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EDITED BY

Minela Kerla,
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Herzegovina

REVIEWED BY

Leonidas Gavrilas,
University of Ioannina, Greece
Rania Bou Saad,
Universitat Politècnica de Catalunya,
Spain

*CORRESPONDENCE

Julián Roa González
✉ julian.roa@udima.es

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Toward a disruptive neuroepistemological pedagogy: a conceptual framework for STEM education

Julián Roa González*, Celia Ortega-Gómez,
Coral González-García and José Luis Díaz Palencia

Department of Mathematics and Education, Universidad a Distancia de Madrid (UDIMA), Madrid, Spain

This article proposes Disruptive Neuroepistemological Pedagogy (DNEP) as a conceptual and design-oriented framework for STEM education. The central claim is that some STEM concepts should not be taught only as stable curricular content, but as products of scientific disruption: they emerged because previous explanations became insufficient, because anomalies required new models, or because their use transformed society. DNEP integrates three dimensions: epistemological disruption, neuroeducational meaningfulness, and ethical-social responsibility. Its novelty does not lie in adding neuroscience, epistemology, or critical pedagogy as independent domains, but in coordinating them around disruptive STEM concepts that require conceptual revision, model-based reasoning, and responsible use. The article follows a conceptual and integrative review methodology. It defines the research gap, presents the core principles of DNEP, specifies design criteria, proposes a partial instructional model, and identifies boundary conditions for implementation. The framework is positioned against behaviorism, cognitivism, constructivism, holistic-humanistic education, and STE(A)M through an analytical comparison focused on learning, disruption, emotion, curriculum, teacher mediation, inquiry, and assessment. The article concludes that DNEP can contribute to STEM education by helping students understand why scientific ideas change, how such change can be learned meaningfully, and why scientific knowledge requires ethical and social responsibility.

KEYWORDS

conceptual change, critical pedagogy, epistemology of science, model-based reasoning, neuroeducation, scientific disruption, stem education

1 Introduction

STEM education often presents scientific knowledge as a stable body of concepts, procedures, and applications. This organization is useful for curricular clarity, but it can hide an essential feature of science: scientific knowledge changes when existing explanations fail, when anomalies appear, when new models become necessary, or when social and technological conditions create new questions. Science is not only cumulative. It is also disruptive.

The history of science provides clear examples. The replacement of geocentric cosmology by heliocentric and later gravitational models, the emergence of evolutionary theory, the development of non-Euclidean geometries, the transition from classical to quantum physics, the rise of molecular genetics, and the use of mathematical models in epidemiology or climate science show that scientific knowledge advances through both

continuity and rupture. These changes are not only technical. They transform how human beings interpret nature, society, technology, and themselves.

This disruptive character of science has been widely discussed in philosophy of science. [Bachelard \(1938\)](#) introduced the idea of epistemological rupture to describe the break with previous intellectual obstacles. [Popper \(1959\)](#) emphasized falsifiability and criticism as central features of scientific progress. [Kuhn \(1970\)](#) showed that scientific revolutions involve changes in paradigms, methods, standards, and forms of explanation. [Lakatos \(1976\)](#) offered a complementary account through research programs, where theories progress or decline depending on their capacity to solve problems and respond to anomalies. [Feyerabend \(1975\)](#) questioned the existence of a single scientific method and emphasized epistemological pluralism.

However, the disruptive nature of science is not always placed at the center of STEM teaching. Students often learn the final form of scientific knowledge without examining why previous ideas became insufficient, how evidence challenged them, or why new models were introduced. As a result, science may appear as a closed system of answers instead of a dynamic process of questioning, modeling, testing, revision, and social use.

At the same time, educational neuroscience has shown that learning depends on attention, emotion, motivation, memory, and the active organization of knowledge ([Damasio, 1994](#); [Dehaene, 2010](#); [Immordino-Yang and Damasio, 2007](#); [Immordino-Yang et al., 2019](#); [Kandel, 2006](#); [Thomas et al., 2019](#)). These findings suggest that complex STEM learning cannot be reduced to exposure to information. Students need learning experiences that are meaningful, cognitively accessible, emotionally relevant, and connected with inquiry.

Critical pedagogy and socially responsible science education add a third requirement. Scientific knowledge is never socially neutral. It affects public health, technology, sustainability, artificial intelligence, environmental policy, and democratic decision-making ([Apple, 2013](#); [Freire, 1970](#); [Fuchs and Tan, 2022](#); [Giroux, 2010](#)). Therefore, STEM education should not only develop conceptual competence. It should also help students understand the ethical and social consequences of scientific knowledge.

This article proposes Disruptive Neuroepistemological Pedagogy (DNEP) to address this need. DNEP is a conceptual and design-oriented framework for STEM education. It is based on the following claim: STEM teaching becomes more educationally meaningful when disruptive scientific concepts are taught through the integration of epistemological analysis, neuroeducational learning conditions, and ethical-social reflection.

DNEP does not claim that neuroscience, epistemology, constructivism, inquiry-based learning, STE(A)M, or critical pedagogy are insufficient by themselves in all contexts. It makes a more specific claim. These approaches do not usually provide a single framework for selecting and teaching STEM concepts according to their disruptive epistemological structure, the neuroeducational conditions that support conceptual change, and the social responsibility linked to scientific knowledge. DNEP addresses this gap.

The article has four objectives. First, it defines the methodological basis of the conceptual review. Second, it establishes the research gap and the criteria of novelty. Third, it presents the core principles of DNEP as an enumerated theoretical framework. Fourth, it proposes a partial operationalization for classroom design and future empirical validation.

2 Methodology

This article follows a conceptual and integrative review methodology. It is not a systematic review or a meta-analysis. Its purpose is not to estimate the effect of a specific intervention, but to integrate theoretical and empirical contributions from different fields in order to construct a coherent pedagogical framework. This type of review is appropriate when the aim is to clarify concepts, reorganize fragmented bodies of literature, and propose a new theoretical structure ([Grant and Booth, 2009](#); [Snyder, 2019](#); [Torraco, 2005](#)).

The review was guided by the following question:

How can epistemology of science, neuroeducation, and critical pedagogy be integrated into a framework for STEM education centered on scientific disruption, meaningful learning, and social responsibility?

The search process combined database searches and backward citation tracking. The main databases consulted were Web of Science, Scopus, ERIC, PsycINFO, PubMed, and Google Scholar. These databases were selected because they cover education, psychology, neuroscience, philosophy of science, STEM education, and interdisciplinary research.

The search used combinations of the following terms: *neuroeducation*, *educational neuroscience*, *emotion and learning*, *motivation and learning*, *epistemology of science*, *scientific revolutions*, *epistemological rupture*, *conceptual change*, *model-based reasoning*, *critical pedagogy*, *socially responsible science education*, *STEM education*, *STEAM education*, *inquiry-based learning*, *transdisciplinary education*, and *scientific thinking*. Boolean combinations included: “neuroeducation” AND “STEM education”; “emotion” AND “science education”; “epistemology of science” AND “science education”; “conceptual change” AND “STEM”; and “critical pedagogy” AND “STEM.”

The inclusion criteria were: works directly related to epistemological disruption, neuroeducational learning conditions, or the ethical-social function of education; studies or theoretical works relevant to STEM education, science education, learning theory, or curriculum design; peer-reviewed articles, academic books, book chapters, and foundational theoretical works; recent studies when current empirical evidence was needed; and classical works when they were necessary to define concepts such as epistemological rupture, falsifiability, paradigm change, constructivism, cognitive load, or critical pedagogy.

The exclusion criteria were: works that used the search terms only tangentially; publications focused on generic innovation without relation to STEM, epistemology, neuroeducation, or social responsibility; non-academic sources; studies focused only on clinical neuroscience without educational relevance; and duplicated sources or works superseded by more complete publications.

The analysis followed three steps. First, the literature was grouped into six domains: epistemology of science, neuroeducation, critical pedagogy, cognitivism, constructivism, and STEM/STE(A)M education. Second, each domain was analyzed through a common set of categories: view of learning, role of emotion, treatment of scientific knowledge, teacher role, curriculum structure, inquiry, creativity, assessment, and social responsibility. Third, the synthesis was used to define the core principles and boundary conditions of DNEP.

This methodology has limits. It does not include a PRISMA flow diagram, formal risk-of-bias assessment, or quantitative synthesis. These procedures are more appropriate for systematic reviews and meta-analyses ([Page et al., 2021](#)). However, the review makes explicit

its search domains, inclusion criteria, exclusion criteria, and analytical categories in order to improve transparency and conceptual rigor.

3 Research gap and criteria of novelty

Several educational approaches already contribute to STEM education. The novelty of DNEP must therefore be defined carefully. It is not enough to say that DNEP combines neuroscience, epistemology, and pedagogy. A framework is only useful if it solves a specific theoretical and practical problem.

Educational neuroscience has clarified the role of attention, emotion, motivation, memory, and brain plasticity in learning (Immordino-Yang et al., 2019; Thomas et al., 2019). Its main contribution is to explain how learning occurs and how educational environments can support it. However, educational neuroscience does not usually place the disruptive structure of scientific knowledge at the center of curriculum design. It does not usually ask which concepts should be selected because they changed the structure of a scientific field, challenged previous assumptions, or transformed social practice.

Constructivism and sociocultural theory have shown that students actively construct meaning through interaction, mediation, prior knowledge, and conceptual reorganization (Bruner, 1966; Piaget, 1952; Vygotsky, 1978). These contributions are essential. However, constructivist approaches often treat conceptual change mainly as a psychological or instructional process. DNEP connects conceptual change with the historical and epistemological dynamics of science: anomaly, rupture, model replacement, and paradigm transformation (Kuhn, 1970; Posner et al., 1982).

STE(A)M education promotes creativity, interdisciplinarity, design, and the integration of artistic practices into scientific-technological education (Bequette and Bequette, 2012; Henriksen, 2014; Land, 2013; Quigley and Herro, 2016). These contributions are valuable, but STE(A)M does not necessarily explain how scientific knowledge changes through rupture, why some concepts reorganize a field, or how students can be guided to understand this process.

Critical pedagogy and socially responsible science education emphasize the ethical, civic, political, and social dimensions of education (Freire, 1970; Fuchs and Tan, 2022; Giroux, 2010). These perspectives are central because STEM education cannot be reduced to technical competence. However, they do not always include a neurocognitive account of how students learn complex scientific ideas or how emotion, attention, and memory support conceptual revision.

The research gap is therefore the lack of a framework that links three elements in a precise way: the disruptive structure of scientific concepts, the neuroeducational conditions that support their learning, and the ethical-social responsibility linked to their use.

DNEP addresses this gap by proposing that some STEM concepts should be taught as disruptive epistemic objects. A disruptive epistemic object is a scientific concept, model, theory, or procedure that meets at least one of the following criteria:

1. It emerged because a previous explanation became insufficient.
2. It reorganized a field of knowledge.
3. It required a change in assumptions, methods, or models.
4. It created new forms of prediction, explanation, or intervention.
5. It generated relevant social, technological, ethical, or environmental consequences.

The novelty of DNEP is therefore not additive. It does not place existing theories side by side. It defines a specific pedagogical object and a design logic: teach disruptive STEM concepts through epistemological clarification, neuroeducational meaningfulness, inquiry, and ethical-social reflection.

4 Core principles of DNEP

DNEP is organized around eight principles. These principles define the theory and separate it from a general synthesis of educational approaches.

4.1 Principle 1: disruption is the starting point of curriculum selection

DNEP begins with the selection of a scientific concept that has disruptive value. The question is not only “Is this concept included in the curriculum?” but also “What previous explanation did this concept challenge?” and “What new form of understanding did it make possible?”

This principle places epistemology at the beginning of didactic design. A DNEP-based lesson does not start from the final concept. It starts from the problem that made the concept necessary. This is connected with Bachelard’s (1938) notion of epistemological rupture, Kuhn’s (1970) account of paradigm change, and Lakatos’ (1976) analysis of research programs.

For example, exponential growth should not be presented only as a formula. It should be introduced as a model that breaks with linear intuition. Climate modeling should not be presented only as data analysis. It should be introduced as a way of reasoning about complex systems, uncertainty, and future scenarios. Artificial intelligence should not be presented only as a technological tool. It should be introduced as a system that modifies decision-making, evidence, bias, responsibility, and human-machine relations.

4.2 Principle 2: learning begins with a controlled epistemic tension

DNEP uses disruption pedagogically through epistemic tension. Epistemic tension appears when students realize that their initial explanation is incomplete, unstable, or insufficient. This tension should be controlled. It must be clear enough to generate inquiry, but not so difficult that it blocks understanding.

This principle is related to conceptual change research, which shows that learning often requires students to confront the limits of prior conceptions (Posner et al., 1982). However, DNEP gives this process an epistemological orientation. The aim is not only to correct misconceptions. The aim is to help students understand why scientific explanations change.

A DNEP task should therefore begin with a problem, anomaly, historical episode, dataset, simulation, experiment, or social dilemma that reveals the limits of an initial model.

4.3 Principle 3: scientific concepts are taught as models with conditions and limits

DNEP treats STEM concepts as models or model-related structures. A model is not a copy of reality. It is a structured

representation that explains, predicts, simplifies, and guides action under certain assumptions.

This principle is important because many students learn formulas and definitions without understanding the conditions under which they are valid. DNEP requires students to identify what a model explains, what it does not explain, which assumptions it uses, and when it must be revised.

This is the pedagogical expression of the disruptive character of science. Scientific knowledge is powerful because it explains, but it remains revisable because each explanation has a domain of validity (Popper, 1959; Kuhn, 1970; Lakatos, 1976).

4.4 Principle 4: emotion is treated as epistemic relevance, not as decoration

DNEP does not use emotion as entertainment. Emotion is relevant when it helps students perceive that a problem matters. A task becomes emotionally meaningful when students see that it affects understanding, decision-making, identity, health, technology, environment, or society.

This principle is grounded in neuroeducational research showing that emotion, cognition, and decision-making are closely connected (Damasio, 1994; Immordino-Yang and Damasio, 2007; Immordino-Yang et al., 2019). It is also consistent with research showing that attention and memory are strengthened when learning is meaningful and relevant (Dehaene, 2010; Kandel, 2006).

In DNEP, emotional relevance does not reduce conceptual rigor. It supports it. Students engage more deeply when they understand why the concept is necessary and what consequences it has.

4.5 Principle 5: inquiry is organized around explanation, not activity alone

DNEP uses inquiry, but not as a generic active methodology. Inquiry must be organized around the construction, comparison, and revision of explanations. Students should formulate hypotheses, examine evidence, compare models, and justify conclusions.

This principle is connected with Dewey's (1916) idea of learning through inquiry and experience, Bruner's (1966) view of discovery and representation, and contemporary research on educational neuroscience and learning (Thomas et al., 2019). However, DNEP adds a specific criterion: inquiry must make scientific disruption visible.

An activity is not DNEP-based only because it is active. It becomes DNEP-based when it helps students understand why one explanation fails and why another becomes necessary.

4.6 Principle 6: the teacher is an epistemic mediator

In DNEP, the teacher is not only a transmitter of information or a facilitator of activity. The teacher is an epistemic mediator. This means that the teacher helps students identify problems, assumptions, evidence, models, limits, and consequences.

The teacher's role includes five actions: selecting a disruptive concept, creating epistemic tension, guiding inquiry, making the epistemological change explicit, and connecting the concept with ethical-social responsibility.

This role is compatible with sociocultural views of mediation (Vygotsky, 1978) and with critical pedagogy's view of education as a

practice linked to social meaning (Freire, 1970; Giroux, 2010). However, DNEP specifies this mediation in relation to the structure of scientific knowledge.

4.7 Principle 7: assessment includes conceptual, epistemological, and social understanding

DNEP assessment cannot evaluate only whether students reproduce the final concept. It should also evaluate whether they understand why the concept was needed, how it changed previous explanations, what assumptions it uses, and what consequences follow from its use.

Assessment should therefore include four dimensions:

1. Scientific accuracy.
2. Explanation of conceptual change.
3. Recognition of model assumptions and limits.
4. Ethical-social reflection.

This is consistent with formative assessment and feedback-oriented approaches (de la Nieves Vega, 2022), with metacognitive regulation in collaborative learning (Järvenoja et al., 2020), and with the need to connect performance with understanding rather than only measurement (Biesta, 2009).

4.8 Principle 8: DNEP has boundary conditions

DNEP is not appropriate for every lesson. It is most useful when the STEM concept has epistemological depth, conceptual difficulty, historical relevance, or social consequences. It is less necessary for routine practice, procedural fluency, or introductory technical skills.

This boundary condition is important. Without it, DNEP would become too broad and vague. DNEP should be used where disruption matters.

5 The DNEP instructional model

The principles above can be translated into a six-phase instructional model. This model is not a rigid protocol. It is a design structure for STEM learning sequences.

5.1 Phase 1: identify the disruptive concept

The teacher selects a STEM concept that has disruptive value. The teacher defines the initial explanation, the limitation of that explanation, and the model or concept that gives a better account.

For example, in exponential growth, the initial explanation is linear intuition. The limitation is the inability to explain rapid increase. The new model is exponential growth.

5.2 Phase 2: create epistemic tension

Students encounter a problem that makes the initial explanation insufficient. This may be done through a case, dataset, historical episode, simulation, experiment, or dilemma.

For example, students may be asked why a small number of infections can become a large outbreak in a short time. Their linear intuition will usually underestimate the result.

5.3 Phase 3: guide inquiry and model construction

Students work with evidence, data, representations, or simplified models. They compare explanations and identify which model explains the phenomenon better.

The teacher does not give the final answer too early. Instead, the teacher guides students toward the need for a new explanatory structure.

5.4 Phase 4: make the epistemological change explicit

The teacher and students name the change in reasoning. They identify the previous assumption, why it was insufficient, what the new model explains, and what limits remain.

This phase is essential. Without it, the activity may become only problem-solving. With it, students understand the nature of scientific knowledge.

5.5 Phase 5: connect the concept with ethical-social responsibility

Students examine how the concept affects real decisions, technologies, institutions, or communities. The social reflection must be linked to the concept, not added as a general moral discussion.

For example, epidemic modeling raises questions about public health, uncertainty, communication, political decision-making, and responsibility.

5.6 Phase 6: assess integrated understanding

The final assessment asks students to explain the concept, the change in reasoning, the limits of the model, and its social consequences. The assessment should be short, concrete, and aligned with the sequence.

6 Example: exponential growth and epidemic modeling

A DNEP-based lesson on exponential growth can be structured as follows.

The teacher begins with a concrete situation. A disease appears in a small population. At first, there are only two infected people. Each infected person infects two more people in the next period. Students are asked whether the situation will remain manageable for several days.

Most students predict slow growth. The teacher then asks them to calculate the number of cases after each period. Students compare two scenarios. In the first, the number of cases increases by adding a fixed number. In the second, each infected person infects two more people. Students observe that the second process grows much faster.

The epistemic tension is now visible. Linear reasoning is not enough. Students need a new model.

The teacher guides the inquiry with precise questions. What pattern appears? Why does addition fail to explain the second process? What changes when growth depends on the current number? What does the exponential model explain? What does it leave out?

Students then formulate the concept of exponential growth. They see that the model explains a process in which the rate of increase depends on the current quantity. The teacher then makes the epistemological point explicit: scientific models are introduced when previous explanations fail to account for a phenomenon. The exponential model explains the early phase of certain processes, but it has limits. Real epidemics also involve immunity, behavior change, vaccination, policy decisions, limited contacts, and uncertainty. At this point, the teacher may briefly situate exponential growth in its historical context by referring to [Malthus' \(1798\)](#) analysis of population growth, where the idea that a quantity may increase geometrically rather than arithmetically introduced a disruptive way of understanding demographic pressure, scarcity, and the limits of linear intuition.

The ethical-social reflection follows directly from the model. Students discuss why exponential growth is difficult to communicate, why early decisions matter, and why models can guide public health policy without being perfect. They also discuss the responsibility of scientists, governments, media, and citizens when predictions involve uncertainty.

The assessment asks students to write a short response with four parts: explain the difference between linear and exponential growth; explain why the linear model was insufficient; identify one limit of the exponential model; and explain how this model can support responsible public decision-making.

This example shows the core of DNEP. The lesson does not teach only a formula. It teaches why a concept becomes necessary, how it changes understanding, why it remains limited, and how it affects social action.

7 Analytical positioning of DNEP

The previous sections define DNEP positively. This section positions it against existing educational approaches. The aim is not to describe each tradition in detail, but to clarify what DNEP integrates and what it adds.

The comparison uses five criteria: view of learning, role of disruption, role of emotion, curriculum logic, and assessment.

7.1 Behaviorism

Behaviorism understands learning as a change in behavior produced by stimulus–response associations and reinforcement ([Pavlov, 1927](#); [Skinner, 1953](#); [Thorndike, 1913](#)). Its strength lies in clarifying objectives, observable performance, reinforcement, and structured practice.

DNEP differs from behaviorism in its view of learning. Learning is not defined mainly as behavioral change. It is defined as the construction and revision of explanations. Students are not only responders to stimuli. They are participants in the interpretation of evidence, the comparison of models, and the reconstruction of meaning.

Behaviorism gives limited attention to scientific disruption. It can support practice and reinforcement, but it does not explain how students understand anomaly, rupture, model change, or the historical transformation of scientific knowledge. DNEP places these elements at the center of STEM learning.

Assessment also differs. Behaviorist assessment usually focuses on observable performance and specific objectives (Skinner, 1953). DNEP includes observable performance, but also requires assessment of conceptual change, model limits, epistemological reasoning, and ethical-social reflection.

7.2 Cognitivism

Cognitivism understands learning through attention, memory, information processing, schemas, and problem-solving (Anderson, 1983; Miller, 1956; Neisser, 1967). It has made important contributions to instructional design, including the organization of content, cognitive load, and meaningful learning (Ausubel, 1968; Mayer, 2002; Sweller, 1988).

DNEP integrates these contributions but does not reduce STEM learning to information processing. Cognitive organization is necessary, but it is not sufficient. Students also need to understand why a scientific concept became necessary, how it changed a previous explanation, and what social consequences it has.

The difference lies in the role of disruption. Cognitivism may address conceptual change, but DNEP makes disruptive scientific change the organizing principle of selected STEM learning sequences. In this sense, DNEP uses cognitive structure to support epistemological understanding.

7.3 Constructivism

Constructivism understands knowledge as actively constructed through assimilation, accommodation, interaction, and mediation (Bruner, 1966; Piaget, 1952; Vygotsky, 1978). DNEP shares this active view of learning.

The difference is that DNEP gives conceptual change a stronger epistemological orientation. Constructivism explains how students reorganize prior knowledge. DNEP asks why some scientific concepts reorganized a field of knowledge and how students can understand that transformation.

DNEP therefore integrates constructivist meaning-making with the history and philosophy of science. It also connects learning with emotion, motivation, and social responsibility (Damasio, 1994; Immordino-Yang et al., 2019; Freire, 1970; Fuchs and Tan, 2022).

7.4 Holistic-humanistic education

Holistic-humanistic education emphasizes the development of the whole person, including cognitive, emotional, social, physical, and spiritual dimensions (Maslow, 1970; Miller, 1996; Rogers, 1969). DNEP shares the concern for the whole learner and the rejection of purely technical education.

The difference is focus. Holistic-humanistic education often emphasizes personal development, meaning, trust, and self-actualization. DNEP focuses specifically on STEM concepts whose scientific and social meaning involves disruption. It does not place spirituality at the center of its framework. It places epistemological rupture, neuroeducational relevance, and ethical-social responsibility at the center of STEM design.

7.5 STE(A)M

STE(A)M connects Science, Technology, Engineering, Arts, and Mathematics in order to promote creativity, interdisciplinarity, design, and problem-solving (Bequette and Bequette, 2012; Henriksen, 2014; Land, 2013; Quigley and Herro, 2016). DNEP shares its interest in interdisciplinarity and creativity.

The difference is that DNEP defines creativity mainly as conceptual and epistemological revision. STE(A)M often emphasizes design, artistic integration, and creative production. DNEP emphasizes the capacity to question assumptions, identify model limits, and reformulate explanations. In this sense, creativity is not only expressive or productive. It is also epistemic.

8 Discussion

DNEP can be understood as a framework for teaching STEM concepts that have disruptive value. This is its main theoretical contribution. It does not aim to be a general theory of all learning. It does not replace existing educational traditions. It defines a specific problem: how to teach scientific concepts whose meaning depends on rupture, anomaly, model revision, or social impact.

This definition allows the framework to generate design criteria. A DNEP-based sequence should begin with a disruptive concept, create epistemic tension, guide inquiry, clarify the change in explanation, connect the concept with social responsibility, and assess integrated understanding. These criteria make the theory more operational and reduce the risk of presenting DNEP as a general synthesis without practical direction.

The framework also generates testable propositions for future research.

First, students who learn disruptive STEM concepts through epistemic tension and explicit model comparison may show stronger conceptual understanding than students who only receive final explanations.

Second, students who receive explicit epistemological clarification may better understand the nature of scientific knowledge, including revision, uncertainty, and model limits.

Third, students who connect STEM concepts with ethical-social consequences may develop stronger awareness of the social responsibility of science.

Fourth, emotionally meaningful problems may improve attention, engagement, and memory when they are linked to conceptual rigor rather than used as external motivation.

Fifth, DNEP-based assessment may capture dimensions of learning that standard content tests do not capture, such as model awareness, epistemological reasoning, and responsible use of knowledge.

These propositions should be examined through empirical studies. Possible designs include classroom-based interventions, quasi-experimental studies, design-based research, mixed-methods studies, and comparative analysis of student explanations before and after instruction.

DNEP also has limits. It requires teachers to understand the scientific content, its epistemological structure, common student intuitions, and social implications. It requires time for inquiry and reflection. It is not necessary for every STEM lesson. It should be used in units where conceptual disruption, modeling, and social responsibility are relevant.

These limits are not weaknesses if they are clearly stated. They define the boundary conditions of the framework and prevent overgeneralization.

9 Conclusion

This article has proposed DNEP as a conceptual and design-oriented framework for STEM education. Its central claim is that some STEM concepts should be taught as disruptive epistemic objects. These concepts matter because they changed previous explanations, introduced new models, generated controversy, or affected society.

The article has clarified the research gap. Existing approaches provide important contributions, but they do not usually coordinate epistemological disruption, neuroeducational meaningfulness, and ethical-social responsibility around the selection and teaching of disruptive STEM concepts. DNEP responds to this gap.

The article has also defined eight core principles: disruption as a criterion for curriculum selection; epistemic tension as the beginning of learning; scientific concepts as models with limits; emotion as epistemic relevance; inquiry as explanation-building; the teacher as epistemic mediator; assessment as conceptual, epistemological, and social understanding; and boundary conditions for use.

A partial instructional model has been proposed. It includes six phases: selection of the disruptive concept, creation of epistemic tension, guided inquiry, epistemological clarification, ethical-social reflection, and integrated assessment. The example of exponential growth and epidemic modeling shows how the framework can be applied without becoming a rigid method.

DNEP remains a conceptual framework and requires empirical validation. Future research should test its effects on conceptual understanding, model-based reasoning, motivation, epistemological understanding, and ethical-social awareness. Research should also develop assessment instruments and examine how the framework works across different STEM disciplines and educational levels.

The final aim of DNEP is to help students understand science as a human, revisable, disruptive, and socially consequential activity. STEM education should not only teach what science knows. It should also teach why scientific knowledge changes, how that change can be understood, and how such knowledge should be used responsibly.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

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Author contributions

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