


Concept Paper

The Modernization Paradox: Digital Scenarios that Contradict an Inquiry-Based Science Curriculum in Greece

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<https://doi.org/10.59652/m5hrwe54>

Abstract: This study investigates a significant discrepancy between Greece's newly established inquiry-based scientific curriculum and the digital instructional scenarios created to facilitate its universal execution. The curriculum presents a modern educational vision based on genuine experimentation, empirical reasoning, and the development of inquiry skills; however, the officially sanctioned digital resources depend solely on virtual simulations, entirely excluding practical hands-on experimentation. The study employs qualitative document analysis to compare the planned curriculum, as delineated in national policy papers and pertinent scholarly publications, with the actual education integrated inside the digital scenarios. The findings indicate significant epistemological and structural inconsistencies: the exclusive virtual model eradicates measurement uncertainty, procedural decision-making, and material interaction, thereby compromising essential competences in inquiry. This misalignment creates a pedagogical contradiction for educators, undermines curriculum adherence, and jeopardizes the coherence of the national change. The Greek instance, analyzed through the lens of international literature on inquiry-based learning, digital transformation, and curriculum governance, demonstrates how technology-driven implementation procedures can undermine or compromise well-structured curricular frameworks. The study asserts that digital instruments ought to complement, rather than supplant, genuine experimentation, and underscores the want for enhanced pedagogical supervision, disciplinary proficiency, and governance frameworks to preserve curricular integrity. The findings emphasize the necessity of anchoring digital innovation in the epistemological principles of science education, guaranteeing that modernization initiatives augment rather than diminish inquiry-based learning.

Keywords: inquiry-based teaching; science education; curriculum fidelity; digital implementation; hands on experimentation

Received: November 17, 2025

Accepted: February 3, 2026

Published: February 12, 2026



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1. Introduction

In recent years, global science education systems have experienced significant reforms intended to match teaching methods with modern perspectives on scientific literacy, inquiry, and competency-based learning. International organizations, including the OECD, UNESCO, and the European Commission, consistently underscore inquiry-based science education (IBSE) as a fundamental pedagogical framework for cultivating scientific reasoning, problem-solving abilities, creativity, and socio-scientific decision-making in students (Pedaste et al., 2015; OECD, 2015). This transition is motivated by the acknowledgment that conventional science education, predominantly defined by instructor-led lectures and mechanical memorization, does not foster genuine scientific practices or equip students for the intellectual challenges of an evolving scientific and technological environment. As a result, numerous nations have implemented curricular frameworks that prioritize inquiry methods, practical experimentation, collaborative problem-solving, and interdisciplinary approaches in science education. Greece is a notably intriguing setting within this global movement.

From 2021 to 2024, the government instituted a novel national scientific curriculum for primary and lower-secondary education, specifically based on inquiry-based learning, genuine experimentation, and STEM integration. However, international research on STEM

education consistently indicates that the success of such reforms depends heavily on teachers' awareness, conceptual understanding, and professional readiness to implement inquiry-oriented and interdisciplinary practices, with significant challenges reported across diverse educational systems (Sahito & Wassan, 2024). The curriculum delineates a distinct instructional framework wherein students formulate and execute authentic experiments, gather empirical data, evaluate hypotheses, and derive evidence-based conclusions through systematic cycles of inquiry and contemplation. The official curriculum chapter, *Designing the New Science Curricula for Primary Education in Greece* (Kotsis et al., 2023), asserts that the Greek framework regards evidential experimentation as a "irreplaceable process" crucial for fostering students' scientific literacy, metacognitive development, and ability to relate school science to real-world phenomena. The recent research (Kotsis et al., 2025) illustrates that this curriculum is based on established IBL theory and was validated through a national two-year pilot that included genuine classroom experimentation, teacher reflection, and student performance data. Kotsis (2024a) offers a detailed analysis of the incorporation of inquiry-based learning into the revised Greek primary science curriculum, thereby underscoring the significance of IBL in the program's pedagogical framework. The Greek case presents not only a national reform but also a carefully assessed model of inquiry-driven curriculum design. The Greek case presents a nationwide reform as well as a carefully assessed model of inquiry-driven curriculum design.

Concurrent advancements within the European Union further elucidate this transition. Comparative analyses of science curricula for ages 11-12 in EU member states indicate a prevalent incorporation of inquiry-based pedagogies, practical experimentation, and interdisciplinary STEM methodologies as shared structural characteristics, notwithstanding national variations in execution (Tsiouri et al., 2024; Kotsis, 2024b). These studies underscore two persistent trends: first, that authentic experimentation is a fundamental pedagogical element in high-performing systems like Finland, Germany, and the UK; and second, that virtual laboratories and digital simulations are recognized as supplementary tools that enhance, but do not supplant, empirical investigation. Throughout Europe, virtual experiments are esteemed for their capacity to visualize abstract phenomena, promote the safe exploration of hazardous concepts, and allow for repetition; nevertheless, they are not considered replacements for practical scientific experience, which constitutes the epistemic basis of science education (Engeln et al., 2013; Evangelou & Kotsis, 2019; Osborne & Dillon, 2008). This consensus highlights a distinct differentiation between digital augmentation and digital substitution in IBSE.

The Greek reform is closely aligned with these international trends. The Cambridge Scholars volume and the *Journal of Mathematics and Science Teacher* article assert that authentic experimentation is essential within the national curriculum, necessitating student engagement with genuine materials, measurement instruments, and collaborative scientific methodologies (Kotsis et al., 2023; Kotsis et al., 2025). The curriculum specifically cautions against teaching methods that diminish science to theoretical abstraction or simulated experiences disconnected from empirical involvement. Nonetheless, despite this strong educational base, a considerable policy-practice gap has arisen at the national implementation level. The Institute of Educational Policy (IEP) commissioned a prominent telecommunications business to develop and provide comprehensive teaching scenarios for all school subjects and grades, as part of a statewide push to establish digital instructional frameworks compatible with the new curriculum. This effort aimed to modernize educational resources and expedite the digital transition of Greek schools; however, the resulting science scenarios depend solely on virtual experiments, lacking any genuine, classroom-based experimentation. This discrepancy positions the official implementation materials in direct opposition to the IBSE model established by the national curriculum.

The discrepancy between curricular objectives and implemented instructional materials prompts significant inquiries on curriculum fidelity, policy consistency, and the dangers of technological solutionism in educational reform. Recent research on primary education digitalization emphasizes that successful digital education initiatives depend less on technological provision itself and more on policy coherence, pedagogical alignment, and institutional support structures (Ventista et al., 2024). The Greek instance exemplifies the wider global conflict between narratives of digital innovation and the pedagogical integrity of science education, reflecting broader national patterns in which modernization policies often advance without sustained public or professional engagement (Lekakis, 2025). Assertions by the Minister of Education advocating for the "digital school" and the comprehensive digitization of educational settings have solidified the political narrative that associates

digitalization with modernity, efficiency, and superiority.

This framing reflects broader European policy discourses that link national competitiveness, innovation capacity, and economic growth to levels of digitalization across sectors, including education (Marti & Puertas, 2023). At the same time, this narrative must be understood within the broader post-crisis governance framework, in which European Union funding mechanisms, cohesion policies, and crisis-management logics have significantly shaped national reform priorities (Ikonou, 2018). Nonetheless, when digital tools are employed in manners that compromise fundamental curricular ideas, particularly those as essential as empirical experimentation, the efficacy and legitimacy of national reform initiatives are at risk.

This study contextualizes the Greek situation within global discussions on inquiry-based learning, the educational significance of virtual laboratories, and the risks associated with replacing actual scientific practice with digital content. And the study seeks to clarify how well-intentioned national changes can be undermined by implementation choices that contradict pedagogical research and the objectives of the curriculum they are intended to enhance, through a thorough review of curriculum and policy.

2. Background and Theoretical Framework

IBSE has developed over the last twenty years as a fundamental framework in modern science education, rooted in constructivist learning theory and bolstered by substantial empirical research. Grounded in Dewey's (1933) philosophy of experiential learning and Bruner's notion of discovery learning, IBSE redefines the classroom as an environment where students participate in genuine scientific practices, formulating inquiries, designing experiments, gathering evidence, constructing explanations, and disseminating results. Pedaste et al. (2015) proposed a frequently referenced synthesis that organizes these stages into a structured inquiry cycle comprising orientation, conceptualization, investigation, conclusion, and debate, providing a coherent framework for integrating classroom activities with scientific thinking. Globally, IBSE is deemed essential for fostering scientific literacy, since it enhances critical thinking, epistemic agency, and the capacity to employ evidence in reasoning on socio-scientific matters (OECD, 2015; Rocard et al., 2007). In this regard, IBSE is not merely a pedagogical method but a whole framework for altering students' engagement with science. Reviews of STEM education research emphasize that when inquiry-based and STEM-oriented curricula are introduced without sufficient teacher understanding and professional support, their implementation is often fragmented or reduced to superficial instructional changes (Sahito & Wassan, 2024).

In the context of the overarching inquiry framework, experiment-based learning possesses a distinguished epistemic significance. Multiple studies underscore that experiential learning is essential for enabling students to establish strong conceptual frameworks and cultivate practical scientific skills (Hofstein & Lunetta, 2004; De Jong et al., 2013). Manipulating materials and experiencing unforeseen results in authentic experiments engender cognitive conflict and embodied engagement, both crucial for conceptual transformation in science education. This perspective is firmly integrated into the Greek national curriculum, wherein experimentation is clearly designated as the fundamental method by which students uncover scientific relationships, generate hypotheses, and assess their own conceptual frameworks. Kotsis et al. (2023) emphasize in their work on the New Science Curricula for Primary Education in Greece that the curriculum prioritizes "evidential experimentation" as a fundamental aspect of inquiry, characterizing it as an "irreplaceable" learning process that enables students to develop their "own theory, discovered by themselves".

This role is consistent with a longstanding body of research indicating that genuine experimental engagement promotes students' metacognitive growth, cultivates deeper involvement in scientific procedures, and improves their capacity to apply information in real-world situations.

A significant body of worldwide literature underscores the importance of practical experimentation in inquiry-based science teaching. Traditional theoretical scholarship has consistently maintained that genuine inquiry is essential for comprehending the empirical underpinnings of scientific knowledge (Hodson, 1993; Driver et al., 1996). Prominent global frameworks, such as the National Research Council's Framework for K-12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (National Research Council, 2013), explicitly mandate that students participate in direct empirical

investigations by manipulating materials, gathering authentic data, and interpreting observations amidst uncertainty.

Empirical research in science education has shown that authentic experiments cultivate inquiry competencies, such as measurement literacy, variable control, and evidence-based reasoning, in ways that virtual environments cannot replicate (Abrahams & Millar, 2008; Gott & Duggan, 1996; Hofstein & Mamlok-Naaman, 2007). These studies repeatedly demonstrate that genuine experimentation facilitates conceptual transformation (Gunstone, 1991), enhances students' understanding of the nature of science (Lederman, 2006), and enables students to relate theoretical models to observable phenomena (Tiberghien et al., 2001). This body of work collectively asserts that material engagement and empirical data are fundamental to inquiry-based learning, serving as indispensable supplements to, rather than substitutes for, digital or simulated settings.

The swift proliferation of educational technology has presented new opportunities and problems for inquiry-based instruction. Digital simulations, virtual laboratories, and interactive modeling tools have become significant, scalable, and accessible resources for science teaching. Virtual experiments enable students to investigate phenomena that could be hazardous, costly, time-intensive, or unfeasible to replicate in an educational environment, like radioactive decay, chemical interactions, or astronomical motion (Rutten et al., 2012).

They provide great repeatability, regulated variable manipulation, and the depiction of complex structures, hence enhancing conceptual comprehension. Nonetheless, research repeatedly posits that virtual laboratories ought to function as complements rather than replacements for practical experimentation (Zacharia & Olympiou, 2011; De Jong et al., 2013). The epistemic characteristics of authentic scientific practice, including measurement inaccuracy, material limitations, tactile interaction, and the unpredictability of empirical systems, are predominantly lacking in virtual environments, and their absence poses a risk of distorting the perception of scientific operation.

Recent European studies of science curricula underscore the contrast between real and virtual experimentation. Tsiouri et al. (2024) demonstrate that in EU member states, inquiry-based learning and practical experimentation are fundamental components of national science curricula, whereas virtual experiments serve mainly as supplementary tools intended to enhance inquiry-based instruction rather than substitute for genuine laboratory activities. Countries excelling in international assessments, such as Finland, Germany, and the UK, clearly incorporate experiments with physical materials as essential elements of scientific literacy, while primarily advocating for digital technologies for visualization and enhancement. Comparative research on EU curricula indicates that inquiry and experimentation are regarded as essential competencies foundational to scientific reasoning, rather than as supplementary elements (Osborne & Dillon, 2008). These findings underscore a widespread European consensus: virtual laboratories augment inquiry-based learning, however, do not independently embody inquiry.

The Greek context embodies this global consensus. Kotsis et al. (2025) illustrate that The New Greek Inquiry-Based Learning Science Curriculum for Primary Education is entirely consistent with modern inquiry-based frameworks and is underpinned by substantial theoretical and empirical evidence. Their analysis elucidates how Greece's curriculum fosters systematic cycles of inquiry, experimental reasoning, and the cultivation of scientific competencies, while concurrently incorporating digital tools and STEM methodologies in a manner that preserves the epistemological integrity of IBSE. The curriculum was enhanced through a two-year national trial, wherein teachers and students largely participated in practical experimentation, yielding evidence of improvements in engagement, reasoning, and involvement, especially among students with learning difficulties. This sequence of design, pilot execution, and empirical evaluation presents a unique national instance where IBSE is both mandated and effectively executed.

The theoretical framework of curriculum faithfulness further elucidates the importance of the Greek case. Curriculum fidelity denotes the extent to which implemented teaching methods correspond with the objectives, pedagogical principles, and structural framework of an approved curriculum (Choppin et al., 2020). Discrepancies between policy and practice frequently arise when curricular reforms are executed via digital platforms or outsourced teaching materials that fail to align with the epistemological principles of the reform. Implementation science research indicates that technological interventions often prioritize convenience, efficiency, or commercial demands, resulting in educational resources that diverge from curricular goals (Fullan, 2016). In the realm of science education, there exists a danger that digital environments may be regarded as contemporary or cutting-edge,

prompting policymakers or content creators to emphasize technical innovation at the expense of pedagogical consistency (Selwyn, 2016).

This results in technology substitution rather than authentic digital transformation, so compromising the ideals of inquiry-based learning.

Collectively, these theoretical perspectives, IBSE, the significance of experimentation, the pedagogical role of virtual laboratories, European curriculum trends, and curriculum fidelity, establish a solid conceptual framework for comprehending the policy and implementation challenges addressed in this study. They emphasize the epistemological significance of experimentation in science education, the supportive yet constrained function of virtual tools, and the systemic hazards that emerge when digital initiatives are created without complete adherence to curricular frameworks. The Greek instance offers a distinctive perspective on how a national curriculum based on inquiry might be undermined or perverted when the processes of implementation do not align with its core ideas.

3. The Greek National Case

The current reform of science education in Greece signifies one of the most significant curriculum overhauls in the nation's contemporary educational history. From 2021 to 2024, the Ministry of Education and the IEP formulated an extensive array of new curricula for all academic topics and grade levels, with science education designated as a pivotal area for innovation. The reform was based on the overarching European dedication to inquiry-based learning, STEM integration, and competency-driven instruction, while also embodying specific national ambitions to modernize pedagogical methods, improve student engagement, and mitigate enduring disparities in scientific literacy. The initiative, as detailed in *Designing the New Science Curricula for Primary Education in Greece* (Kotsis et al., 2023), employed a multi-stage, research-based approach that included curriculum design, empirical piloting, iterative refinement, and nationwide consultation with educators, subject matter experts, academic researchers, and policymakers. This systematic approach established the Greek curriculum not only as a directive from above but as a pedagogically sound and empirically substantiated model consistent with modern world science education standards.

A key characteristic of the new Greek scientific curriculum is its clear and steadfast focus on inquiry-based learning and genuine experimentation. The curriculum materials provide a systematic framework for inquiry, wherein students methodically engage in predicting, observing, measuring, gathering data, assessing results, and constructing evidence-based interpretations. The new framework, unlike previous curricular versions criticized for their emphasis on theoretical exposition and less practical involvement, prioritizes experimentation as key to content acquisition and skill development. Kotsis et al. (2025) assert that inquiry-based experimentation serves as the primary method by which students “generate their own scientific explanations” and cultivate a tangible comprehension of natural phenomena. The curriculum establishes experimentation as the essential instructional approach through which scientific thinking develops, rather than only an optional enrichment activity. This epistemological perspective is substantiated by global research indicating that experiential inquiry fosters profound conceptual understanding, augments epistemic agency, and offers students a more genuine depiction of the scientific knowledge production process (Hofstein & Lunetta, 2004; Furtak et al., 2012).

The significance of experimentation in the Greek curriculum is further emphasized when analyzed within the wider European setting. Comparative research on EU science curricula, exemplified by the multicountry study conducted by Tsiouri et al. (2024), indicates that Greece's new curriculum closely aligns with the prevailing European focus on inquiry-based, student-centered investigation and hands-on experimentation for students aged 11-12 and earlier grades. Their analysis reveals that in EU member states, especially in high-performing systems, genuine experimentation and inquiry cycles are fundamental structural elements of science education, whereas digital simulations serve mainly as extensions rather than replacements. The synchronization of the Greek curriculum with these European trends highlights that the reform is not an isolated national change but rather a component of a broader continental shift towards inquiry-based, evidence-based pedagogy.

The Greek Ministry of Education initiated extensive programs to facilitate the nationwide implementation of the new curriculum, aimed at equipping teachers with essential pedagogical tools, digital platforms, and instructional frameworks.

The IEP was assigned the responsibility of supervising the creation of instructional materials that would embody the new curricular concept. This initiative's scale was

unparalleled in Greek education: it aimed to develop comprehensive instructional scenarios for every subject across all grade levels in both primary and secondary education. Research indicates that entities like the Greek Experimental Model Schools are essential in facilitating, testing, and solidifying curriculum modifications (Kotsis & Tsiouri, 2024). Each scenario was anticipated to accurately convey the curriculum's inquiry-based framework through practical classroom activities, incorporating authentic experimentation, collaborative problem-solving, and student-centered inquiries.

A significant and unforeseen event transpired during the implementation phase. The Ministry engaged a prominent commercial telecommunications firm to create and implement the complete range of educational scenarios, rather than delegating content production to university institutions, pedagogical research centers, or subject matter specialists. Although outsourcing is not intrinsically problematic, the choice of a non-educational entity elicited immediate apprehensions over disciplinary knowledge, pedagogical coherence, and adherence to the curriculum's inquiry-based framework.

The worries escalated as the project progressed: despite an extended timetable and augmented budget, the scenarios developed for science instruction depended solely on virtual experiments, lacking any incorporation of genuine, hands-on experimental activities in classroom environments.

This complete dependence on virtual experimentation fundamentally contradicts the epistemological, pedagogical, and methodological norms outlined in the national curriculum. The exclusion of genuine experimentation from the instructional design compromises the fundamental principles upon which the curriculum is established. This divergence illustrates what the implementation science literature terms "curriculum slippage" or "policy-practice gap," where the executed curriculum (in this instance, the digital scenarios) markedly diverges from the intended curriculum (the national inquiry-based framework) (Choppin et al., 2020). The Greek scenario illustrates how technology-driven efforts might inadvertently supplant instructional priorities when implementation decisions lack adequate supervision from curriculum experts or discipline specialists.

The Minister of Education's public utterances intensify this tension. The ministerial discourse often advocates for a technologically advanced "digital school" and regards digital technologies as emblems of modernization and efficiency. This discourse may support wider political agendas, but it risks merging digital innovation with educational enhancement, especially when applied without consideration of established curriculum design principles or actual research on science education. In science education, such language seems to have facilitated the development of exclusively virtual instructional resources that are inconsistent with the curriculum's fundamental epistemological principles. The Greek educational system currently confronts a paradox where its official, research-driven curriculum endorses genuine inquiry and authentic experimentation, while its government-funded instructional materials endorse a technologically expedient yet pedagogically deficient model of virtual simulation.

The Greek national situation exemplifies a fundamental contradiction: a meticulously crafted, theoretically sound, and empirically substantiated inquiry-based curriculum is in direct opposition to its digitally generated implementation materials. This misalignment prompts significant inquiries on curricular governance, the involvement of private entities in educational design, and the systemic hazards of educational digitalization when executed without pedagogical rigor. The Greek example offers a valuable backdrop for analyzing how curriculum objectives might be undermined by implementation choices that favor technological solutions over evidence-based instructional principles. Grasping this conflict is crucial for maintaining consistency in national reforms, regardless of their ambition, during the shift from design to implementation.

4. The Implementation – Curriculum Misalignment

The disparity between Greece's proposed inquiry-based science curriculum and the national implementation materials expose a fundamental contradiction within the nation's recent educational reform. The new curriculum presents a strong pedagogical vision focused on genuine experimentation, collaborative inquiry, and the iterative development of scientific explanations; however, the instructional scenarios generated by the national digital initiative embody a fundamentally different model of science education, relying solely on virtual experimentation. This misalignment is not merely cosmetic or procedural but epistemological, as it contradicts the underlying concepts of the curriculum and jeopardizes the coherence and credibility of the reform.

A rigorous examination of the digital educational scenarios generated by the contracted telecommunications firm reveals that each science activity, at all school levels, is organized around prefabricated virtual simulations instead of authentic, hands-on experimental inquiry. These scenarios generally direct students through linear, fully regulated digital processes that imitate idealized representations of scientific phenomena while removing the material, methodological, and empirical complexities intrinsic to genuine scientific research. Although virtual experimentation can provide significant visualization and conceptual assistance under some teaching situations, its sole use fundamentally contradicts the inquiry-based methodology outlined in the Greek curriculum. The curriculum's primary design documents characterize experimenting with authentic materials as the fundamental catalyst for students' discovery, conceptual transformation, and meaning-making processes (Kotsis et al., 2023).

The curriculum prioritizes experiential engagement, measurement error, empirical uncertainty, and collaborative manipulation of physical objects as fundamental elements of science education, reflecting international studies on the critical importance of laboratory work in enhancing students' scientific reasoning (Hofstein & Lunetta, 2004; Furtak et al., 2012).

The implementation scenarios significantly diverge from these requirements. In reality, they eliminate the ambiguity, tactile experience, and embodied reasoning inherent in empirical investigation, substituting them with refined computer representations that depict scientific relationships as predetermined, infallible, and procedurally uncomplicated. Consequently, students interact with an idealized representation of scientific activity where variables exhibit perfect responsiveness, measurements are devoid of error, and occurrences occur quickly and predictably. This "frictionless science," despite its technological sophistication, conceals the epistemological underpinnings of scientific inquiry and clearly contradicts the curriculum's emphasis on students engaging with authentic data, tangible objects, and real-world anomalies. The divergence between the curriculum's focus on genuine manipulation and the exclusive virtual implementation reduces the curriculum's inquiry cycle to a simulation cycle, so compromising the epistemological integrity of the national reform.

The extent of the misalignment is further highlighted when directly correlated with the curriculum's specified competencies. The revised Greek curriculum delineates a set of inquiry competencies, including the formulation of questions, design of investigations, execution of measurements, selection and utilization of tools, analysis of empirical data, evaluation of evidence, and conclusion drawing, all contingent upon interaction with physical phenomena (Kotsis et al., 2025). Genuine experimentation is essential to these competences, as the collection and interpretation of empirical data necessitate cognitive reasoning, procedural fluency, coordination, and the cultivation of measurement literacy. In contrast, virtual-only scenarios obviate the necessity for tool selection, experimental design, and data collection, as the simulation environment preconfigures these components. Students no longer participate in genuine planning or decision-making; rather, they adhere to predefined computerized pathways that provide little scope for spontaneous reasoning or procedural independence. The implementation resources do not fulfil the curriculum's vision of inquiry as an open-ended, evidence-based process.

This situation illustrates a quintessential instance of "implementation drift," where the executed curriculum diverges markedly from the intended curriculum, failing to reflect the pedagogical or epistemic objectives of the original design (Choppin et al., 2020). Studies on curriculum fidelity indicate that discrepancies frequently arise when implementation is assigned to external parties lacking competence or understanding of the curriculum's foundational pedagogical concepts (Fullan, 2016). Recent evaluations of the Greek reform indicate that educators have significant obstacles in implementing the new inquiry-based curriculum, especially with assessment requirements and the pressures stemming from digital innovation (Kotsis, 2025). These issues align with research indicating that primary school teachers' views toward experimentation significantly affect the degree of implementation of authentic, hands-on inquiry in physics instruction (Vlachos et al., 2024). More broadly, international research demonstrates that inquiry-based curricula are enacted in highly context-dependent ways, shaped by school environments, institutional constraints, and teachers' localized interpretations of reform mandates (Ramnarain & Hlatswayo, 2018).

The Greek case exemplifies this pattern: the choice to engage a telecommunications company instead of educational institutions, university researchers, or subject matter experts to develop science education scenarios led to materials that emphasize digital delivery rather than curricular coherence. The company's expertise in digital content production may have influenced the design towards technologically efficient solutions; nonetheless, these solutions

lack the pedagogical intricacy necessary for IBSE.

The broader political narrative of Greece's digital transformation goal exacerbates this challenge. The Minister of Education's public comments depict the digital school as an emblem of modernization, efficiency, and innovation. Although this rhetoric is prevalent in national reform contexts, it may unintentionally create pressure to demonstrate the efficacy of digital instruments, thereby compromising pedagogical integrity. The discourse of digital modernity in scientific contexts seems to have sanctioned the sole use of virtual experiments, presenting them as sophisticated, forward-looking substitutes for conventional laboratory methods. This perspective, however, clearly contradicts the curriculum's clear acknowledgment that virtual tools function as supplements rather than replacements for actual experimentation. Comparative studies in Europe demonstrate that successful education systems typically integrate digital tools with experiential inquiry, maintaining the tangible aspects of science while utilizing digital resources for visualization and enhancement (Tsiouri et al., 2024).

Greece's implementation decisions deviate from established international norms, resulting in a paradox where the curriculum adheres to global best practices while being executed through resources that contradict those practices.

The resultant mismatch has numerous repercussions. Students may cultivate a deficient comprehension of scientific reasoning due to the lack of opportunity for genuine empirical engagement. The epistemological replacement of actual experimentation with virtual simulations affects students' understanding of the production of scientific knowledge, potentially undermining their comprehension of the nature of scientific evidence. The conflict systematically erodes teacher confidence in the curriculum, as the official implementation tools do not facilitate the activities required by the curriculum. The Greek situation exemplifies the dangers of national curriculum reform when implementation is dictated by technology or administrative interests instead of educational integrity.

The misalignment between implementation and curriculum in Greece underscores a significant conflict between the objectives of IBSE and the practicalities of extensive digital material development. It underscores the difficulty of preserving curriculum fidelity in situations when educational resources are created through external collaborations that may not align with the program's epistemological principles. The Greek case serves as a cautionary example for global audiences, illustrating how even meticulously constructed inquiry-based curriculum can be undermined when implementation choices disregard the essential role of actual experimentation in scientific education.

5. Methodology

This study utilizes a qualitative research design based on curriculum analysis, policy analysis, and document analysis. Considering the research challenge, the disparity between Greece's inquiry-based science curriculum and its national implementation materials necessitates techniques centered on textual analysis, structural comparison, and the alignment of policy and practice. The study does not aim to directly assess teacher implementation or classroom results; instead, it seeks to investigate the epistemological, pedagogical, and structural alignment between official curriculum documents and the instructional scenarios created under the national digital transformation initiative. This methodology aligns with known conventions in curriculum research, notably those highlighting the differentiation among the intended, written, and enacted curriculum, as well as the role of curriculum materials in mediating teaching and learning (Choppin et al., 2020). The principal data sources for the study comprise the official Greek science curriculum materials for primary education, released from 2021 to 2024, along with the relevant scholarly studies generated by the curriculum developers. These sources delineate the desired educational concepts, inquiry-based frameworks, and experimental expectations of the program.

Prominent among these are *Designing the New Science Curricula for Primary Education in Greece* (Kotsis et al., 2023) and *The New Greek Inquiry-Based Learning Science Curriculum for Primary Education* (Kotsis et al., 2025), which offer theoretical exposition, design rationales, and empirical evidence from the national pilot implementation. Collectively, these texts reflect the intended curriculum of the study. The European Union-wide analysis (Tsiouri et al., 2024), provides supplementary comparative context by situating the Greek curriculum within broader European trends, thereby reinforcing the cross-system validity of the analytical categories.

The second significant data set comprises the national instructional scenarios generated

by the telecoms firm engaged to execute Greece's digital educational revolution. The materials, reflecting the implemented or forthcoming curriculum, encompass science teaching scenarios for all grade levels and scientific disciplines. They were available via the official national site established for the digital school concept. The examination examines the structural attributes of the scenarios, the type and function of experimental activities, the order of inquiry phases, and the degree to which virtual experiments substitute or enhance real experimentation. Special emphasis is placed on the functionality of these scenarios in relation to the inquiry competencies outlined in the curriculum, including the formulation of investigative questions, the design of empirical procedures, the selection of tools, the execution of measurements, the analysis of data, and the communication of evidence-based explanations.

The analytical framework for the study is based on three intersecting areas of literature: inquiry-based learning, curricular fidelity, and the significance of experimentation in science education. The study utilizes the synthesis inquiry cycle established by Pedaste et al. (2015), which delineates the structural phases of inquiry and offers a framework for assessing the incorporation of inquiry-based pedagogy in instructional materials. The study utilizes the conceptual model by Choppin et al. (2020) from curriculum fidelity research, which differentiates between intended and enacted curricula and investigates the role of curricular materials in mediating teacher practice. This methodology assesses the extent of alignment between the epistemological commitments of the national curriculum and the design of digital scenarios. The comprehensive research on hands-on experimentation (Hofstein & Lunetta, 2004; De Jong et al., 2013) establishes criteria for assessing whether the materials facilitate the advancement of procedural fluency, measurement literacy, and embodied scientific reasoning.

Document analysis was performed by iterative coding and thematic comparison. Initially, all curriculum materials and academic analyses were scrutinized to discern the fundamental epistemological and pedagogical ideas underpinning the Greek curriculum overhaul, particularly the designated function of empirical experimentation. The digital scenarios were categorized based on their incorporation of virtual experiments, the presence or absence of actual experimental activities, the structure of inquiry cycles, and their connection with the curriculum's inquiry competencies. Thematic categories, encompassing the epistemological positioning of experimentation, inquiry structure, digital affordances, and pedagogical coherence, were inductively derived through this coding procedure. Themes were later analyzed throughout curriculum texts and situations to identify points of convergence and divergence.

To augment the credibility of the analysis, the study utilized triangulation of data sources, encompassing curriculum documents, peer-reviewed articles by the curriculum developers, European comparative research, and publicly accessible statements from the Minister of Education regarding the digital transformation agenda. Despite the absence of classroom observations or teacher interviews, the integration of official documents and academic studies yields a sufficiently robust dataset to ascertain curriculum aims and assess their fidelity within the implementation materials. Limitations encompass the lack of direct evidence regarding scenario application in actual classrooms and the unavailability of internal documents from the implementing company; nonetheless, the existing data suffice for analysing the structural and epistemological alignment between intended and enacted curriculum elements.

This methodological approach for a thorough assessment of whether the digitally created educational scenarios accurately embody the pedagogical concepts of Greece's inquiry-based science curriculum. By anchoring the analysis in established theoretical frameworks and cross-referencing multiple authoritative sources, the study offers a comprehensive account of the discord between curriculum design and implementation, contextualizing this discord within the wider discourse on educational reform and technological transformation.

6. Findings

The examination of the Greek scientific curriculum and the national digital instructional scenarios uncovered a significant and complex misalignment between the planned curricular vision and the implemented pedagogical methodology. This misalignment occurs across epistemological, pedagogical, structural, and systemic dimensions, leading to a fundamental contradiction between the inquiry-based underpinnings of the curriculum and the digital tools intended to implement them. This section's findings consolidate evidence from the comparative document analysis and are structured around five principal themes: (a) structural discrepancies between curriculum and scenarios, (b) epistemological distortions from the

exclusive use of virtual experiments, (c) erosion of inquiry competencies, (d) implications for teacher practice, and (e) systemic consequences for national curriculum coherence.

A primary and significant conclusion pertains to the structural incongruence between the inquiry cycles outlined in the curriculum and the linear, simulation-based activities integrated inside the digital scenarios. The Greek curriculum delineates an educational framework based on open-ended inquiry, iterative concept refining, practical experimentation, and reflection on empirical data (Kotsis et al., 2023; Kotsis et al., 2025). In contrast, the digital teaching scenarios lack chances for students to develop or alter experiments, select measurement options, or gather empirical data.

They offer predefined virtual environments where variables are adjusted by fixed digital controllers, and outcomes are dictated by the simulation's coding parameters.

The scenario framework reduces the inquiry process to a sequence of planned digital encounters, hindering students' ability to engage in genuine scientific thinking. This structural discrepancy illustrates a failure in curriculum fidelity, as the implemented materials cannot achieve the investigative procedures outlined in the planned curriculum.

A second significant conclusion pertains to the epistemological distortion caused by the sole dependence on virtual experimentation. The Greek curriculum characterizes experimentation as a tangible process wherein students engage with uncertainty, variability, and the physical limitations of the natural world, factors crucial for comprehending the epistemic essence of scientific evidence (Kotsis et al., 2023). Virtual simulations inherently eradicate measurement error, reduce ambiguity, and depict idealized phenomena that operate with algorithmic precision. Although these simulations can aid in conceptual visualization, their sole use skews students' comprehension of the process by which scientific information is produced. Global literature cautions against this epistemological simplification: virtual environments may foster deterministic views of science that conceal the importance of empirical judgment, error identification, and the iterative enhancement of experimental methodologies (Hofstein & Lunetta, 2004; De Jong et al., 2013). The Greek scenario's complete lack of genuine experimentation in the instructional materials results in students interacting solely with an idealized and sanitized depiction of science, which contradicts the curriculum's clear emphasis on evidence-based reasoning rooted in actual reality.

A third finding underscores the deterioration of inquiry competencies attributable to the exclusive virtual paradigm. The national curriculum specifies competences such as question formulation, investigative design, tool selection, measurement, data analysis, and evidence-based explanation, which are essential for IBSE (Kotsis et al., 2025). These talents are intrinsically linked to genuine engagement with tangible materials and empirical data. Nevertheless, the examination of the digital situations indicates that pupils are not necessitated to choose or employ measuring instruments, as the virtual interfaces automate these functions. They are not obligated to create experimental protocols, as simulations offer predefined processes. They do not gather data empirically, as digital outputs are produced automatically by the simulation engine. As a result, students' involvement in inquiry is diminished to the mechanical handling of interface components instead of substantive engagement with empirical reasoning. This finding reflects apprehensions in international comparative research. For example, Tsiouri et al. (2024) demonstrate that hands-on experimentation is deemed crucial across European curricula for fostering investigative and procedural competencies, with virtual tools utilized primarily as supplements rather than substitutes, as they cannot effectively develop these skills. The Greek implementation, by contrast, weakens the competency foundation central to the curriculum.

The fourth finding pertains to the ramifications of the misalignment for pedagogical practice. Educators depend on sanctioned instructional resources as intermediaries between curriculum objectives and classroom implementation. When these materials deviate from the curriculum's epistemological and pedagogical principles, educators face contradictory instructions on the teaching of science, a condition that has been shown to undermine teachers' motivation to engage with reforms and to implement pedagogical innovations in practice (Gorozidis & Papaioannou, 2014). The exclusively virtual scenarios implicitly push educators to embrace a technology-centric, simulation-based teaching approach, while the curriculum anticipates their facilitation of practical inquiry, support for experimental design, and orchestration of collaborative empirical research. Choppin et al. (2020) assert that such discrepancies can undermine teachers' curriculum agency by generating ambiguity over the pedagogical paradigm they are required to implement. In the Greek context, educators may face pressure to implement digital scenarios that conflict with the curriculum's inquiry-based methodology, particularly due to the political focus on digital modernization and the

institutional dominance of the national digital platform. Research on primary teachers' technology acceptance indicates that such pressure-driven digital adoption, especially when framed as compulsory or crisis-responsive, significantly shapes teachers' attitudes toward technology use, often independently of pedagogical value (Georgiou et al., 2023). Evidence from secondary education during the COVID-19 pandemic further demonstrates that teachers' engagement with centrally imposed digital platforms was largely pragmatic and compliance-oriented, driven by institutional obligation rather than pedagogical suitability (Violakis & Tzakopoulos, 2024). The outcome is an educational setting where educators are both urged to adopt inquiry-based learning while being supplied with resources that inherently obstruct it, a contradiction that research has shown to negatively affect teachers' willingness to participate in professional development and to adopt instructional innovations (Gorozidis & Papaioannou, 2014).

A concluding observation pertains to the extensive systemic ramifications of the divergence between implementation and curriculum. The Greek curriculum reform, underpinned by comprehensive research and consistent with European trends, provides a cohesive and evidence-based framework for inquiry-based science instruction. The implementation materials generated by the national digital initiative embody a contradictory educational approach that jeopardizes the integrity of the reform.

These conflicts threaten to erode public trust in curricular policies, diminish teacher support, and foster inconsistencies within the national education system. This raises significant governance issues about the involvement of private entities in curriculum execution and the dangers of delegating pedagogically intricate responsibilities to organizations devoid of disciplinary proficiency. Global studies on educational reform warn that technology solutionism, which positions digital technologies as intrinsically superior or more contemporary, might undermine curriculum objectives when technological factors take precedence over pedagogical concerns (Fullan, 2016). The Greek case exemplifies this risk clearly: the political dialogue regarding the digital school seems to have eclipsed the pedagogical necessities of IBSE, leading to implementation materials that fail to support, and in certain instances contradict, the fundamental educational objectives of the reform.

Collectively, these data indicate a significant mismatch between Greece's inquiry-based curriculum and its digital teaching frameworks. The misalignment jeopardizes the epistemological foundations of the curriculum, diminishes inquiry competencies, restricts teacher practice, and endangers the systemic coherence of the national reform initiative. These findings emphasize the necessity for stringent control, pedagogical proficiency, and curricular adherence in the execution of extensive digital educational programs. They emphasize the significance of preserving the core of genuine experimentation in science education, particularly within technologically sophisticated learning contexts.

7. Discussion

This study's findings indicate a continual and structurally important misalignment between Greece's inquiry-based science curriculum and the digital instructional scenarios developed for its statewide implementation. This section interprets these findings in the context of international research, wider discussions on digital revolution in education, and the epistemological requirements of science learning. The Greek situation exemplifies not only a geographical issue but a phenomenon with worldwide ramifications for curriculum reform: the danger that technology-driven implementation attempts may unintentionally weaken the pedagogical underpinnings of well-constructed curricula. This tension illustrates what academics increasingly identify as the "modernization paradox," wherein digital innovation initiatives foster seemingly progressive learning methods that, in actuality, limit the depth and authenticity of students' involvement with disciplinary practices (Dalakoglou & Kallianos, 2018). When digitalization is primarily justified through competitiveness and innovation indicators, pedagogical considerations risk becoming secondary implementation concerns rather than guiding principles (Marti & Puertas, 2023).

The initial feature of this conundrum is to the epistemological displacement seen in the Greek context. The curriculum's dedication to genuine experimentation is based on extensive research highlighting the significance of material interaction, uncertainty, and empirical reasoning in fostering scientific literacy (Hofstein & Lunetta, 2004; Furtak et al., 2012). In contrast, digital scenarios redefine scientific inquiry as an endeavor solely facilitated by simulations, unwittingly fostering a technocratic view of research where procedures are predefined, variables are meticulously controlled, and findings are consistently trustworthy.

This transition corresponds with apprehensions articulated in the literature regarding the virtualization of science education, wherein researchers caution that simulations, when employed as replacements instead of enhancements, jeopardize the epistemic intricacy inherent in authentic scientific methodologies (De Jong et al., 2013). The Greek instance illustrates how digital tools, when presented as universal solutions, can reduce scientific inquiry to streamlined processes that conceal the complex, iterative, and embodied aspects of empirical research.

A significant corpus of international research supports the assertion that IBSE necessitates direct, tangible interaction with authentic occurrences. Prominent frameworks, including the Framework for K-12 Science Education (National Research Council, 2012) and the Next Generation Science Standards (National Research Council, 2013), explicitly mandate that students participate in direct investigations, which encompass the manipulation of materials, the collection of empirical data, and the application of reasoning with actual measurements. Throughout Europe and the broader international community, practical laboratory work is acknowledged for offering indispensable epistemic experiences that simulations cannot replicate, such as addressing measurement error, managing unforeseen results, and confronting the physical limitations inherent in natural systems (Abrahams & Millar, 2008; Millar, 2004; Séré, 2002; Lunetta et al., 2013). Research on blended laboratory models underscores that virtual tools serve optimally as enhancements to conceptual understanding, rather than as replacements for empirical investigation (Zacharia & Olympiou, 2011; Hofstein, 2017). These foreign perspectives collectively assert that research devoid of practical experience may foster a deterministic and excessively idealized conception of science, hence hindering students' cultivation of genuine scientific practices.

A secondary interpretive topic pertains to curricular fidelity as a systemic challenge within modern reform contexts. The Greek inquiry-based curriculum is theoretically robust, empirically substantiated, and consistent with European research and policy trends (Kotsis et al., 2023; Tsiouri et al., 2024). Nonetheless, the implementation materials diverge significantly from curricular objectives, so forming an alternative educational paradigm that fails to foster the development of inquiry competencies. This signifies what Choppin et al. (2020) describe as a failure in the mediational role of educational materials. When educators receive resources that conflict with the curriculum's epistemological foundation, the implemented curriculum becomes disjointed, inconsistent, and susceptible to institutional influences. In Greece, the dominant political discourse on digital modernization conflates technological adoption with educational advancement, a tendency that reflects governance patterns established during the management of the economic crisis and the strategic use of European cohesion funding (Ikonomou, 2018), incentivizing schools and educators to utilize resources that seem new, despite potentially undermining inquiry-based learning. This interaction illustrates how curricular coherence can be compromised when implementation is influenced more by political agendas than by pedagogical considerations. Studies of IBSE across diverse schooling contexts show that when reforms are imposed without sensitivity to local conditions, teachers adapt, or dilute, inquiry practices in ways that diverge from curriculum intentions (Ramnarain & Hlatswayo, 2018).

A third facet of the discourse pertains to the wider worldwide context of digitization in science education. Throughout Europe, inquiry-based learning and practical experimentation are fundamental components of science curricula, with digital simulations primarily appreciated for their ability to improve visualization, foster conceptual comprehension, and facilitate experimentation in areas unattainable in school laboratories (Tsiouri et al., 2024). The projected curriculum of Greece closely adheres to this approach, integrating virtual instruments within a well-balanced framework of scientific activities. The digital instructional scenarios, however, disrupt this equilibrium by completely removing authentic exploration. This illustrates a wider global trend where digital transformation efforts, frequently propelled by commercial alliances or swift technical implementation, emphasize efficiency and scalability rather than pedagogical profundity. The Greek example adds to the expanding international literature that critiques the educational assumptions inherent in large-scale digital platforms and their impact on legitimate disciplinary learning.

A fourth interpretive aspect pertains to the teacher's function as a curriculum gatekeeper. Global research constantly highlights that educators facilitate the conversion of curricular objectives into classroom practices, and that their professional autonomy relies on the congruence of curriculum resources with cohesive pedagogical principles (Biesta, 2015). In situations when official resources conflict with curricular direction, educators encounter conflicting demands: to follow inquiry-based science instruction or to implement politically

endorsed digital scenarios. This contradiction diminishes teacher autonomy and threatens to normalize practices that impede students' engagement with scientific research, particularly when teachers' acceptance of digital tools is driven by external constraints, emergency conditions, or institutional expectations rather than by perceived instructional effectiveness (Georgiou et al., 2023). From a broader democratic and governance perspective, such technocratic approaches to digital education risk marginalizing principles of digital citizenship, professional judgment, and re-sponsible research and innovation within schools (Vallès-Peris & Domènech, 2024). The Greek situation exemplifies a wider risk inherent in digital reform initiatives: the potential for teachers to become mere implementers of externally devised materials instead than engaged interpreters and co-creators of the curriculum. This issue is exacerbated when implementation is delegated to corporate entities lacking a comprehensive understanding of the disciplinary epistemologies foundational to academic topics.

The conversation ultimately underscores the wider governance ramifications of the imbalance. The reform process in Greece illustrates how effectively structured curricular frameworks can be undermined when implementation strategies lack pedagogical supervision or when technical infrastructures are treated as pedagogical replacements rather than as supportive tools. The collaboration with a private telecommunications firm, albeit technologically ambitious, prompts inquiries regarding expertise, accountability, and the influence of commercial entities in the implementation of the national curriculum. Comparable patterns have been identified in other public policy domains in Greece, where modernization agendas prioritize technical efficiency over participatory engagement and contextual sensitivity, resulting in limited public alignment with policy objectives (Lekakis, 2025). These governance concerns align with global discussions over the privatization of educational infrastructure and the capacity of digital platforms to impact pedagogical practices in ways that surpass or conflict with curricular goals (Landri, 2018). The Greek situation exemplifies how digital reforms, lacking adequate disciplinary and pedagogical foundations, can undermine even the most logical curriculum frameworks.

Collectively, these perspectives indicate that the disparity between Greece's intended curriculum and its implementation materials is not solely a technical concern but an epistemological and systemic issue. It illustrates a significant conflict between the objectives of IBSE and the demands of digital modernization, emphasizing the necessity for enhanced pedagogical oversight in the creation and use of digital educational materials. It emphasizes the importance of preserving the primacy of genuine experimentation in science education, despite the growing use of digital instruments. The findings underscore the necessity for Greece, and comparable international education systems undergoing similar reforms, to harmonize technological innovation with disciplinary integrity, thereby ensuring that digital transformation enhances rather than compromises the epistemic foundations of science education.

8. Conclusions

This study underscores a significant contradiction within Greece's recent science education reform: although the national curriculum advocates for inquiry-based learning rooted in genuine experimentation, the official digital implementation materials endorse a distinctly divergent pedagogical model reliant solely on virtual simulations. This gap is not a trivial technical inconsistency but a significant epistemological rupture that alters the presentation, instruction, and comprehension of science in educational institutions. The inquiry-based curriculum delineates a distinct perspective of science education as an empirical, material, and evidence-based process. In this context, experimenting serves not as a supplementary activity but as the primary means by which students generate knowledge, address ambiguity, and cultivate scientific reasoning. Nonetheless, the digital educational scenarios created to facilitate curriculum implementation entirely exclude authentic experimentation, substituting it with idealized and fully regulated virtual worlds. Consequently, critical aspects of scientific inquiry, such as measurement inaccuracy, procedural decision-making, material interaction, and engagement with unforeseen outcomes, are systematically excluded from students' educational experiences.

This imbalance has considerable educational implications. Relying solely on simulations at the student level may cultivate a reductive and deterministic perception of science, undermining the cultivation of inquiry skills that require direct interaction with real events. The availability of official resources that conflict with curricular concepts generates

pedagogical ambiguity at the teacher level, diminishing educators' ability to implement the curriculum with assurance and consistency. The conflict at the system level undermines curricular fidelity and poses issues with governance, supervision, and accountability in extensive digital reform programs.

The findings do not undermine the significance of digital tools in science education. Instead, they emphasize that digital technologies should be regarded as supplementary aids to inquiry, rather than replacements for empirical investigation. When intelligently integrated, virtual environments can improve visualization, preparation, and conceptual comprehension; nevertheless, when utilized in isolation, they may undermine the epistemic basis of scientific education.

The Greek example provides a significant insight for educational systems experiencing digital transformation. Modernization initiatives that emphasize technological implementation over pedagogical coherence may inadvertently undermine well-structured courses. Maintaining curricular integrity necessitates the development of implementation materials, whether digital or otherwise, under rigorous pedagogical oversight, with continuous engagement from subject matter experts and educators.

In summary, successful transformation in science education relies not on the degree of digitalization but on maintaining inquiry as a materially grounded, evidence-based discipline. Digital innovation may enhance this goal only when it is firmly grounded in the epistemological principles of science education.

Funding: This research received no external funding.

Informed Consent Statement: Not applicable.

Conflicts of Interest: The author declares no conflict of interest.

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