identify conditions under which it might fail. Scientific creativity does not require learners always to arrive at an established scientific answer. It requires creativity to remain accountable to questions of observation, inference, causal plausibility and justification. The National Research Council (2012) accordingly integrates science content knowledge with practices of inquiry, modelling, evidence and argumentation.

The broader creativity literature also cautions against interpreting individual scores as self-contained traits. Hennessey and Amabile (2010) describe creativity as involving interrelated psychological and environmental influences, suggesting that the opportunity to develop a strong idea depends partly on motivational and social conditions. This matters for classroom science because a pupil who offers few responses under public scrutiny may nevertheless reason well when given time, materials and a non-threatening opportunity to explain. Neither an ideation score nor teacher enthusiasm is a sufficient proxy for the quality of scientific learning.

Xu et al. (2025) develop a more comprehensive assessment covering scientific knowledge, motivation and thinking styles, illustrating how modern measurement models can move beyond a single divergent-thinking task. The implication for theory building is twofold. First, creative scientific performance is multidimensional; second, even multidimensional scores do not automatically establish what happens between generating an answer and using evidence to improve or apply it. The issue at stake is therefore not the absence of creativity models, but the under-articulated conditions of movement between ideation, warrant and situated action.

Brainstorming broadens possibilities but does not test them

Osborn's (1953) treatment of creative thinking popularised the deliberate generation of ideas before immediate evaluation. In school science this separation can be helpful: students who expect instant correction may offer only familiar textbook responses, whereas deferred judgement can widen the space of possible explanations. A recent meta-analysis finds that brainstorming interventions are associated, on average, with positive academic and creative-thinking outcomes across the included studies; the authors nevertheless report substantial heterogeneity (Çelik & Akay, 2025). Such evidence supports the plausibility of idea-generation pedagogy without establishing that brainstorming alone fosters well-tested scientific reasoning in any given setting.

The social organisation of brainstorming also matters. Early experimental research identified production blocking as a source of reduced idea generation in interacting groups (Diehl & Stroebe, 1987). In a large class, a teacher who asks pupils to shout answers can inadvertently create an environment in which confident speakers dominate, less fluent speakers remain silent and initial responses anchor subsequent ideas. Low-cost alternatives include brief individual preparation, paired comparison and anonymous written contribution before whole-class discussion. These measures can broaden access to participation; whether they improve scientific creativity still depends on what happens after ideas are generated.

Brainstorming is therefore best conceptualised as an *opening move*. Its educational success cannot be inferred from the number of suggestions on the board. If learners identify several possible causes of stagnant water but never examine data, the lesson may have practised divergent thinking without developing an adequate explanation. The conceptual problem is not that brainstorming is defective. Rather, its principal affordance lies in producing alternatives whose quality remains to be established by other practices.

Cases Create Opportunities for Evaluating Ideas

Case-based learning can contribute what ideation alone lacks: situated information, competing constraints and a basis for reasoning about consequences. Allchin (2013) cautions against collapsing problem-based and case-based methods into a single strategy, identifying consequential differences in autonomy, authenticity, historical outcomes and the role of applying versus generating knowledge. Cases range from relatively closed problems with a settled answer to contested situations in which learners must decide what evidence would justify a recommendation. A review by Dewi and Rahayu (2023) documents wide implementation of case-based approaches in science education, while also acknowledging practical difficulties, including time demands.

Yet case pedagogy cannot be assumed to generate creative thinking automatically. A case accompanied by prescriptive questions may train pupils to locate a teacher-approved solution. Conversely, an open case can encourage speculation without establishing criteria for judging competing proposals. The instructional value arises when learners can ask what counts as an explanation, which evidence is missing, what alternative mechanisms could account for observations and which consequences follow from acting on limited information. Scientific argumentation research distinguishes sensemaking, articulation and persuasion as related but different aims of classroom discourse (Berland & Reiser, 2009). Explicit support for argument quality is also learnable through appropriately structured lessons (Osborne et al., 2004).

Accordingly, case-based inquiry is here assigned a particular, non-exclusive function: it helps transform an imaginative option into a claim answerable to evidence, context and consequences. It does not replace brainstorming; nor is brainstorming always required. Some scientifically valuable inquiry starts from an existing explanation that needs critical refinement. The proposed account is deliberately flexible about routes while being demanding about warrant.

Language, Local Knowledge and Resources Shape Inquiry

A common limitation of generic innovation frameworks is to treat 'context' as a box surrounding otherwise universal mental stages. This understates how available resources, participation norms and language determine what can be asked, heard, tested and accepted. Funds-of-knowledge scholarship recognises that household and community practices can provide intellectual resources for instruction (Moll et al., 1992), while Bang and Medin (2010) show why science learning should support navigation among multiple epistemological orientations rather than presume a culturally neutral classroom. These perspectives do not displace scientific evidence. They complicate whose observations count as a starting point and who has access to disciplinary means of evaluation.

Language is especially consequential. A pupil may understand a flooding pattern or household water treatment practice but lack the English terminology expected in a formal answer. Evidence from a multilingual South African science classroom illustrates that translanguaging can be part of meaning-making rather than a simple departure from legitimate science talk (Charamba, 2023). Whether this is similarly productive in a particular Nigerian classroom requires local study; it should not be presumed. The proposed model therefore separates the scientific quality of a response from its conformity to a single language variety. Teachers can invite multilingual first explanations and then work with learners to translate and sharpen their scientific claims, without lowering evidentiary standards.

Resource constraints are likewise double-edged. Locally sourced objects and small-scale demonstrations can make investigation more meaningful, but inadequate safe water, laboratory equipment, staffing or classroom time may prevent the testing that science inquiry demands. In such circumstances, a reasoned decision not to recommend implementation may represent stronger scientific judgement than an imaginative but unsafe intervention. This distinction is central to the proposed theoretical contribution.

The Epistemically Warranted Idea-to-Action framework

The EWIA framework distinguishes five kinds of work that may occur during a creative science lesson. The first is deciding what needs explaining. The second is generating possible explanations or responses. The third is examining the evidence for those possibilities. The fourth is considering whether a proposed inquiry or solution is feasible and safe in its setting. The fifth is deciding what can be demonstrated, communicated or responsibly left unresolved. The framework does not prescribe a rigid sequence. Evidence may send a class back to the original question, and an apparently feasible response may expose a new scientific uncertainty.

Two terms require clarification. Epistemic warrant refers to the reasons for accepting a scientific claim provisionally, such as relevant observations, a fair comparison, a plausible mechanism and recognition of uncertainty. Contextual feasibility refers to whether an investigation or response can be undertaken responsibly with the materials, time, knowledge and safeguards available. Both need to be considered separately from originality: an unusual idea may lack evidence, and a well-supported explanation may not yet permit safe action. EWIA names these differences so that they can be taught, discussed and, eventually, assessed.

Situating A Meaningful Problem

Scientific creative work begins neither with novelty for its own sake nor with the assumption that the teacher alone defines worthy questions. Pupils are invited to describe a phenomenon, identify who is affected and separate the observations that need explanation from judgements already made about them. An apparently simple question, such as why a particular water source becomes muddy after heavy rain, may conceal ecological, infrastructural and social issues. Teacher guidance remains necessary to select developmentally appropriate and safe questions, but the practice of situating a problem can legitimise learners' experiences as sources of inquiry. This is not equivalent to treating anecdotal explanation as established scientific knowledge.

The term *authorisation* refers to epistemic participation: whose account may enter the discussion, in which language, and under what conditions? Where only a confident minority can frame the problem, later brainstorming may amplify that early exclusion. Starting with individual observations, local-language discussion where appropriate and explicit clarification of terms may broaden what the class can investigate. The observable achievement is a question that learners can recognise, specify and place within the scope of scientific inquiry.

Generating Alternative Explanations and Responses

The second function uses deliberately divergent tasks. Pupils might identify alternative explanations, imagine modified procedures or propose different ways to gather relevant evidence. Brainstorming is one tool, alongside drawings, paired talk, analogies and individual written idea lists. In principle, fluency matters because a single immediate answer may prematurely close inquiry; flexibility matters because alternatives may represent different mechanisms; and originality matters insofar as an idea is not merely copied from the most obvious available answer. But an exotic hypothesis without a possible evidentiary path is an invitation to investigation, not itself a scientific achievement.

Teachers should avoid ranking ideas solely by how unusual they sound. They can record alternatives without premature dismissal, then invite students to group them according to plausible causes or required evidence. Learners who cannot easily speak publicly might contribute a diagram or short written proposal. The purpose is to create a field of options that can subsequently be examined, not to award 'innovation' status for producing the longest list.

Examining The Evidence for Each Idea

The third function is the conceptual pivot. Each promising idea is translated into a claim for which the class can state what would count as support or challenge. A learner who proposes that soil erosion causes muddy floodwater might suggest comparing water from sites with different vegetation cover, identifying possible confounders and explaining why a visual contrast alone cannot establish cause. Pupils are asked to make the logic of their claims visible: the observation, the inference, the assumed mechanism and the remaining uncertainty. Critique is directed at claims, not at pupils' worth.

Cases can be used to insert discrepant observations or realistic constraints. A case may describe two households with different water-storage practices; the class must ask what additional measurements would be needed before attributing differences in illness to storage. Such discussion makes room for explanation and scientific argumentation (Berland & Reiser, 2009; Osborne et al., 2004), while guarding against a common mistake: reasoning about a familiar situation is not the same as demonstrating that a claim is true. Epistemic warrant is therefore graded, provisional and revisable, not a binary certificate of correctness.

Adapting Ideas to What Is Feasible and Safe

A scientifically plausible proposal may demand materials or safety provisions unavailable to the class. The fourth function asks learners to revise a proposed inquiry or response in ways that preserve its explanatory purpose while acknowledging these constraints. A design requiring a microscope might be replaced by a teacher-provided image for initial comparison; a water-quality claim requiring microbiological testing might be explicitly left unresolved rather than pretended to have been verified by sight or smell. This is a crucial distinction: material adaptation must not be confused with a reduction of evidentiary standards.

Feasibility analysis also asks who would benefit, who could bear risk and whose existing practices may be overlooked. Learners might propose a low-cost flood-warning display, but a teacher would need to help them consider maintenance, accessibility, false alarms and the distinction between a classroom prototype and a deployed public-safety system. Iteration here is not just engineering optimisation. It is a form of socially and materially accountable scientific judgement, especially relevant where the immediate use of a proposal has non-trivial consequences.

Communicating, Acting or Recognising the Limits of Evidence

The final function recognises several legitimate forms of output. A class might construct and test a harmless prototype, revise an explanatory model, communicate a recommendation with explicitly stated uncertainty or decide that available evidence is insufficient for safe action. Innovation should be reserved for implemented, useful change, not retroactively attached to a novel thought. When implementation is not possible, students may still demonstrate substantial scientific creativity through defensible reasoning and practical redesign. This

protects assessment from rewarding risky demonstrations or penalising learners whose schools lack expensive equipment.

Scientific communication provides the public-accountability dimension. A credible classroom product states what was proposed, what evidence was considered, why a claim was revised and what was not established. Different languages or representations can support early reasoning, while a final public statement should make the relevant scientific grounds intelligible to its audience. A neat poster is not equivalent to a scientifically warranted conclusion; nor should weak artistic presentation erase a well-justified scientific argument.

Figure 1. The Epistemically Warranted Idea-to-Action (EWIA) framework.



Note. Five functions are connected by revisable decisions rather than a guaranteed sequence. Failure of evidentiary warrant, feasibility or inclusion can return the inquiry to earlier functions or justify reasoned non-action. The framework is a theoretical proposal, not an empirically validated instructional model.

Table 1. The five teaching functions in the EWIA framework.

Pedagogical function	Core question	Evidence of learning
1. Situate and authorise	Whose problem is this, and why investigate it?	Locally grounded question; multiple perspectives acknowledged
2. Generate possibilities	Which explanations or responses are possible?	Diverse, distinct and reasoned alternatives
3. Establish epistemic warrant	What evidence supports or challenges each idea?	Testable claim; comparison; uncertainty; counter-evidence

Pedagogical function	Core question	Evidence of learning
4. Adapt to context	What is feasible, safe and justifiable here?	Revised design; resource and language accessibility; risk analysis
5. Enact or communicate responsibly	What can be demonstrated, recommended or withheld?	Transparent claim, prototype or cautious recommendation

What does EWIA add to existing approaches?

EWIA does not claim to have invented the movement between divergent and convergent thinking. Nor is the distinction between claims and evidence new. The OECD's creative-thinking model (2023, 2024) already asks learners to generate and improve ideas; scientific-creativity instruments examine several dimensions of originality and subject knowledge (Hu & Adey, 2002; Xu et al., 2025); and scientific argumentation research investigates how claims become justified (Berland & Reiser, 2009; Osborne et al., 2004). More recently, Dauer et al. (2026) have argued that teaching socio-scientific issues should help students form grounded opinions, while Novak and Treagust (2026) examine how students connect data with scientific ideas when revising explanations. These are important neighbouring accounts rather than gaps to be ignored.

The narrower contribution of EWIA is to connect those concerns with the decisions a teacher makes when students propose responses to an authentic problem. It separates four outcomes that are often reported together: an original idea, a scientifically justified claim, a feasible plan and a useful action. It also asks whose evidence is heard, what material and ethical conditions make a response possible, and when a responsible conclusion is that more evidence is required. These distinctions create a basis for examining learning that a single creativity-and-innovation score would otherwise hide.

The separation between creativity and innovation also has a precedent outside schooling. Amabile and Pratt (2016) distinguish creative processes from organisational innovation within a dynamic model that attends to motivation and work environments. However, a school pupil does not occupy the decision-making position of an organisation implementing new products or procedures. It would be conceptually inappropriate to transfer organisational criteria of successful market or procedural adoption unchanged to adolescent science education. EWIA therefore treats enacted innovation as one possible outcome while recognising that warranted explanation, revision or responsible refusal may constitute a substantial educational achievement without institutional implementation.

The model also differs from a simple ladder by allowing recursive pathways and failure points. A case might expose a misconception that sends learners back to problem framing; a local constraint might require new ideas; feedback from a community interlocutor might reveal a communication barrier. Such reversals are not inefficient deviations from creativity. They constitute disciplined scientific work. Nevertheless, the model may be overly demanding for some age groups or curricula; its explanatory usefulness rather than its visual completeness must be tested.

A comparative reading clarifies the level at which EWIA seeks to contribute. The OECD framework already includes evaluation and improvement, and scientific argumentation already makes evidence and justification central to inquiry. EWIA should therefore not be credited with discovering evaluation, evidence or contextual learning. Its proposed contribution is the integrated account of decision boundaries among these established constructs, including situations in which a novel idea must be revised, tested further or not enacted.

Table 2. Established approaches and the specific problem EWIA seeks to address.

Related approach	What it already explains	What EWIA examines further
OECD creative thinking (2023, 2024)	Generate diverse or creative ideas; evaluate and improve ideas	What warrants a scientifically defensible recommendation in resource-constrained classrooms?
Hu and Adey (2002); Xu et al. (2025)	Assess scientific originality and multidimensional creative performance	How distinguish novelty scores from evidence-based decisions and feasible action?
Science argumentation (Berland & Reiser, 2009; Osborne et al., 2004)	Connect claims, evidence, explanation and disciplinary discourse	How can diverging possibilities be brought into argument and refined without prematurely foreclosing creativity?
Funds of knowledge and multilingual science (Moll et al., 1992; Charamba, 2023)	Recognise community resources and multilingual participation in learning	Whose scientific questions and explanations become discussable and assessable?
Grounded opinion-forming and data-based explanation (Dauer et al., 2026; Novak & Treagust, 2026)	Explain how learners ground judgements and revise claims with evidence	How does idea generation connect with evidence, local feasibility and responsible action in ordinary school science?

This comparison also identifies a boundary of the proposed account. EWIA is not an alternative assessment of general creative ability, a comprehensive theory of knowledge, or a replacement for established inquiry pedagogy. It is an intermediate-level pedagogical explanation, specifying how teachers might make the transitions among ideational, evidentiary and practical judgments observable and revisable. Its value will depend on whether those distinctions predict or clarify classroom activity better than existing frameworks; no superiority is claimed in advance.

Two Classroom Examples from Junior Secondary Basic Science

Flood-Related Water Safety: Learning When Not to Overclaim

Consider a hypothetical four-lesson Basic Science sequence in a Nigerian junior secondary classroom investigating the question: 'What can and cannot be concluded about household

water safety after heavy rain?' The example is hypothetical; it does not describe observed pupils or a completed classroom intervention. It is chosen because it connects familiar environmental problems with basic ideas about mixtures, pollution, filtration, microorganisms and evidence, while raising genuine questions about safety. The aim is not to teach pupils to certify drinking water as safe with improvised experiments. Rather, it is to distinguish visible changes in water from claims that require testing beyond the classroom.
In the first lesson, learners share observations about water colour, storage and runoff. The teacher invites short notes or drawings and, where appropriate, oral discussion in familiar languages before establishing the scientific terms used in the lesson. Groups frame questions such as whether clear water is necessarily safe and what changes after rainfall. A short case depicts two fictional households drawing water from different sources. Pupils identify which details are observations, which are assumptions and what facts are missing. The classroom output is a set of investigable questions rather than a verdict on household practices.

In the second lesson, pupils generate alternative explanations for changes in water appearance, including suspended soil, runoff and contamination from different sources. Each pupil first records independent ideas; groups then compare alternatives before a whole-class synthesis. Ideas are provisionally grouped by mechanisms, not ranked by popularity. In the third lesson, learners examine teacher-prepared samples containing safe, non-hazardous suspended particles and compare what settling and a simple paper-filter demonstration can and cannot show. They learn that visible clarity and removal of sediment do not establish microbiological safety. The class records uncertainties and evaluates a fictional claim that clear-looking water must be safe to drink.
The fourth lesson is devoted to revision and communication. Each group produces an evidence map indicating which ideas were supported, which remain unresolved and what further measurements would be required. Pupils prepare a cautious information poster stating that visual inspection alone cannot establish drinking-water safety and that actual water treatment should follow locally applicable public-health guidance. The poster is evaluated for evidence, clarity, uncertainty and accessibility rather than novelty of design alone. A learner who retracts an unsafe recommendation after recognising missing evidence demonstrates scientific judgement, not failure to innovate.

This episode requires ordinary classroom materials and well-designed paper cases, but that does not make it universally transferable. Even a simple demonstration needs risk assessment and suitable access to water, containers and supervision. The teacher must avoid presenting a low-cost filtration activity as water disinfection. More generally, the example illustrates how an apparently local and modest inquiry can make the boundaries among creativity, scientific warrant, practical feasibility and public communication explicit.

Soil Erosion Around School Grounds: Comparing Explanations Fairly
A second, contrasting illustration concerns soil erosion along a footpath on school grounds. Instead of asking learners to name a universal solution, the teacher presents two photographs or sketches of contrasting surfaces after rainfall and asks which features might affect runoff and soil loss. The purpose is scientific explanation and fair comparison, not the claim that pupils have already solved a local environmental problem. Learners propose possibilities such as ground cover, slope, surface compaction and the direction of water flow; short

independent brainstorming precedes discussion so that early speakers do not dominate the range of suggestions.

The class then considers a short case in which a proposed planting solution fails on a steep, frequently walked slope. Pupils must distinguish a reasoned causal hypothesis from a plausible-sounding recommendation. Groups design small comparative tray models using locally available soil, sand, ground-cover materials and measured water poured under carefully controlled conditions. They identify variables that should remain similar, describe practical sources of error and record observations in sketches or simple tables. Such classroom models cannot reproduce all physical conditions of actual heavy rainfall, and any simulated differences should be presented as model evidence rather than definitive evidence about a particular school site.

At the adaptation stage, learners ask what could be inspected or communicated safely without excavating the school grounds, obstructing drainage or making unsupported promises. Their final product may be a labelled explanation, a revised tray design or a cautious recommendation for further observation after rainfall. EWIA treats a pupil who retracts an unsupported planting recommendation, explains a competing runoff mechanism and specifies what evidence is still needed as having demonstrated important scientific reasoning, even if no physical intervention follows.

The two examples test distinct affordances of the framework. The water-safety case requires explicit attention to uncertainty and non-action where microbiological safety cannot be inferred from appearance. The erosion case foregrounds fair comparison, scale limitations and feasible modelling. In both, creative possibilities are judged separately from warranted conclusions and responsible action. These illustrations are pedagogical constructions; they do not constitute field observations, trial results or validated lesson packages.

Assessing What Learners Have Actually Achieved

A teacher can praise a learner for producing an original idea while still asking for stronger evidence. The reverse is also true: a learner may produce few ideas but assess them carefully and explain an important limitation. Assessment should make room for both achievements. EWIA therefore proposes a profile of evidence, rather than treating creativity and innovation as a single undifferentiated score (Hu & Adey, 2002; Xu et al., 2025).

The proposed profile has five dimensions: (a) whether learners formulate a meaningful and investigable problem; (b) the range of alternatives they can propose; (c) the quality of the evidence and reasoning used to evaluate them; (d) attention to safety, resources and consequences; and (e) whether the final explanation or recommendation communicates both what is known and what remains uncertain. Table 3 illustrates possible descriptors. It is a starting point for designing assessments, not a validated scale. Future use would require piloting, agreement among scorers, and examination of linguistic and cultural fairness.

Dimension	**Emerging performance**	**Developing performance**	**Stronger performance**
Problem framing	States a topic without a researchable question	Poses a question with limited context	Poses a tractable question, identifies assumptions and relevant perspectives
Ideational range	Offers one familiar response	Offers more than one meaningfully different response	Generates alternatives reflecting distinct plausible mechanisms
Epistemic warrant	Asserts without support	Links some observations to a claim	Identifies evidence, alternative explanations, limitations and revision criteria
Situated feasibility	Ignores resources or safety	Names one practical constraint	Revises responsively while protecting safety and evidentiary adequacy
Accountable output	States certainty without basis	Communicates a recommendation with limited caveats	Clearly communicates verified, unverified and unsafe-to-infer conclusions

Table 3. Proposed analytic descriptors for classroom design and future assessment validation.

Scoring should not assume that all dimensions are interchangeable or equally weighted. In a classroom lesson centred on hypothesis generation, ideational diversity may legitimately receive greater instructional emphasis; in a public-health case, evidentiary limits and safety should be non-compensatory conditions. For example, an ingenious water-treatment proposal cannot earn a 'highly successful' overall rating if it inaccurately asserts microbiological safety. A two-stage judgement should first require minimum scientific and ethical adequacy, then assess additional originality and refinement within that boundary. A threshold model would record unsupported or unsafe proposals as requiring revision even where they are highly original. This proposal responds to the distinction between originality and appropriateness in creativity research (Runco & Jaeger, 2012) without simply duplicating existing creativity-test totals.

The point is not to make creative thinking subservient to measurement. Biesta (2009) warns that educational evaluation becomes impoverished when questions about the purposes of education are displaced by the availability of scores. For the present account, this implies that a rubric should make pedagogical judgements discussable, not create an impression that

originality, curiosity, agency or safety are fully captured by a five-column instrument. A teacher should be able to explain what the scoring descriptors leave out and revise an assessment task when it fails to recognise legitimate forms of scientific participation.

Cultural and linguistic validity also require attention. Evaluators should distinguish scientific reasoning from fluency in the language chosen for final reporting, and use translated or multimodal explanations where appropriate. Pupils' access to familiar examples can influence response quality; an instrument should therefore avoid awarding higher scores merely for familiarity with middle-class technologies. Empirical development would require cognitive interviews, scoring moderation, inter-rater agreement, subgroup fairness analyses and examination of whether the dimensions function coherently across classrooms. The present paper does not supply such data and makes no reliability or validity claims for the proposed rubric.

For a future instrument, assessment instructions should differentiate an original-but-untested possibility from a scientifically supported claim and from an action actually implemented. Raters should be required to cite observable features of a learner response rather than infer motivation or creativity from fluent English or technological sophistication. A pilot validation study could compare rubric decisions against separately scored argumentation tasks and existing scientific-creativity measures, assess inter-rater agreement, and test whether the proposed epistemic and feasibility judgments contribute information beyond established originality scores.

Five propositions for future research

The framework is useful only if it generates claims that could be scrutinised or falsified. The following propositions concern expected learning processes and boundary conditions. They are not empirical results, and their strength should be adjudicated through appropriate research design rather than authority of theoretical derivation.

P1. When learners first generate alternatives independently and subsequently compare them in groups, the participation and diversity of scientific ideas will be greater than under immediate whole-class oral brainstorming, provided tasks are comprehensible and adequate discussion time is available.

P2. Adding explicit evidence-testing prompts to idea-generation activities will improve the quality of scientific warrants and recognition of uncertainty more consistently than idea-generation activities alone, without necessarily increasing the number of ideas generated.

P3. Case-based tasks incorporating realistic and ethically relevant constraints will elicit more defensible adaptation of proposed solutions than otherwise similar decontextualised tasks, when the added case complexity remains developmentally manageable.

P4. Opportunities to formulate early explanations using familiar languages and representations, followed by explicit science-language bridging, will broaden access to epistemic participation without lowering warrant quality, where teachers can responsibly support such exchanges.

P5. Assessment that distinguishes originality, warrant, feasibility and communication will reveal profiles of learning that a single creativity-innovation composite score conceals, including cases of responsible non-action after evidentiary review.

A first research programme could compare three classroom routines within the same curriculum topics: brainstorming alone; case-based evaluation alone; and an integrated routine including individual idea generation, case interrogation and explicit evidentiary revision. Such a study would need multiple classrooms per condition, comparable teachers or teacher-crossed implementation, pre-specified outcomes and an analysis sensitive to clustering. It should avoid repeating the well-known problem of treating one school as each experimental arm. The predicted outcome is not simply that the integrated routine yields the highest total score, but that it particularly improves the epistemic and feasibility dimensions while preserving a meaningful range of alternatives.

A second programme could focus on assessment validation. Researchers could develop culturally relevant tasks in several science domains, independently score products using the proposed rubric, conduct think-aloud or interview studies about how pupils interpret the tasks, and examine whether originality and scientific warrant form empirically separable dimensions. Existing approaches, including Hu and Adey (2002) and Xu et al. (2025), offer useful comparators. The strongest test would investigate predictive or explanatory value: does a profile of warranted idea adaptation forecast later inquiry performance better than fluency scores alone? The answer cannot be assumed.

A third strand would investigate classroom discourse and contextual justice. Video-supported studies could examine which ideas are taken up, which are ignored, how vernacular and formal language mediate evidence, and whether resource scarcity changes the kinds of claims pupils are invited to make. Rather than romanticising constraint, such studies should distinguish adaptation that improves agency from deprivation that truncates inquiry. Comparative studies across rural, peri-urban and urban contexts could examine boundary conditions, but only if classroom comparability and local ethical expectations are adequately addressed.

Implications For Teaching, Curriculum and Policy

For teachers, the practical message is to keep the lesson going after pupils have generated ideas. Set aside time to compare explanations, ask what evidence would change a conclusion, and give learners opportunities to revise what they first proposed. These activities need not rely on elaborate technology. A carefully written case, a sketch, a safe demonstration and a discussion of competing explanations can provide rich opportunities for inquiry. A teacher might explicitly ask: Which idea is interesting? Which is supported? Which could we test safely? What can we responsibly tell someone else?

Curriculum writers can make those distinctions visible in learning tasks and assessment criteria. A pupil should be rewarded not only for offering an imaginative response but also for recognising a faulty assumption or revising a proposal after considering evidence. This is not an argument for weakening disciplinary content. Knowledge of scientific mechanisms is what makes the evaluation of unusual suggestions possible (National Research Council, 2012). For school leaders and policymakers, creative science teaching requires more than a call for "student-centred" methods or an occasional supply of digital devices. Teachers need time to guide discussion, examples that connect with learners' experiences, materials for safe investigation and professional support in judging scientific explanations. A multilingual classroom also needs participation norms that allow students to develop an idea in a familiar

language while learning to express its scientific reasoning in the required instructional language. These conditions are educational responsibilities, not problems that individual teachers can always solve through ingenuity.

Limits Of the Framework and Conclusion

EWIA remains a conceptual proposal. Its functions may overlap in practice, and separating them too rigidly could make lessons cumbersome. Some topics are better taught through direct explanation or carefully guided practice, especially when the knowledge is well established or safety is at stake. There may also be tension between encouraging pupils' questions and completing a prescribed syllabus. These are reasons to test and adapt the framework, not to assume that it will fit every classroom.

The central claim is modest but consequential: doing creative science involves more than producing an unusual answer. Learners also need to examine what could make that answer credible, decide what can be done safely with available resources and communicate the limits of their conclusions. A student who changes an explanation after seeing contrary evidence has learned something important, even if no invention results. By making those outcomes distinct and connecting them to classroom decisions, EWIA offers a framework that can be used critically, improved through research and judged against alternatives.

Data Availability and Research Ethics

No new human-participant data were collected or analysed for this conceptual article. The classroom examples and the EWIA framework are proposed for discussion and future testing; they should not be interpreted as field-tested interventions. Consequently, no research dataset or participant-specific ethics approval is associated with this manuscript.

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