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Rebuilding Scientific Thinking at School: A Critical Epistemological Reading of Inquiry-Based Learning

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The Laboratory of the Educational Issue in Algeria in Light of the Current Challenges

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Abstract:
This study examines the conceptual relationship between scientific thinking and inquiry-based learning in science education, in light of the widespread adoption of inquiry-oriented approaches as a means of developing learners' scientific thinking. However, despite this prevalence, the educational literature often presents the relationship between the two as a direct causal link without sufficiently analysing the epistemological and pedagogical foundations that make such integration feasible within the school context.
Against this background, the study aims to re-examine this relationship from a critical, conceptual, analytical perspective. It seeks to dismantle the simplifying assumptions that reduce inquiry to a set of classroom procedures, which are detached from the cognitive structure of scientific practice. It shows that reducing inquiry to procedural activities may weaken its capacity to support scientific thinking because it disconnects inquiry from the epistemic and argumentative dimensions that characterise the construction of scientific knowledge.
From this standpoint, the study argues that the relationship between scientific thinking and inquiry-based learning cannot be understood as a direct causal relationship, but rather as a conditional structural relationship involving a set of interrelated factors. Accordingly, the study proposes a conceptual framework that contextualises inquiry as a cognitive practice involving constructing scientific problems, formulating hypotheses, analysing evidence, engaging in scientific argumentation and practising epistemic reflection. This contributes to a more integrated theoretical understanding of the relationship between inquiry and scientific thinking in science education.

Keywords: Scientific thinking; inquiry-based learning; educational epistemology.

Introduction:
Advances in knowledge and technology have driven profound transformations in modern science education. This has prompted a rethink of the aims of science teaching, shifting the focus from knowledge transmission to developing learners' analytical, reasoning, problem-solving and evidence-based decision-making abilities. In this context, scientific thinking has become essential for enabling learners to engage with knowledge consciously and dynamically, and to actively participate in the construction of knowledge.
Inquiry-based learning is considered one of the most prominent pedagogical approaches as it provides learning environments that simulate scientific practice. This involves learners in asking questions, formulating hypotheses, collecting and analysing data, and constructing explanations. However, when implemented in schools, inquiry is often limited to procedural classroom activities that do not sufficiently address the nature of scientific knowledge or the pedagogical and epistemological conditions required to transform inquiry into an authentic cognitive practice.
Despite the widespread adoption of inquiry-based learning in science education, much of the literature still presents the link between it and the development of scientific thinking as a near self-evident relationship. According to this view, there is a

direct causal connection between practising inquiry and acquiring patterns of scientific thinking. However, this assumption obscures a deeper epistemological issue concerning the nature of scientific thinking itself: is it merely the product of a process, or is it a form of knowledge production influenced by particular normative and argumentative structures?

A critical reading of the literature reveals that inquiry is frequently reduced to a classroom technique or a sequence of procedures that is relatively detached from the epistemological conditions that characterise actual scientific practice. This creates a gap between theoretical discourse, which celebrates inquiry as an approach to developing scientific thinking, and classroom practice, which reproduces inquiry as a teaching activity that has been stripped of its cognitive dimensions.

This gives rise to the central problem of this study:

1. How can the relationship between scientific thinking and inquiry-based learning in science education be reframed so that it is understood as a conditional structural relationship grounded in epistemological and pedagogical factors rather than as a direct causal relationship?
2. What educational implications does this conceptual reframing have with respect to the representation of scientific knowledge and the organisation of teaching practices within the school context?

Importance of the study

This study challenges the common assumption that the use of inquiry has a direct causal relationship with the development of scientific thinking. Rather than treating inquiry as a sufficient pedagogical strategy in itself, this work proposes an epistemic-argumentative reading that contextualises the relationship between the two concepts as a form of structural co-implication, constituted within specific cognitive and normative conditions. By doing so, the study shifts the debate from the effectiveness of tools to the nature of scientific knowledge and how it is represented pedagogically. It also provides a conceptual framework through which science teaching design and assessment can be reconsidered.

Aim and scope (reframing within an epistemic-argumentative perspective)

This article seeks to reframe the relationship between scientific thinking and inquiry-based learning from an epistemic-argumentative perspective by interrogating the implicit assumptions that govern the use of inquiry in school settings. The aim is to dismantle the dominant instrumental interpretation and highlight the cognitive and normative nature of scientific thinking as a practice shaped by specific organisational conditions. Furthermore, it proposes an alternative theoretical framework that enables a more nuanced understanding of the relationship between scientific practice and its pedagogical representation, moving beyond approaches that reduce this relationship to its procedural aspect.

1. Scientific thinking: From a Procedural Skill to an Epistemic Practice

Scientific thinking is a central concept in contemporary science education due to its close connection with how learners engage with scientific knowledge in terms of both understanding and construction. However, an analysis of its representation in school curricula and a substantial body of educational literature reveals the continued dominance of the traditional view that frames scientific thinking as a set of discrete procedural skills. These skills include observation, classification, hypothesis formulation and inference.

This perspective has been linked in educational literature to the teaching of basic and integrated science process skills (Padilla, 1990). While the organisational value of this skills-based approach supports the design of classroom activities, subsequent studies in the field of scientific reasoning have demonstrated that scientific thinking cannot be reduced to the performance of these skills alone. Instead, it is based on a deeper cognitive structure involving patterns of justification, hypothesis testing, evaluating evidence and other epistemic processes (Lawson, 2004). Therefore, limiting scientific thinking to procedural skills reduces it to its technical dimension and overlooks its nature as an interpretive cognitive practice.

This procedural conception is also associated with a pedagogical logic that prioritises observable performance over an examination of the mental processes that imbue these procedures with scientific meaning. Consequently, teaching scientific thinking in many classroom practices becomes stereotyped training in applying specific steps within controlled school contexts. This approach does not enable learners to understand the underlying epistemic basis of these procedures or their relationship to the construction of scientific knowledge itself (Duschl, 2008). This approach produces a gap between learners possessing certain procedural skills and their ability to actually employ scientific thinking in new situations requiring interpretation, reasoning and evidence-based decision-making.

Contemporary interpretive frameworks call for treating scientific thinking as an integrated epistemic practice carried out within complex dialogical and cognitive contexts, in contrast to the procedural view that reduces scientific thinking to the performance of fixed methodological steps. From this perspective, scientific thinking involves engaging in a complex mental activity that includes formulating scientific questions with theoretical dimensions, interpreting data and evaluating evidence, linking evidence to possible explanations and balancing multiple explanatory alternatives in light of clear epistemic criteria, rather than being limited to following a stereotyped procedural sequence.

Research addressing the linguistic analysis and argumentative critique of scientific discourse supports this understanding. Such research indicates that scientific knowledge is constructed through interpretive and argumentative practices within a learning community, where learners interact with one another in meaningful contexts of scientific enquiry (Kelly, 2008). Furthermore, studies in the philosophy of science and the nature of scientific learning demonstrate that participating in the processes of generating and justifying knowledge is integral to the development of scientific thinking, rather than merely possessing separate technical skills (Ford, 2015). Accordingly, scientific thinking is viewed as an epistemic practice constituted and deepened through interaction, interpretation and systematic reflection rather than as a technical procedure taught and reproduced mechanically.

This understanding also has its origins in the constructivist perspective on learning. This perspective holds that scientific knowledge is not simply passed on, but is gradually constructed through the active interaction between learners and the phenomena they are studying. Within this framework, Piaget (1970) emphasises that cognitive development occurs through processes of assimilation and accommodation resulting from encounters with epistemic problems that destabilise existing structures. Similarly, Driver and his colleagues (1994) demonstrated that learning science in the classroom involves reconstructing scientific meanings through negotiation and shared interpretation rather than passive information reception.

Therefore, it can be argued that the failure to develop scientific thinking in schools, which is sometimes observed, is not primarily related to the absence of this goal in the official curriculum discourse. Rather, it stems from the continued treatment of scientific thinking in terms of procedural skills rather than recognising it as a complex epistemic practice requiring specific pedagogical and epistemological conditions. This highlights the need to develop educational frameworks that can operationalise this constructivist view of scientific thinking in schools — thereby paving the way for a discussion of inquiry-based learning as a possible framework.

2. Inquiry-Based Learning as a Model for Re-Representing Scientific Practice

Considered one of the central approaches that has reshaped science teaching in recent decades, inquiry-based learning has shifted the focus from knowledge transmission to epistemic practice and understanding. It is not merely a teaching strategy, but rather an approach grounded in an integrated pedagogical and epistemological perspective that redefines the nature of learning, the role of the learner and the status of scientific knowledge within the classroom.

2.1 Pedagogical Foundations of Inquiry

From a pedagogical standpoint, inquiry-based learning can be defined as an educational approach comprising a set of activities that help learners (i) acquire knowledge independently and (ii) familiarise themselves with the nature of science and its processes while developing research-related skills and adopting scientific attitudes (Asaad, 2017, p. 159). It also organises classroom experience according to the logic of scientific practice by involving learners in activities such as asking questions, formulating hypotheses, collecting evidence, analysing it and constructing explanations that are subject to discussion, justification and evaluation.

However, this similarity should not be understood as a literal simulation of a scientific laboratory, but rather as a pedagogical reconstruction of the practices involved in knowledge production within an organised school context. This reconstruction aims to deepen learning and give learners an active role in building knowledge instead of confining them to the passive reception of knowledge in its final form.

Moreover, in some cases, this approach has been misunderstood: it is assumed that inquiry-based learning requires the teacher's role to be minimised as much as possible. However, contemporary educational literature shows that the effectiveness of inquiry-based learning depends on the quality and extent of the accompanying pedagogical guidance. Hmelo-Silver et al. (2007), for example, argue that inquiry-based approaches are not based on unguided discovery. Instead, they rely on cognitive scaffolding that supports the organisation of thinking, directs attention towards relevant evidence and helps learners to progress from initial understanding to explanations that are more coherent and deeper without stripping inquiry of its exploratory nature.

Accordingly, the pedagogical dimension of inquiry-based learning does not rest on absolute autonomy. Rather, it involves reorganising the learning situation as a space for guided cognitive interaction, where scientific dialogue is managed, hypotheses are examined in light of evidence and meaning is constructed through disciplined processes of cognitive negotiation. In this sense, inquiry functions as an organising framework that translates the constructivist conception of scientific thinking into classroom practices that can be implemented effectively without losing their epistemic dimension, and not merely as a channel for transmitting content.

2.2 The Epistemological Foundations of Inquiry-Based Learning

Inquiry-based learning extends beyond its pedagogical dimension, reflecting a particular epistemological stance on the nature of scientific knowledge. From this perspective, knowledge is not viewed as a set of final, fixed truths that can be easily transmitted and reduced to the mere imparting of information to students. Instead, the objective is to foster students' capacity to engage in scientific reasoning, which is considered a fundamental human trait in the modern era (Atta Allah, 2001), as well as an interpretive process that evolves through successive stages. Accordingly, educational enquiry derives its legitimacy from this dynamic understanding of science as an open, revisable cognitive activity.

This view aligns with the constructivist approach to scientific knowledge, which asserts that learning science in the classroom does not solely occur through the assimilation of scientific knowledge outcomes. Rather, it occurs through learners engaging in processes of reconstructing concepts within social contexts in which cognitive and epistemological dimensions interact. In this framework, the classroom is not merely a space for transmitting facts, but a setting for reorganising experience and constructing scientific meaning.

Similarly, Duschl (2008) suggests that science teaching should not be confined to conveying concepts. Instead, it should integrate three interrelated components: scientific content; scientific practices; and an understanding of the nature of scientific knowledge itself. Inquiry-based learning is one of the few approaches capable of achieving this integration because it involves learners in epistemic practices that mirror the logic of producing scientific knowledge to some extent, rather than confining them to receiving finished knowledge.

Furthermore, an understanding of the nature of science cannot be developed through the direct teaching of epistemological concepts alone. Rather, it is achieved by embedding these ideas within authentic educational practices. Inquiry-based learning provides this possibility because it activates learners and creates instructional conditions that make scientific thinking a conscious practice, grounded in the nature of the knowledge produced.

Thus, as clarified above, inquiry-based learning is not merely a pedagogical option. It is a theoretical framework that combines an active educational approach with a modern epistemological view of scientific knowledge. Within this framework, learners engage in practices that develop their understanding of the nature of science and how knowledge is produced and validated, as well as learning scientific concepts.

3. Dynamics of Constructing Scientific Thinking within Inquiry Learning Environments

The construction of scientific thinking within educational environments does not occur automatically merely by adopting inquiry-based learning. Rather, it requires activating precise cognitive and pedagogical mechanisms that make inquiry an effective mediator for developing patterns of scientific thinking. The essential difference between inquiry that remains superficial and inquiry that genuinely produces scientific thinking does not lie in the nature of the activity itself, but in the quality of the mental processes that learners are prompted to carry out in the educational situation.

3.1 Constructing Scientific Problems and Formulating Questions

The ability to construct scientific problems and formulate questions is one of the fundamental pillars of scientific thinking. It enables students to identify, define and attempt to solve problems by relying on observation, experimentation and drawing their own conclusions (Sarhan, 2016, p. 27). Furthermore, scientific activity involves generating testable and verifiable questions, not just providing answers.

Effective inquiry-based learning environments therefore develop learners' movement from descriptive questions towards explanatory and procedural questions through gradual progression. This progression strengthens learners' ability to engage in causal reasoning and construct deep scientific explanations.

Additionally, enabling learners to propose and discuss new questions within a supportive educational environment fosters higher-order thinking skills and serves as a precise indicator of their level of scientific thinking. Open-ended questions support causal reasoning and enhance deep understanding of scientific phenomena. Thus, inquiry is not merely preparatory for experiments or observations, nor is it based on a predetermined problem. Rather, it is an integral epistemic practice reflecting the essence of scientific thinking, establishing a coherent approach to inquiry that links scientific activity with theoretical understanding and scientific explanation.

3.2 Hypothetical Thinking and Formulating Hypotheses

A scientific hypothesis is a key part of scientific thinking because it is an attempt to explain something that is based on observation and prior knowledge. Inquiry-based learning environments enable learners to practise this mode of thinking by proposing multiple interpretations of phenomena and testing how consistent these are with evidence and data.

Training learners to formulate hypotheses effectively develops inferential thinking and strengthens the ability to make logical connections between variables, moving beyond the mere superficial description of scientific phenomena. However, this development does not occur automatically. It requires conscious pedagogical guidance to clarify the difference between a scientific hypothesis supported by evidence, and uncontrolled speculation or personal assumptions not based on scientific methodology.

From an enquiry perspective, practising hypothesis formulation helps learners develop an awareness of the concept of science. They gain an understanding of how scientific knowledge is constructed, tested and revised in interactive contexts, enhancing their critical thinking and scientific reasoning abilities. Thus, inquiry-based learning becomes a practical framework for applying advanced scientific thinking skills rather than being limited to a narrow technical activity.

3.3 Evidence Analysis and Building Reasoning

Evidence analysis is considered one of the most important mechanisms for developing scientific thinking. It enables learners to distinguish between personal opinion and scientific data, as well as between interpretation and inference based on evidence. Inquiry-based learning environments provide a suitable context for developing this skill, involving learners in the process of collecting, organising and analysing data in light of the presented hypotheses, while encouraging critical discussion about whether the evidence is sufficient to support the conclusions.

Furthermore, scientific thinking is not merely developed by carrying out experiments, but rather by analysing the data and discussing how adequate the evidence is in supporting the conclusions reached. This strengthens learners' ability to evaluate and revise scientific inferences. Through this process, learners develop a coherent understanding of scientific knowledge by balancing evidence with possible explanations, and honing the critical and analytical thinking skills necessary for scientific research.

Furthermore, it can be argued that the systematic handling of evidence and data analysis is not merely a technical step in the educational process, but a key mechanism for integrating scientific culture into inquiry-based learning environments. It also integrates scientific thinking, combining understanding, critique, and inference within an interactive educational context.

3.4 Scientific debate and building interpretation

Debating practices are an essential element of scientific thinking. Scientific knowledge is formed through discussion and the exchange of evidence-based arguments, as well as the evaluation of different interpretations. Integrating scientific debate into inquiry-based learning environments can enhance learners' logical reasoning and critical thinking skills. This allows them to review their ideas and compare their conclusions with those of others.

Furthermore, encouraging learners to justify and defend their conclusions using evidence, as well as review counterarguments, helps them to develop a deeper understanding of the nature of science. It also improves their ability to critically evaluate alternative interpretations. Therefore, scientific debate should be viewed not as an additional skill, but as a central mechanism that enables learners to practise scientific thinking as an interactive, argumentative cognitive activity integrating inference, interpretation and critical evaluation of evidence within an engaging educational context.

3.5 Metacognition and Organising Scientific Thinking

Metacognition is an advanced approach to developing scientific thinking. Here, learners learn to monitor their thought processes, evaluate their strategies and recognise the limits of their knowledge. Inquiry-based learning environments that encourage cognitive reflection help to consolidate patterns of scientific thinking, making them transferable and applicable in new contexts.

Furthermore, integrating metacognitive thinking activities into inquiry-based learning promotes a shift from limited procedural performance to a deeper understanding of scientific phenomena. These activities also develop the ability to consciously and systematically regulate scientific thinking, thereby supporting the development of inference, interpretation, and critical judgement skills.

Thus, it is evident that developing scientific thinking within inquiry-based learning environments requires an integrated network of cognitive processes. These include problem construction, hypothesis formulation, evidence analysis, interpretation development, and reflection on thinking itself. This integration shows that, when activated within a deliberate pedagogical and epistemological framework, the role of inquiry is not limited to teaching procedural skills. Instead, it transforms scientific thinking from a limited school skill into an organised, critical and argumentative cognitive practice, enabling learners to engage with scientific knowledge consciously and independently.

4. The Paradoxes of Transferring Scientific Practice to the Classroom Context

Although inquiry-based learning is theoretically presented as a way of representing scientific practice in schools, when it is transferred to the classroom, structural paradoxes emerge that extend beyond mere procedural implementation. It is not only a question of whether the teacher follows the steps of the enquiry process, but also of the nature of the school system itself and the conceptual shifts that occur when ideas move from their epistemological field into their pedagogical context. As institutions with a specific organisational logic, schools do not simply adopt scientific practice 'as it is'; rather, they adapt it according to their internal constraints. This creates hidden tensions between theoretical discourse and the reality of teaching.

4.1 The Gap Between Epistemological Conception and Classroom Practice

The epistemological view of science is based on an open dynamic involving problems, hypotheses, debate, revision and the continuous reconstruction of knowledge. However, when this dynamic is translated into classroom practice, it is often reduced to a sequential series of almost standardised methodological steps. This creates the first paradox: while enquiry is assumed to develop scientific thinking as an epistemic practice, it can become a predetermined and tightly controlled school procedure.

Accordingly, the gap does not stem solely from poor implementation; rather, it arises from a difference in logic. One is the logic of knowledge, which tolerates uncertainty, hesitation and shifting lines of enquiry. The other is the logic of the classroom, which seeks control, clarity and expected outcomes. Consequently, scientific thinking in school is constrained within a stabilising framework, despite its original nature being based on openness and possibility.

4.2 Constraints of School Culture

Inquiry does not take place in isolation; it operates within a hierarchical, assessment-driven school culture centred on performance. This culture redefines the roles of participants: teachers become sources of control and regulation, while learners become those required to achieve. In this context, scientific debate or methodological doubt may be viewed not as epistemic mechanisms, but as signs of disorder or deviations from the 'lesson flow'.

Consequently, school culture produces a pattern of implicit expectations that limits the critical nature of enquiry and reintegrates it within a logic of compliance. Thus, transferring scientific practice confronts organisational obstacles as well as a cultural structure that reinterprets enquiry according to the values of stability, efficiency and rapid achievement.

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4.5 The Tension Between Autonomy and Guidance

Inquiry is based on the principle of learner autonomy when it comes to generating questions and formulating hypotheses. However, this autonomy is always subject to a guiding framework that ensures the educational path is followed. A subtle paradox emerges: the more guidance increases, the more the activity leans towards a procedural model, and the greater the risk of cognitive disorientation or superficiality becomes as guidance decreases.

Therefore, the issue is not simply a choice between freedom and control. Rather, it is about redefining their relationship. School autonomy is not absolute freedom; it is an organised practice that requires precise cognitive support in order to preserve the epistemic nature of the activity without it becoming disguised instruction

4.6 The Problem of Assessing Scientific Thinking

Assessment is one of the most sensitive aspects of transferring scientific practice. Scientific thinking, as a discursive and probabilistic process, cannot be reduced to a correct answer or a final result. Yet school assessment systems remain more focused on measuring outputs than evaluating processes. Often, students are evaluated through general school exams based on questions requiring lower-level cognitive skills, such as knowledge and understanding, with these being treated as the ultimate endpoints of the prescribed curriculum and the goals of education (Al-Maʿmar, 2006, p. 43). (Al-Maʿmar, 2006, p. 43).

This creates a structural paradox: learners are encouraged to practise doubt, hypothesising and revising, yet are then assessed according to criteria of stability, accuracy and specific expected achievement. Consequently, the absence of argumentative and analytical assessment tools redirects learners' behaviour towards searching for the 'expected answer' instead of engaging in genuine thinking processes.

4.7 The challenges of teacher professional training

These paradoxes are inextricably linked to the issue of teachers' professional training. Incorporating inquiry as an epistemic practice necessitates a transformation in teachers' conceptions of knowledge and their professional role. However, in many contexts, teacher training programmes focus more on teaching techniques than on addressing the knowledge structure of science itself.

Therefore, the challenge lies not only in providing teachers with strategies, but also in enabling them to develop a deep understanding of the nature of scientific thinking as an argumentative and reflective activity. Without this shift, inquiry remains vulnerable to being reduced within traditional teaching patterns, albeit cloaked in modern language.

Therefore, these paradoxes demonstrate that the issue of transferring scientific practice to schools is not only procedural, but also structural and linked to the divergence between two logics: the logic of enquiry and the logic of the institution. Thus, the real issue is not improving the implementation of enquiry itself, but questioning the conditions under which enquiry is formulated and reconstructed within the school system.

In this sense, scientific thinking in an educational context is the result of the interplay between the epistemological framework of science and the structure of the school, including all the associated cultural, organisational, temporal and assessment factors. Overcoming these paradoxes remains conditional upon reframing the relationship between enquiry and school — not because they are identical, but because they are two systems that continuously negotiate the limits of knowledge and its application

5. Moving Beyond the Instrumental Approach: Reframing the Relationship Between Inquiry and Scientific Thinking

The previous analysis of the paradoxes involved in transferring scientific practice to the school environment shows that the issue cannot be resolved by improving teaching techniques or refining the steps of the enquiry process. Instead, the conceptual framework governing how the relationship between inquiry and scientific thinking is understood must be reviewed. The instrumental approach, which views inquiry as a teaching strategy for activating specific skills, strips scientific thinking of its epistemic character, turning it into a procedural outcome that can be partially measured. Therefore, moving beyond this approach is not just a methodological option, but a theoretical necessity for rebuilding the entire system.

5.1 Reframing Inquiry as an Epistemic Practice

From this perspective, inquiry is not viewed as a set of steps or a motivational technique. Instead, it is considered an epistemic practice involved in creating meaning and constructing interpretation. The core lies not in the visible activity itself, but in the argumentative structure that organises the relationship between questions, evidence and interpretation.

Consequently, scientific thinking is not merely the result of inquiry; it is an integral part of it. When inquiry is reduced to a practical activity, it becomes separated from scientific thinking. However, when it is reframed as an epistemic practice, it becomes a space in which scientific thinking itself takes shape. This conceptual shift transforms their relationship from one of means and ends to one of structural interdependence.

5.2 The Centrality of Scientific Argumentation

If contemporary science is understood as a collective argumentative activity rather than a linear accumulation of facts, school-level scientific thinking cannot be developed independently of the logic of argumentation. The focus shifts from producing an answer to justifying, questioning and comparing it with alternative explanations. This is why scientific argumentation occupies a central position in the proposed reframing. It is the mechanism through which knowledge evolves from opinion to grounded interpretation. The more argumentation is integrated into the core of the enquiry process, the more learning shifts from a technical exercise to a critical, rational practice. Consequently, the absence of argumentation confines inquiry to the realm of mere activity, whereas its presence elevates it to a genuinely epistemic practice.

5.3 Balancing cognitive support and autonomy

Reframing inquiry does not mean removing the teacher's involvement entirely or granting complete autonomy. Scientific thinking does not develop in isolation; it grows within a directed cognitive structure. Therefore, the essence of cognitive support lies not in reducing guidance, but in redefining it. A study by Fayad (2022) emphasised the importance of guiding and supporting learners, which improves the quality of education and academic achievement. Similarly, Jong Valk's (2009) study showed that gradual teacher support helps learners acquire knowledge more effectively and encourages their active participation in the classroom.

In this framework, cognitive support does not involve guiding learners towards a 'correct' answer. Rather, it involves organising the thought process, broadening the scope of questioning and establishing the standards of reasoning. True autonomy does not mean the absence of structure, but rather the learner's ability to navigate that structure with critical awareness. Consequently, the relationship between teacher and learner is reframed as one of epistemic supervision, rather than one of intellectual authority.

5.4 Scientific Thinking in Light of Contemporary Epistemological Shifts

Contemporary epistemology has moved beyond rigid positivist views of science and emphasized its probabilistic, dialogical, and contextual nature. If science itself is now understood as a negotiated activity shaped through research communities, then school scientific thinking cannot remain confined to a linear experimental model.

Therefore, the proposed reframing is in line with this shift. It views scientific thinking as the ability to construct interpretations, evaluate evidence and participate in rational discussion. In this sense, inquiry becomes a space for representing the logic of contemporary science rather than a simplified reproduction of the traditional image of it.

Rethinking Inquiry within the Epistemic-Conceptual Structure of Science Education:

Understanding inquiry through scientific thinking requires re-examining the conceptual structure that dominates everyday classroom practices in science education. The traditional view, which treats inquiry as a technical tool for developing specific skills, narrows its role and overlooks the complex knowledge structure on which scientific thinking is based. Therefore, the integration of scientific thinking and inquiry should not be viewed as a simple causal relationship. Rather, it should be considered a dynamic, interactive process in which inquiry serves as a cognitive context that fosters reasoning, analysis, and interpretation within a well-defined argumentative framework.

A structural analysis of recent literature shows that inquiry becomes effective when placed within an epistemic-argumentative framework enabling learners to balance epistemic autonomy with guided support. This framework redefines the teacher's role, shifting the focus from content delivery to acting as an epistemic supervisor who guides dialogue, encourages questioning, supervises hypothesis formulation and oversees evidence analysis. Meanwhile, learners become cognitive agents capable of producing scientific meaning within a specific social-educational context.

The centrality of argumentation and metacognition:

In this context, argumentation is fundamental to the practice of enquiry. Scientific thinking involves not only producing results, but also defending, critiquing and revising them in light of available evidence. Furthermore, incorporating metacognition allows learners to monitor their thinking, evaluate their strategies, and recognise the limitations of their knowledge — a vital step in transforming inquiry into a comprehensive tool for developing rational scientific thinking.

Based on this, a theoretical epistemic-argumentative framework for school-based enquiry is proposed, built on three main axes:

- Redefining inquiry as a dynamic epistemic practice, not merely a technical procedure.
- Making argumentation central across all stages of school-based scientific work.
- Achieving a precise balance between pedagogical guidance and learners' epistemic autonomy to ensure the deep development of scientific thinking.
- Redefining assessment as evaluating the processes of argumentation, rather than isolated final outcomes.
- Integrating metacognition as an integral part of every enquiry activity.

This framework redefines the relationship between enquiry and scientific thinking, shifting the focus from enquiry as a tool for achieving cognitive goals to enquiry as an epistemic structure that accompanies and shapes scientific thinking itself. In this way, it offers a clear conceptual contribution that can be applied in the design of modern curricula.

Conclusion

The problem is not the difficulty of implementing inquiry in the classroom, but rather the conceptual framework through which it is understood. When inquiry is reduced to a pedagogical tool intended to promote learning, its epistemic roots are severed and the critical, argumentative nature of scientific thinking is lost. Therefore, this study aimed to demonstrate that the relationship between inquiry and scientific thinking is not merely instrumental. Rather, it is a structural interdependence: scientific thinking is formed within an inquiry practice that is epistemically framed, not merely within an organised procedural activity.

The analysis also shows that school science transfer paradoxes are not resolved by adding techniques or improving lesson scenarios. Rather, they require repositioning inquiry within a cognitive framework that recognises the importance of argumentation and awareness of standards, and acknowledges the probabilistic nature of scientific knowledge. Within this framework, the teacher's role evolves from controlling procedures to facilitating the formation of meaning by creating the appropriate conditions. Meanwhile, learners are redefined as rational agents engaged in constructing interpretations, rather than consumers of predetermined outcomes.

Rather than offering a ready-made recipe, the proposed epistemic–argumentative framework reformulates the question: how can school become a space for forming scientific reasoning, rather than merely training scientific skills? The answer does not lie in intensifying activities, but in rethinking the logic of learning itself and the conditions under which knowledge is produced. Thus, inquiry is not viewed as an additional teaching strategy, but as a cognitive structure that enables scientific thinking in a contemporary school context.

From this perspective, the presented approach expands the scope of research beyond the question of the 'effectiveness of inquiry' to address deeper issues concerning the conditions of its epistemic positioning within school culture and the development of analytical and evaluative tools that align with the argumentative nature of scientific thinking. Furthering the theoretical construction proposed by this study requires testing the proposed framework and unpacking the representations of educational actors regarding the nature of scientific knowledge.

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