International Journal of Professional Development, Learners and Learning
2026, 8(2), e2616
ISSN 2754-0618 (Online)
https://www.ijpdll.com/
Research Article
OPEN ACCESS

Disciplinary balance in primary science education: The Greek curriculum in a European comparative perspective

Konstantinos T. Kotsis [1]*

[1] Department of Primary Education, University of Ioannina, Ioannina, GREECE
***Corresponding Author:** kkotsis@uoi.gr

Citation: Kotsis, K. T. (2026). Disciplinary balance in primary science education: The Greek curriculum in a European comparative perspective. *International Journal of Professional Development, Learners and Learning*, 8(2), Article e2616. https://doi.org/10.30935/ijpdll/19002

ABSTRACT

Primary school science education promotes scientific literacy, curiosity, and understanding of natural phenomena. European educational reforms have prioritized inquiry-based learning, multidisciplinary approaches, and the development of competencies to solve current social and environmental issues. Despite these common goals, national curricula structure scientific knowledge and distribute discipline information differently. This study investigates primary science education in selected European countries, focusing on the place of physics in the national curriculum. The study evaluates official curriculum frameworks and policy documents from Greece, Finland, the UK, France, and Germany using qualitative comparative document analysis. The analysis examines science subject organization, topic distribution, and physics' relative importance to biology, chemistry, and earth sciences. The findings show that most European curricula use integrated science models that evenly distribute knowledge across disciplines to enhance interdisciplinary understanding and scientific literacy. In contrast, the Greek curriculum places physics at the center of the upper primary classes, introducing scientific principles. This approach encourages the development of causal reasoning and supports experimental investigation, but it may limit students' exposure to other scientific fields that are increasingly vital for understanding global concerns. The study emphasizes balanced representation of disciplines and provides ideas for primary science curriculum development.

Keywords: primary science education, physics education, curriculum analysis, scientific literacy, European education systems

Received: 17 Mar. 2026 ◆ Accepted: 14 Jul. 2026

INTRODUCTION

The structure of science in primary education is a starting point for comparison. In several European countries, science is taught early on as an integrated topic. The multidisciplinary subject of environmental studies in Finland introduces science, critical thinking, and informed citizenship in early primary education. Early schooling shapes children's views of science and their long-term engagement with science learning and related careers. Science education research has shown that meaningful encounters with scientific ideas in primary education help students explain natural phenomena, develop curiosity about the world, and build cognitive frameworks for later scientific understanding. In modern knowledge societies, where scientific and technological advances affect nearly every aspect of daily life, primary science education develops reasoning, inquiry, and critical thinking skills.

International organizations and policies emphasize scientific literacy as a key education goal. Scientific literacy includes conceptual understanding, the real-world application of scientific reasoning, engagement with the social sciences, and responsible democratic decision-making. The OECD (2019) learning compass 2030 and UNESCO's education for sustainable development agenda emphasize interdisciplinary understanding, inquiry-based learning, and environmental and societal challenges in science curricula (Rieckmann, 2017). These frameworks promote education systems to integrate scientific knowledge across disciplines.

In this global setting, elementary science curricula vary considerably. Some school systems teach physics, biology, chemistry, and earth sciences as a single topic, whereas others emphasize specialized scientific fields. Many European countries have adopted integrated or interdisciplinary curriculum to enhance a holistic understanding of science and its societal implications

(Sjøberg, 2010; Tsiouri et al., 2024). Such approaches aim to expose students to a variety of scientific phenomena and establish linkages between scientific fields to promote scientific literacy.

Despite these transnational trends, country traditions and educational policies impact scientific curricula differently. Due to its systematic explanatory frameworks and ability to describe fundamental natural phenomena, physics is considered the foundational science in various countries. Motion, energy, electricity, and light can help students understand daily phenomena and improve causal reasoning (Osborne & Dillon, 2008). Physical science is generally fundamental to scientific education, especially in conceptual coherence and analytical thinking curricula.

In this worldwide context, Greek primary education is particularly interesting. The first three years of Greek primary school include science in "environmental studies," which includes natural sciences, geography, and social studies. Science is taught as "physics" (Φυσικά) from fourth grade onward, despite covering themes spanning biology, chemistry, and earth sciences. Numerous studies have found that this curriculum structure emphasizes physics notions like forces, energy, electricity, sound, and light while neglecting other scientific fields. As a result, science education in Greek primary schools is often effectively framed as physics education, particularly in the upper grades.

Physics dominates the Greek curriculum due to cultural and institutional traditions that view it as the most fundamental natural science. This approach has clear pedagogical advantages. Teachers can teach scientific reasoning using personal experiences and simple experiments because physical phenomena are typically visible in daily life. Carefully designed instructional exercises can help young learners reconstruct intuitive explanations and establish more scientifically accurate models of physical occurrences (Duit & Treagust, 2003; Ravanis, 2017). Physics can serve as an effective entry point for the development of scientific thinking and inquiry in early education.

A strong emphasis on physics may also raise concerns regarding the breadth of students' scientific experiences. Modern educational frameworks stress exposing students to life sciences, environmental science, and chemistry, which are linked to global issues like climate change, biodiversity loss, and public health. A curriculum that emphasizes physical phenomena may limit students' exposure to these scientific contexts and multidisciplinary viewpoints (Bybee, 2013; OECD, 2019). Research indicates that exposure to diverse scientific disciplines can enhance students' engagement with science and improve their scientific literacy (Sjøberg, 2010; Tsiouri et al., 2024).

Given these factors, studying how different countries build their primary scientific curricula can illuminate the link between academic traditions, educational policies, and pedagogical priorities. Comparative curriculum studies help researchers compare country education systems and assess how well they meet scientific education goals. Such evaluations are especially pertinent in Europe, where education systems share policy foundations but have significant curriculum autonomy.

This study primarily examines the Greek primary science curriculum as a central case, situating it within a comparative European framework to explore how disciplinary balance is constructed across different educational systems. The study compares Greek and other European education systems to determine how scientific disciplines are dispersed in elementary science curricula and how these patterns affect scientific literacy. The research intends to contribute to discussions regarding primary school science education organization and the balance between disciplinary depth and interdisciplinary breadth by qualitatively analyzing official curriculum documents and policy resources.

THEORETICAL FRAMEWORK

Current science education theories emphasize that primary school science education should foster scientific reasoning, inquiry skills, and informed citizenship in addition to factual information. Primary science education theories often emphasize scientific literacy as a key goal. Scientific literacy is the ability to grasp scientific concepts, analyze evidence, and apply scientific reasoning to everyday and socio-scientific problems. Modern educational frameworks emphasize that scientific literacy requires conceptual knowledge and critical engagement with scientific information in social, environmental, and technological contexts (Bybee, 2013; OECD, 2019). Scientific literacy from the start has been a goal in educational policy and curriculum design as societies become more dependent on science and technology.

In science education research, constructivist learning theory has helped explain how children learn science. Constructivism holds that students actively generate knowledge by interacting with their environment and reinterpreting their concepts. Students gain conceptual understanding by relating new experiences to past beliefs and mental models, not just absorbing information from professors or textbooks. According to Driver et al. (1994), young students typically enter the classroom with intuitive explanations of natural events that differ greatly from scientific views. These intuitive assumptions can remain in motion, heat, electricity, and light unless instruction clearly confronts students' preconceptions and provides conceptual restructuring chances (Kotsis, 2023). Thus, good science education must foster exploration, experimentation, and dialogue to help students test and enhance their ideas through guided inquiry.

International policy frameworks and educational reforms encourage inquiry-based scientific education (IBSE), which is heavily influenced by constructivism. Students research issues, establish hypotheses, collect evidence, and construct explanations based on empirical observations in inquiry-based approaches. These approaches mimic scientists' methods and allow students to experience science as a dynamic knowledge production process (Kotsis, 2024). Many studies have shown that inquiry-based learning can improve students' motivation, conceptual comprehension, and problem-solving skills when accompanied by adequate training and resources. Thus, many modern science curricula emphasize inquiry-based methods.

Besides pedagogical issues, science education theoretical disputes include curriculum organization. As academic scientific fields are organized, science education has traditionally taught physics, chemistry, and biology separately. Many educational scholars believe such disciplinary distinctions may not match how young learners perceive and interpret nature. Proposed integrated science curriculum stress the interconnectedness of scientific knowledge by integrating several disciplines under broader thematic frameworks (Sjøberg, 2010). Primary education often uses integrated models to educate children to a variety of scientific phenomena while retaining curriculum consistency and accessibility.

Physics has remained important in primary scientific teaching despite the rise of integrated science curriculum. This significance is due to physical notions' ability to explain everyday events. Motion, sound, heat, light, and electricity are easily visible and may be investigated through simple experiments, making them ideal for inquiry-based learning. Engaging with such occurrences may help youngsters develop causal reasoning and analytical thinking (Osborne & Dillon, 2008). Studies on conceptual development demonstrate that well-structured instructional interventions can help students turn intuitive beliefs about physical processes into scientific explanations (Duit & Treagust, 2003; Ravanis, 2017). Physics can introduce scientific reasoning and experimental inquiry in early schooling.

Physics' presence in science education raises problems regarding disciplinary balance and scientific literacy's goals. Students should be exposed to life, environmental, and chemical sciences in modern education. These fields are linked to climate change, sustainability, biodiversity conservation, and public health. Rieckmann (2017) and Bybee (2013) argue that a fair representation of scientific fields is necessary to prepare students to understand and handle complex global concerns. If some subjects dominate the curriculum, students may have a limited understanding of science and less opportunity to engage with social and environmentally relevant scientific problems.

Comparative research on European science curricula shows that several nations use multidisciplinary or integrated approaches that distribute knowledge fairly across scientific fields. Students will learn about a variety of scientific processes and the interdependence of natural systems using these models (Kotsis et al., 2025; Tsiouri et al., 2024). National education systems vary due to cultural traditions, educational policies, and historical trends. Some curriculum emphasizes intellectual depth and disciplinary coherence, while others emphasize interdisciplinary breadth and thematic integration.

The foregoing theoretical ideas highlight numerous important primary science curriculum analysis features. These include the importance of scientific literacy as an educational goal, constructivist and inquiry-based pedagogies, and disciplinary vs integrated science instruction. How these dimensions are mirrored in national curricula can reveal science education system aims and preconceptions. In example, studying the distribution of scientific disciplines in primary science curriculum can show how different countries view physics and other sciences in early scientific understanding. This study uses these theoretical views to assess and compare the disciplinary structures of selected European primary science curricula, focusing on physics' role.

SCIENCE EDUCATION IN EUROPEAN PRIMARY CURRICULA

Over the past few decades, European primary schools have changed science instruction to address changing social, technical, and environmental issues. Policymakers are reconsidering school science organization and goals as scientific literacy becomes more important for democratic participation and economic success. Primary education is vital for introducing pupils to scientific modes of thinking, generating interest about nature, and fostering good attitudes toward science learning (Harlen & Qualter, 2018). In response, many European countries have updated their curricula to emphasize inquiry-based learning, multidisciplinary viewpoints, and modern-day competences.

The progressive shift toward integrated primary science curricula in Europe has been a major development. Many national education systems currently teach science as a single topic that includes physics, biology, chemistry, and earth sciences. This approach recognizes that young learners experience natural events as interrelated processes rather than isolated disciplinary categories. Integrated curricula strive to give pupils a comprehensive view of nature, minimizing fragmentation from disciplinary learning (Sjøberg, 2010). Early learning emphasizes observation, investigation, and scientific thinking, hence such curriculum designs are prevalent.

European policies helped promote these curricular improvements. European Commission (2015) reports have frequently stressed the significance of inquiry-based science education to improve science instruction and student engagement. Inquiry-based techniques allow students to ask questions, create experiments, assess evidence, and form answers, resembling scientific inquiry. Besides improving conceptual understanding, such approaches have been linked to greater student motivation and science attitudes. Thus, many European primary science curricula emphasize inquiry-based activities, hands-on experimentation, and problem-solving.

Despite these similar strategic objectives, European science education systems vary greatly. Some education systems include science as a separate topic from early elementary school, while others integrate it into interdisciplinary disciplines like environmental education, geography, and social studies. These discrepancies reflect country curriculum design traditions and different views on how to teach young learners science. Science is integrated into environmental studies in Finland's early elementary years, highlighting links between natural occurrences, environmental awareness, and daily life. Several other European countries adopt interdisciplinary ways to combine science education with sustainability, health, and environmental responsibility (OECD, 2019).

Another noteworthy diversity is the distribution of scientific fields in primary science courses. Although integrated models are prevalent, governments' scientific domain priorities vary. Some curricula emphasize biology and the environment to promote ecological awareness and sustainable development. Some emphasize motion, energy, electricity, and light because these help build analytical reasoning and experimental skills. Comparative study shows that historical, cultural, scientific, and educational variables shape these differences (Tsiouri et al., 2024).

Physics is important in many science curricula because it can explain many natural occurrences. Fundamental concepts like force, motion, energy, and waves help students grasp everyday events and technological systems. Thus, basic education introduces physics through hands-on activities and simple experiments that explain physical concepts (Osborne & Dillon, 2008). Engaging with physical phenomena can help students build causal reasoning and go from intuitive explanations to formal scientific understanding (Duit & Treagust, 2003).

Modern science education frameworks emphasize disciplinary balance in curricula. Students need life, chemistry, and earth science to understand biological systems, environmental processes, and the world's materials. These domains are increasingly important for addressing climate change, biodiversity loss, public health concerns, and sustainable resource management. Thus, international educational programs promote the incorporation of environmental and socio-scientific themes into primary science curricula to link scientific knowledge to real-world situations (Bybee, 2013; Rieckmann, 2017).

Curriculum guidelines in Europe generally distribute thematic units across several scientific disciplines to balance disciplinary coverage. Many integrated curricula cover ecosystems, human health, materials and matter, energy transitions, and planetary systems. This method lets students examine scientific issues from several angles and emphasizes their interconnectedness. Comparative assessments have shown that multidisciplinary structures help broaden students' scientific knowledge (Tsiouri et al., 2024).

The degree of disciplinary balance differs between each country. Some education systems stress certain scientific disciplines more than others, reflecting long-standing science education traditions. Physics dominates the introduction of scientific concepts in upper primary school. These differences raise crucial questions regarding how curricular strategies affect students' science understanding and participation. Comparative examination reveals the educational assumptions behind country curricula and their conformity with scientific education aims.

Thus, understanding scientific education in European primary curriculum requires attention to shared policy frameworks and national educational traditions. International programs encourage inquiry-based learning, multidisciplinary viewpoints, and scientific literacy, although countries execute these concepts differently. Comparative curriculum analysis can help discover these similarities and assess how different education systems shape early scientific learning. Based on this perspective, this study examines the distribution of scientific disciplines in selected European primary science curricula, focusing on physics' relative significance and its effects on scientific literacy.

METHODOLOGY

This study examines how scientific disciplines are distributed across primary science curricula in selected European education systems using qualitative comparative document analysis. Educational research routinely analyzes policy documents, curriculum frameworks, and instructional materials to uncover trends, conceptual structures, and educational priorities (Bowen, 2009). National curricula are ideal for studying policy-level scientific education because they state educational goals, pedagogical principles, and disciplinary organization.

Comparative research allows detection of parallels and variations between national education systems. Education research has long used comparative curriculum analysis to examine how various countries organize learning objectives, instructional time, and disciplinary knowledge in school disciplines. Such analyses can show how historical traditions, policy agendas, and international frameworks shape national curriculum (Bray et al., 2014). Comparative studies are useful in science education to understand how different systems approach scientific literacy and balance disciplinary and interdisciplinary knowledge (Sjøberg, 2010).

The paper examines a few European countries whose main science curricula demonstrate different organizational patterns in European education. Greece is the main case study since science is integrated into environmental studies in the early grades and taught as "physics" in the upper elementary years. To place this situation in context, the analysis includes other European school systems with diverse science curricula and approaches. Finland, the UK, France, and Germany were chosen. These countries were chosen for their diversified

Table 1. Structure of science education in selected European primary curricula

Country	Structure of science in early primary grades	Structure in upper primary grades	Time/week	Curriculum orientation
Greece	Environmental studies and geography (integrating natural and social sciences)	Science taught as physics (*Φυσικά*) including elements of biology, chemistry, and earth sciences	~2 hours	Physics-centered
Finland	Environmental studies integrating science and geography	Continued interdisciplinary science learning	~2-3 hours	Phenomenon-based interdisciplinary
UK	Science is taught as a unified subject	Integrated science covering physics, biology, and chemistry	~2–3 hours	Balanced disciplinary model
France	Integrated science and technology education	Continued integrated science teaching	~2 hours	Interdisciplinary experimental approach
Germany	Science topics within interdisciplinary subjects (e.g., Sachunterricht)	Continued interdisciplinary science instruction	~2-3 hours	Environmental and integrated science

educational methods and well-documented curriculum frameworks in official educational policy documents and international comparative reports.

The analysis uses official curriculum materials, national education policy frameworks, and publicly available curriculum guidelines from ministries of education or similar national educational agencies. These texts outline primary education, science subject organization, curricular topic modules, and science teaching pedagogy. Supplementary sources include OECD (2019) and European Commission (2015) publications and scholarly literature on European science education policy development and implementation. Multiple sources help the study triangulate information and comprehend curricular systems more thoroughly.

The analysis proceeded in three main stages. First, curricular documents from each selected country were analyzed to determine how science instruction is positioned in elementary school. Science organization as a separate discipline or as part of an interdisciplinary domain like environmental studies or integrated science was emphasized. The second step examined science curriculum theme units and learning objectives to determine content distribution across disciplines. This study divided scientific material into four categories: physics, biology, chemistry, and earth or environmental sciences. These categories were chosen because they represent the key disciplinary fields in elementary scientific education and allow systematic comparison across country curricula.

The third stage of study examined the number and extent of thematic units and the conceptual complexity of themes for each discipline domain to determine the curricula's relative priority. The study identified patterns of disciplinary emphasis and assessed whether certain scientific topics dominate national curricula at this level. Comparative tables and descriptive summaries showed similarities and contrasts across the education systems.

Document analysis can reveal the structure and priorities of official curricula, but it has methodological limits. Curriculum materials reflect educational policy, not classroom practice. Based on teacher preparation, resources, and institutional support, instructors may interpret and apply curricular rules differently. In circumstances where instructors confront time, resource, or professional training constraints, IBSE can differ greatly from policy documents (Harlen & Qualter, 2018). The present study does not analyze classroom teaching approaches or student learning outcomes, but rather the conceptual and structural structuring of scientific curricula at the policy level.

Comparative document analysis is useful for studying national education systems and curriculum design patterns despite these constraints. The study examines curriculum frameworks in numerous European nations to see how different education systems view scientific fields in primary education. The investigation seeks to clarify physics' role in these curricula and examine how disciplinary distributions affect primary school students' scientific literacy. Comparative results in the next section are based on the methodological framework above.

RESULTS

Comparing primary science curriculum in selected European nations shows similarities and variances in scientific content arrangement and disciplinary distribution. Most European education systems promote scientific literacy and inquiry-based learning, although how scientific fields are represented in the curriculum varies. Different historical traditions, policy agendas, and pedagogical philosophies impact national science education frameworks.

The structure of science in primary education is compared first. In several European countries, science is taught early on as an integrated topic. In Finland's first years of elementary school, environmental studies cover nature, society, and daily living, including science. In France and the UK, science is taught as a single topic that includes physics, biology, chemistry, and earth science. This integrated approach supports the instructional goal of giving students a holistic grasp of natural events and developing scientific links.

As indicated in **Table 1**, most European primary education systems use an integrated science architecture, but scientific subjects are arranged and stressed differently. Finland, the UK, France, and Germany use interdisciplinary techniques in primary education, but the Greek curriculum organizes science on physics in the upper primary classes. These designs align with worldwide recommendations for

Table 2. Distribution of scientific disciplines in selected European primary science curricula

Country	Physics topics	Biology topics	Chemistry topics	Earth/environmental science	Overall disciplinary balance
Greece	Forces, motion, electricity, magnetism, sound, light, heat	Ecosystems, the human body	Matter, mixtures, simple chemical changes	Climate and environmental issues	Physics dominant
Finland	Energy, motion, light	Plants, animals, ecosystems	Materials and substances	Weather, environment, sustainability	Balanced interdisciplinary
UK	Forces, electricity, light, sound	Living things and habitats	Properties of materials	Earth and space	Balanced across disciplines
France	Energy, simple mechanics	Living organisms	Matter and transformations	Earth systems and environment	Moderately balanced
Germany	Physical phenomena, energy	Plants, animals, and the human body	Materials and matter	Environment and sustainability	Interdisciplinary

early scientific education that promote interdisciplinary learning and inquisitiveness (OECD, 2019).

Although primary science curricula are structurally similar, discipline content distribution varies widely among countries. Many European curricula emphasize biology and the environment, especially in early grades. Students are often introduced to scientific observation and reasoning through ecosystems, plant and animal life, human health, and environmental sustainability. These topics are relevant to daily life and social and environmental challenges, making them ideal for young learners (Bybee, 2013). Science concepts like matter, energy, and physical processes are covered throughout primary education.

Table 2 indicates a broadly balanced distribution of scientific disciplines across most European primary science curricula, in contrast to the Greek case, where physics assumes a dominant position. Biology, environmental science, and physical phenomena are usually taught together, giving primary school kids a broad scientific education. In contrast, the Greek curriculum emphasizes physics in the upper primary classes, where motion, electricity, sound, and thermal processes comprise the scientific framework.

In most European education systems, physics is embedded within integrated science curricula rather than functioning as a dominant disciplinary axis. Students learn about force and motion, electricity, light, sound, and energy transformations through simple experiments. These subjects encourage inquiry-based science education's focus on causal reasoning and hands-on experimentation (Osborne & Dillon, 2008). Physics is taught alongside biological, chemical, and environmental issues in most of the curriculum, ensuring that primary school kids learn a variety of scientific concepts.

In comparison with other European education systems, the Greek curriculum represents a distinctive disciplinary configuration. Environmental studies, which integrates natural sciences, geography, and social studies, covers science in the first three grades of primary school in Greece. From the fourth grade, science is taught as physics (*Φυσικά*). Although the curriculum covers biology, chemistry, and earth sciences, the texts and thematic sections emphasize physics. Electricity, magnetism, forces and motion, sound, light, and thermal phenomena are covered sequentially in upper primary. This arrangement positions physics as the primary gateway through which scientific knowledge is introduced in Greek primary education (Kallery & Psillos, 2001; Ravanis et al., 2004).

The comparison highlights that the Greek curriculum's emphasis on physics diverges from the more integrated disciplinary configurations observed in other European education systems. Finland, the UK, and France spread scientific information among many fields under a cohesive science topic, however the Greek curriculum emphasizes physics in later elementary school. Physics principles provide systematic explanatory frameworks for everyday phenomena, which can offer significant pedagogical advantages. When studied through hands-on experimentation, motion, heat transfer, and electrical circuits can help build causal reasoning and analytical thinking (Duit & Treagust, 2003).

However, the comparison findings show that the Greek curriculum's focus on physics may limit the presence of other scientific fields in elementary science education. Biological and environmental subjects are included throughout the elementary years in numerous curricula and linked to sustainability, health, and environmental awareness goals. In order to prepare students for global concerns, international educational frameworks increasingly highlight such subjects in school science (Rieckmann, 2017). A curriculum that devotes less room to life sciences and environmental issues may limit early student exploration of these issues.

Another interesting discovery is the relationship between disciplinary organization and pedagogy. Science teaching in European curricula emphasizes investigative approaches. To support conceptual understanding, curriculum guidelines encourage observation, experimentation, and classroom dialogue (Stylos et al., 2023). The ways inquiry is integrated into the curriculum depend on how scientific fields are structured and on the resources available in each educational situation.

Table 3 shows that European curricula emphasize inquiry-based learning. However, national educational traditions, resources, and teacher preparation affect inquiry-based methods. Many education systems promote interdisciplinary investigation and hands-on exploration, although classroom implementation varies.

Table 3. Inquiry-based learning features in selected European primary science curricula

Country	Inquiry-based activities	Experimental work	Use of everyday phenomena	ICT/digital tools	Teacher guidance in curriculum
Greece	Encouraged through observation, prediction, and simple investigations	Limited laboratory infrastructure; experiments often teacher-led	Strong emphasis on familiar physical phenomena	Increasing use of digital simulations	Inquiry recommended but unevenly implemented
Finland	Phenomenon-based learning encouraging student investigation	Hands-on experimentation integrated into interdisciplinary projects	Everyday contexts used to explore natural processes	Digital tools widely integrated	Strong emphasis on student-centered inquiry
UK	Inquiry encouraged through practical investigations and questioning	Regular practical classroom experiments	Scientific concepts linked to real-world contexts	ICT used for simulations and data collection	Structured guidance for experimental learning
France	Inquiry promoted through observation and guided experimentation	Classroom experimentation integrated with science and technology	Everyday situations used to introduce scientific ideas	Digital resources increasingly incorporated	Guided inquiry supported by teacher instruction
Germany	Inquiry integrated within interdisciplinary learning frameworks	Practical exploration of natural phenomena emphasized	Strong environmental and societal contexts	ICT varies by regional curriculum	Structured teaching materials supporting inquiry

Investigating interdisciplinary phenomena that link physical, biological, and environmental systems is common in integrated science models. More disciplinary inquiry activities may focus on experiments relating to certain scientific subjects, such as physics.

The comparative research shows that European primary science curricula share scientific literacy and inquiry-based learning goals but organize discipline knowledge differently. The Greek curriculum emphasizes physics in the upper primary schools, unlike many other countries' integrated approaches. This unique structure shows how national educational traditions continue to impact curriculum design and provides a setting for studying how disciplinary goals shape students' early science learning.

DISCUSSION

The comparative findings highlight the complex interplay between disciplinary traditions, pedagogical priorities, and policy objectives in elementary science curriculum design. European education systems promote scientific literacy and inquiry-based learning, yet scientific subjects are organized differently in national curricula. These variations reflect differing historical trajectories in science education and different views on how young learners should study science.

The analysis shows that many European education systems use integrated science frameworks. In some nations, elementary science courses incorporate physics, biology, chemistry, and earth sciences. This method supports theoretical approaches that emphasize scientific knowledge's interconnectedness and the need to portray research in ways that reflect real-world complexity. According to Sjøberg (2010), integrated curricula enable students to study scientific concepts in various contexts and understand the connections between physical, biological, and environmental processes. Interdisciplinary exposure may help students grasp how diverse scientific fields explain natural systems, promoting scientific literacy.

In addition, the comparative research shows that national curricula generally preserve conventional disciplinary structures, particularly in their emphasis on certain scientific disciplines. Physics is prominent in scientific education because it provides systematic frameworks for explaining fundamental natural processes. Motion, energy, and electricity can help pupils explain common events and build causal reasoning. Engaging with physical phenomena can help students go from intuitive explanations to formal scientific models, according to educational research (Driver et al., 1994; Osborne & Dillon, 2008). From this approach, physics in primary science courses can improve analytical and conceptual thinking.

The Greek elementary curriculum emphasizes physics. In the upper primary schools, the Greek curriculum constitutes a distinct disciplinary configuration in which physics serves as the primary epistemic framework for introducing scientific reasoning, unlike in many European countries. Longstanding educational traditions view physics as the basic science and an effective way to introduce pupils to scientific thinking (Kallery & Psillos, 2001). Students can construct structured explanatory frameworks and conduct experimental inquiry by exploring physical phenomena like motion, electricity, and thermal processes.

However, the Greek curriculum's emphasis on physics raises problems about disciplinary balance and students' scientific experiences. Modern science education frameworks stress exposing students to many scientific areas, especially biological and environmental systems that are increasingly relevant to global societal concerns. Because they link science to sustainability and social responsibility, ecosystems, biodiversity, climate change, and human health dominate worldwide science education discourse (Bybee, 2013; Rieckmann, 2017). If the curriculum emphasizes physical phenomena, students may have fewer chances to investigate these domains and build multidisciplinary perspectives on complicated scientific challenges.

Another key finding is the interaction between curricular structure and pedagogy. European policy texts increasingly emphasize inquiry-based science education's fundamental method. Inquiry-based approaches allow students to actively investigate scientific topics, design experiments, assess evidence, and form empirical interpretations. These methods mimic scientific inquiry and improve conceptual understanding and student involvement when executed properly (European Commission, 2015; Harlen & Qualter, 2018). Inquiry-based techniques can succeed depending on curriculum design, resources, teacher expertise, and institutional support.

Curriculum intentions and classroom implementation often differ in many educational settings, according to study. In settings where teachers lack science pedagogy training or laboratory resources are scarce, textbooks, demonstrations, and teacher-centered instruction may dominate inquiry-based curricula (Harlen & Qualter, 2018). Primary school systems with generalist teachers are most affected by this issue. Effective inquiry-based science education requires persistent investment in teacher professional development, instructional materials, and supportive educational infrastructures.

This study's comparative approach raises problems regarding science education's goals in modern nations. Science education must prepare students to understand and address complex social issues including climate change, technological change, and public health crises. This goal demands conceptual knowledge, critical thinking, interdisciplinary reasoning, and socio-scientific problem-solving in curriculum (OECD, 2019). This may need careful examination of how different scientific fields are represented in the curriculum and how they contribute to comprehensive scientific literacy.

The Greek curriculum exemplifies the tension between disciplinary coherence and interdisciplinary breadth in primary science education in many science education systems. The focus on physics encourages systematic thinking and experimental investigation, but it may obscure other scientific fields that are becoming more essential in science education. A fairer distribution of discipline content may increase students' exposure to scientific ideas and connect science education to social issues.

This study suggests that while European primary science curriculum share inquiry-based learning and scientific literacy goals, they differ in disciplinary knowledge organization. The Greek story shows how national educational traditions can alter science instruction and young learners' scientific experiences. Comparative analysis of these variations can inform science curriculum design and elementary education scientific literacy conversations.

IMPLICATIONS FOR CURRICULUM DEVELOPMENT

This study's comparative findings offer various insights into European elementary science curriculum improvement. Scientific literacy and inquiry-based learning are common goals in the investigated education systems, yet national curricula structure scientific fields differently. The variations show that curriculum design must balance disciplinary coherence with interdisciplinary breadth to facilitate meaningful and comprehensive science learning in early education.

The necessity for balanced scientific disciplines in primary science curricula is vital. Physics provides powerful explanations for natural occurrences, but modern science education increasingly integrates life sciences, environmental science, and chemistry into early science study. These fields are linked to modern society's sustainability, biodiversity, public health, and environmental stewardship. International educational frameworks underline that such themes can help students understand science and its relation to society (OECD, 2019; Rieckmann, 2017). Thus, curriculum makers may need to rethink how they distribute scientific knowledge to give elementary school kids a variety of scientific perspectives.

Secondary implications include integrative primary science education. Physical, biological, and environmental phenomena can be integrated into curricula to help students understand scientific knowledge and natural systems holistically. Energy utilization, climate change, and ecological dynamics necessitate multidisciplinary approaches. Curricula designed on thematic or problem-based frameworks enhance students' understanding of cross-disciplinary scientific concepts (Sjøberg, 2010). Such approaches may help promote systems thinking, which is crucial for solving complex environmental and technical issues.

Maintaining disciplinary organization in science programs helps conceptual clarity and advancement. Fundamental physics concepts like force, motion, and energy can help build causal reasoning and experimental thinking. Structured engagement with physical phenomena can help learners progress beyond intuitive explanations to scientific models, according to conceptual change research (Duit & Treagust, 2003). Curriculum designers must incorporate disciplinary perspectives into broader thematic frameworks that reflect scientific knowledge's interconnectedness.

Also significant is the interaction between curriculum design and teacher preparation. Primary school teachers' expertise and confidence are crucial to inquiry-based and transdisciplinary science curricula. Many school systems, including Greece, employ generalist primary teachers with little science knowledge. This can make it difficult for teachers to lead experiments, scientific inquiries, or integrate multiple scientific fields in a class. Research shows that prolonged professional development programs help instructors adopt inquiry-based instructional practices and improve their scientific knowledge (Harlen & Qualter, 2018). Successful curriculum reform requires improving teacher education and professional development.

Education infrastructure and materials are essential for inquiry-based science instruction. Many curricular frameworks encourage hands-on experimentation, collaborative investigation, and digital science exploration. However, adequate equipment, lab facilities, and digital learning tools are often needed to achieve these pedagogical goals. Without enough resources, teachers may use textbooks more, limiting student engagement and inquiry-based learning (Vlachos et al., 2024). Effective implementation of current science curricula requires investments in educational infrastructure like science labs, computer simulations, and classroom experimental equipment.

Assessment techniques are another area where curriculum development affects science teaching. Traditional primary scientific assessments like factual memory and written tests may not appropriately assess students' inquiry, problem-solving, and conceptual comprehension. Formative and performance-based assessments that allow students to create studies, understand evidence, and articulate scientific explanations are increasingly valued in educational research (Black & Wiliam, 2009). Thus, aligning assessment methodologies with science curricula's inquiry-based goals can improve learning.

These conclusions suggest that good elementary science curriculum must balance complementary goals. They should let students explore basic scientific concepts and learn about the diversity of scientific disciplines and their relevance to real-world challenges. Encourage inquiry-based learning and transdisciplinary thinking while ensuring conceptual progression across grades. Finally, curriculum change must include teacher professional development, instructional materials, and assessment techniques that promote modern science education pedagogy. This study's comparative viewpoint shows that primary scientific education has no single model. Instead, countries have created curricula that reflect their educational traditions and policy interests. The shared emphasis on scientific literacy and inquiry-based learning across Europe shows that future curriculum creation may benefit from education system discourse and collaboration. Such exchanges can help policymakers and educators find and adapt beneficial techniques to local contexts, improving scientific education for all children.

CONCLUSIONS

This study examined the organization and disciplinary distribution of science instruction across selected European primary education systems, focusing on physics' standing in relation to other scientific areas. The research compared official curriculum papers and educational policy frameworks to uncover patterns in primary science education and examine their effects on scientific literacy.

The findings show that European primary science curricula promote scientific literacy, inquiry-based learning, and science integration with everyday experiences. Many school systems use integrated science models that combine physics, biology, chemistry, and earth science principles. Modern educational viewpoints emphasize the interconnectedness of scientific knowledge and the need of introducing children to varied scientific phenomena in early learning. Sjøberg (2010) suggests that integrated curricula offer learners the chance to examine natural phenomena from various perspectives and get a deeper knowledge of scientific concepts.

The comparison analysis also showed that national curricula place different scientific subjects differently. Some European education systems evenly divide scientific information across disciplines, while others favor certain scientific fields. The Greek upper primary curriculum is centered around physics, making it unique. The curriculum covers biology, chemistry, and environmental science, but physics fundamentals like motion, energy, electricity, and thermal phenomena dominate. This structure reflects longstanding traditions in Greek science education and helps introduce scientific concepts to primary school students through physics (Kallery & Psillos, 2001; Ravanis et al., 2004).

The dominance of physics in the Greek curriculum presents both pedagogical strengths and limitations for science education. Physical phenomena offer easy entry points for scientific thinking and experimentation. Simple hands-on exercises can teach observation, prediction, and explanation of basic concepts like force, motion, and energy. Science education research suggests that such events can help students acquire causal reasoning and transition from intuitive to scientific explanations (Driver et al., 1994; Duit & Treagust, 2003). The emphasis on physics may help improve analytical thinking and conceptual comprehension in early scientific learning.

However, a single disciplinary approach may limit students' exposure to modern science's diverse scientific disciplines. To address global issues like climate change, biodiversity loss, and public health, modern educational frameworks stress integrating life sciences, environmental science, and chemistry into school curricula. Students need these areas to grasp biological systems, ecological linkages, and scientific knowledge's social impacts (Bybee, 2013; Rieckmann, 2017). Providing balanced exposure to diverse scientific fields in primary science courses may help children develop broad scientific literacy and engage with current scientific challenges.

The study also emphasizes curriculum design's role in early science learning. How scientific knowledge is arranged in the curriculum affects what students learn and how they view science. Curricula that emphasize interdisciplinary connections may help students see science as a dynamic and interconnected field, while those that emphasize individual disciplines may highlight concepts and explanations associated with specific scientific traditions. Both methods provide valuable instruction, but curriculum developers struggle to strike a balance between disciplinary coherence and interdisciplinary breadth.

Teacher preparation, instructional resources, and assessment practices affect elementary science curriculum implementation in addition to disciplinary factors. Curricula that encourage inquiry-based learning and transdisciplinary investigation may be difficult to implement without teacher and school support. Meaningful curriculum transformation requires teacher professional development, access to laboratory equipment and digital technologies, and inquiry-based assessment processes (Harlen & Qualter, 2018; OECD, 2019).

This study's comparative perspective shows that European primary schools have many science instruction techniques. Many countries share governmental goals for scientific literacy and inquiry-based learning, but scientific disciplines are organized inside curricula according to national educational traditions and interests. The Greek curriculum shows how a strong physics concentration can impact science education, with both pedagogical merits and weaknesses.

This analysis could be expanded by studying how these curricular structures are applied in classrooms and how they affect students' scientific learning and attitudes. An empirical study of teachers and students could reveal how different curricular models encourage inquiry-based learning and transdisciplinary understanding. The Greek case underscores how deeply rooted disciplinary traditions continue to shape curriculum design, highlighting the need for more balanced and context-sensitive approaches to primary science education.

Funding: The author received no financial support for the research and/or authorship of this article.

Ethics declaration: This study was based exclusively on the analysis of publicly available curriculum and policy documents and did not involve human participants, personal data, or interventions. Therefore, ethical approval and informed consent were not required.

AI statement: Generative AI tools were used solely to improve the English language of the manuscript. The author reviewed and approved all revisions and assumes full responsibility for the final content.

Declaration of interest: The author declares no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

REFERENCES

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21(1), 5-31. https://doi.org/10.1007/s11092-008-9068-5

Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative Research Journal*, 9(2), 27-40. https://doi.org/10.3316/QRJ0902027

Bray, M., Adamson, B., & Mason, M. (2014). *Comparative education research: Approaches and methods* (2nd ed.). Springer. https://doi.org/10.1007/978-3-319-05594-7

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA Press.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science: Research into children's ideas*. Routledge. https://doi.org/10.4324/9780203823583

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671-688. https://doi.org/10.1080/09500690305016

European Commission. (2015). *Science education for responsible citizenship: Report to the European Commission of the expert group on science education*. Publications Office of the European Union. https://doi.org/10.2777/12626

Harlen, W., & Qualter, A. (2018). *The teaching of science in primary schools* (7th ed.). Taylor & Francis. https://doi.org/10.4324/9781315398907

Kallery, M., & Psillos, D. (2001). Pre-school teachers' content knowledge in science: Their understanding of elementary science concepts and of issues raised by children's questions. *International Journal of Early Years Education*, 9(3), 165-179. https://doi.org/10.1080/09669760120086929

Kotsis, K. T. (2023). Alternative ideas about concepts of physics are a timelessly valuable tool for physics education. *Eurasian Journal of Science and Environmental Education*, 3(2), 83-97. https://doi.org/10.30935/ejsee/13776

Kotsis, K. T. (2024). Integrating inquiry-based learning in the new Greek primary science curriculum. *European Journal of Education and Pedagogy*, 5(6), 63-71. https://doi.org/10.24018/ejedu.2024.5.6.899

Kotsis, K. T., Randjelovic, B. M., Tsiouri, E., & Ilibašić, S. (2025). Comparing science curriculum for primary education in Greece and Serbia. *Journal of Studies in Education*, 15(1), 57-77. https://doi.org/10.5296/jse.v15i1.22528

OECD. (2019). *The future of education and skills 2030: OECD learning compass 2030*. OECD Publishing.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections*. Nuffield Foundation.

Ravanis, K. (2017). Early childhood science education: State of the art and perspectives. *Journal of Baltic Science Education*, 16(3), 284-288. https://doi.org/10.33225/jbse/17.16.284

Ravanis, K., Koliopoulos, D., & Hadzigeorgiou, Y. (2004). What factors does friction depend on? A socio-cognitive teaching intervention with young children. *International Journal of Science Education*, 26(8), 997-1007. https://doi.org/10.1080/0950069032000138851

Rieckmann, M. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO Publishing.

Sjøberg, S. (2010). *The ROSE project: An overview and key findings*. University of Oslo. https://www.uv.uio.no/ils/english/research/projects/rose/publications/the-rose-project.pdf

Stylos, G., Christonasis, A., & Kotsis, K. T. (2023). Pre-service primary teachers' views about scientific inquiry. *International Journal of Studies in Education and Science*, 4(2), 100-112. https://doi.org/10.46328/ijses.66

Tsiouri, E., Tsihouridis, C., & Kotsis, K. T. (2024). The science curricula for ages 11-12 across the European Union: A comparative analysis. *Eurasian Journal of Science and Environmental Education*, 4(2), 39-46. https://doi.org/10.30935/ejsee/15732

Vlachos, I., Stylos, G., & Kotsis, K. T. (2024). Primary school teachers' attitudes towards experimentation in physics teaching. *European Journal of Science and Mathematics Education*, 12(1), 60-70. https://doi.org/10.30935/scimath/13830