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## **Greek Preschool and Primary Teachers' Perceptions, Readiness and Challenges in Teaching Magnetism through Technology-Enhanced Inquiry-Based Science Education, as STEM, Robotics, and AI**

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### **Abstract**

This article reviews the preschool and primary teachers' perceptions, readiness, challenges, and professional needs in relation to teaching magnetism through Technology-Enhanced Inquiry-Based Science Education, as STEM integration, educational robotics, and AI. Magnetism is a conceptually demanding domain in early physics education due to its invisible, non-contact, and relational nature, and its effective teaching depends critically on teachers' epistemic confidence, pedagogical reasoning, and technological preparedness. Drawing on studies from the Greek educational context and the international literature, the article synthesizes empirical findings on how teachers interpret and enact innovation, highlighting the interplay of beliefs, professional identity, self-efficacy, and institutional context. The analysis reveals that while teachers generally recognize the motivational and pedagogical potential of STEM, robotics, and AI, they also confront significant

barriers related to limited content knowledge, insufficient training, time constraints, resource availability, and emotional insecurity. Teachers' experiences are characterized by a productive tension between enthusiasm for innovation and anxiety about competence, control, and developmental appropriateness. The article argues that meaningful transformation of magnetism teaching in the early years requires more than technological provision or curricular mandates; it demands sustained investment in teacher education, coherent professional development, collaborative cultures, and institutional support. By centering teachers as active agents of change, the article contributes to broader debates in physics education and teacher education about the human dimensions of pedagogical innovation and the conditions under which early science education can become epistemically rich, inclusive, and sustainable.

**Keywords:** Teachers' Perceptions, Magnetism, Early Childhood, Primary Education, STEM, Educational Robotics, Artificial Intelligence, Teacher Readiness

### **Introduction**

The successful integration of STEM education, educational robotics, and artificial intelligence (AI) into early childhood and primary science education is fundamentally mediated by teachers. Regardless of the sophistication of technological tools or the coherence of curricular frameworks, it is teachers' beliefs, knowledge, confidence, and pedagogical orientations that shape how innovations are interpreted and enacted in classroom practice <sup>[1]</sup>. This centrality of the teacher is particularly evident in the teaching of magnetism, a conceptually demanding domain characterized by invisible forces, action at a distance, and relational properties that are not directly accessible to perception. For many educators, magnetism represents not only a challenging topic for students but also an area of personal uncertainty, limited content knowledge, and restricted pedagogical repertoire <sup>[2, 3]</sup>. In early childhood and primary education, teachers play a pivotal role in shaping children's first encounters with scientific concepts. These early encounters are consequential, as they influence not only conceptual understanding but also learners' epistemic beliefs, attitudes toward science, and willingness to engage in inquiry. When teachers feel confident, supported, and pedagogically prepared, they are more likely to design learning environments that encourage exploration, dialogue, and conceptual development. Conversely, when teachers experience insecurity, lack of training, or institutional constraints, innovation is often reduced to superficial activity or avoided altogether <sup>[4, 5]</sup>. In the case of magnetism, where conceptual

difficulty intersects with limited everyday experience, the teacher's role as mediator and interpreter becomes even more critical.

The international literature consistently emphasizes that educational change is not achieved through the introduction of new tools alone but through the transformation of teachers' practices, beliefs, and professional identities, particularly through pedagogical approaches that foster innovation, agency, and problem solving in STEM learning [6]. STEM integration, educational robotics, and AI each require teachers to rethink traditional instructional roles, shift from transmissive to inquiry-oriented pedagogy, and engage with new forms of mediation and representation [7, 8, 9]. For many early childhood and primary teachers, this shift represents a significant departure from established routines and comfort zones. Studies show that while teachers often express positive attitudes toward innovation, these attitudes do not automatically translate into confident or sustained practice [3, 5].

In the Greek educational context, recent research has begun to systematically explore teachers' perceptions, readiness, and challenges in relation to STEM, educational robotics, and AI in early science education. Survey and qualitative studies reveal a complex picture in which enthusiasm for innovation coexists with uncertainty about content knowledge, pedagogical strategies, and classroom management [4, 5]. Many teachers recognize the potential of robotics and AI to enhance engagement and support experiential learning yet limited training and low self-efficacy in using these tools effectively. This tension is particularly pronounced in the teaching of magnetism, where teachers must navigate both conceptual complexity and technological novelty.

Magnetism occupies a unique position in early science curricula. It is often introduced through simple demonstrations or playful activities, yet its underlying mechanisms are rarely explored in depth. Teachers' own conceptual understanding of magnetism has been shown to be variable, with some educators holding misconceptions similar to those of their students [10, 11]. When teachers lack confidence in their content knowledge, they may avoid extended inquiry, rely on textbook explanations, or restrict activities to surface-level engagement. The introduction of STEM, robotics, and AI into this already challenging domain can therefore be perceived as both an opportunity and a threat: an opportunity to enrich learning, and a threat to professional competence and classroom control.

Educational robotics, in particular, has been widely promoted as a tool for enhancing engagement and supporting hands-on learning in early education. Research in Greece and internationally indicates that teachers generally view robotics positively, associating it with motivation, creativity, and active participation [12]. However, these positive attitudes are often accompanied by concerns about lack of training, insufficient resources, time constraints, and uncertainty about how robotics aligns with curricular goals. Similar patterns are evident in teachers' views on STEM integration, where enthusiasm for interdisciplinary learning is tempered by concerns about workload, assessment, and institutional support [3, 5].

AI introduces additional layers of complexity. While AI holds promise for adaptive learning, dialogic support, and visualization of abstract processes, it also raises ethical, pedagogical, and practical questions. Teachers may be

uncertain about the reliability of AI systems, the appropriateness of their use with young children, and their own role in AI-mediated learning environments [9, 13]. In early childhood contexts, where relationships, play, and human interaction are central, the introduction of AI can provoke ambivalence as well as curiosity. Understanding how teachers perceive and negotiate these tensions is therefore essential for any realistic account of AI integration in early science education.

Despite the growing body of research on STEM, robotics, and AI in education, there remains a lack of focused, integrative analysis of teachers' experiences specifically in relation to the teaching of magnetism in early childhood and primary education. Much of the existing literature treats teacher perceptions in general terms or focuses on single innovations without considering how multiple approaches intersect in practice. Moreover, studies often examine attitudes in isolation from institutional, cultural, and curricular contexts. This fragmentation limits our understanding of how teachers make sense of innovation and how their beliefs, readiness, and challenges shape implementation.

The present article addresses this gap by offering a comprehensive review and synthesis of research on preschool and primary teachers' perceptions, readiness, and challenges in teaching magnetism through STEM, educational robotics, and AI. Drawing primarily on studies conducted in the Greek educational context and situated within the international literature, the article examines how teachers interpret these pedagogical approaches, what opportunities and difficulties they perceive, and how institutional and cultural factors shape their practices. The focus is not on evaluating specific interventions but on understanding teachers as active agents who negotiate innovation within complex professional landscapes.

The present article examines how teachers perceive, enact, and sometimes resist these approaches. In doing so, it contributes to broader discussions in physics education and teacher education about the conditions under which pedagogical innovation can be meaningfully and sustainably realized. Understanding teachers' perceptions, readiness, and challenges is not a peripheral concern but a central component of any effort to transform early physics education.

### Methodological Approach of the Review

This article adopts a narrative-integrative literature review approach, aiming to synthesize and critically interpret research findings on preschool and primary teachers' perceptions, readiness, and challenges in teaching magnetism through Technology-Enhanced Inquiry-Based Science Education, including STEM integration, educational robotics, and artificial intelligence. Rather than pursuing exhaustive coverage, the review seeks theoretical coherence and conceptual depth, foregrounding teachers' beliefs, professional identities, and contextual constraints as central analytical lenses.

The literature included in this review was selected based on its direct relevance to at least one of the following criteria:

- (a) teaching magnetism or closely related physical science concepts in early childhood or primary education,
- (b) teachers' perceptions, self-efficacy, readiness, or professional development in relation to STEM, educational robotics, or AI, and

(c) inquiry-based and technology-enhanced approaches to science education with a focus on pedagogical implementation.

Peer-reviewed journal articles, scholarly books, and authoritative review studies published were considered, reflecting the rapid development of STEM education, educational robotics, and AI in educational contexts. Particular attention was given to studies conducted within the Greek educational context, which served as an analytically rich case embedded within the international literature.

Sources were identified through searches of major academic databases complemented by backward citation tracking of key publications. The selected studies were analyzed thematically, with emphasis on recurring patterns related to teachers' beliefs, epistemic confidence, emotional experiences, institutional conditions, and professional learning needs. This integrative approach allows for a nuanced understanding of how teachers interpret and negotiate pedagogical innovation in the conceptually demanding domain of magnetism.

### **Theoretical Perspectives on Teacher Beliefs, Readiness, and Change**

Understanding how preschool and primary teachers perceive, interpret, and enact innovation in magnetism requires a robust theoretical framework that foregrounds teacher cognition, professional identity, and change processes. Educational innovation does not occur in a vacuum; it is filtered through teachers' beliefs about teaching and learning, their sense of professional competence, and their perceptions of institutional expectations. In the context of STEM integration, educational robotics, and AI, these filters become particularly salient, as teachers are asked to adopt practices that may challenge long-standing routines, epistemological commitments, and comfort zones [7, 8].

Teacher beliefs constitute a central construct in educational research because they shape how teachers interpret curricula, select instructional strategies, and respond to reform initiatives. Beliefs about the nature of science, the purposes of education, and the role of the teacher influence whether innovations are embraced, adapted, or resisted.

In early childhood and primary education, teachers often held strong beliefs about the importance of care, play, and emotional security. These beliefs can intersect in complex ways with inquiry-based and technology-enhanced approaches, particularly when innovation challenges established pedagogical routines.

Research indicates that when teachers view science primarily as a fixed body of knowledge rather than as a process of inquiry, they are less likely to engage students in open-ended exploration and more likely to rely on demonstration and explanation. In the teaching of magnetism, such orientations can constrain opportunities for conceptual development and dialogic engagement [3, 10]. In magnetism teaching, such beliefs can lead to superficial treatment of phenomena and avoidance of conceptual challenge, particularly when teachers do not deliberately engage with learners' alternative ideas as productive resources for conceptual development [14].

Pedagogical beliefs are closely intertwined with teachers' professional identities. Identity encompasses teachers' self-perceptions as competent professionals, their sense of

belonging to a community of practice, and their moral commitments to students. The introduction of STEM, robotics, and AI can disrupt established identities by requiring teachers to adopt unfamiliar roles, such as facilitator of inquiry, designer of learning environments, or mediator of human-machine interaction. For some teachers, this disruption is experienced as an opportunity for growth and renewal; for others, it is a source of anxiety and resistance [4, 5]. Studies in the Greek context suggest that early childhood teachers, in particular, may experience tension between traditional images of the caring educator and emerging expectations to integrate digital technologies and engineering practices into their classrooms.

Teacher readiness is another critical dimension of innovation adoption. Readiness encompasses not only technical skills but also self-efficacy, content knowledge, and pedagogical confidence. Self-efficacy theory posits that individuals' beliefs in their capacity to perform tasks influence their willingness to attempt new practices, persist in the face of difficulty, and recover from setbacks [15]. In early science education, teachers' self-efficacy in relation to physics content has been shown to be variable and often low, particularly in domains such as magnetism that are perceived as abstract or difficult [10]. When low content confidence intersects with low technological confidence, as in the case of robotics and AI, readiness for innovation can be significantly undermined.

Professional development and prior experience play a central role in shaping readiness. Teachers who have participated in targeted training programs or collaborative projects are more likely to feel prepared to integrate STEM, robotics, and AI into their practice [5]. Conversely, teachers who have limited exposure to such approaches often report uncertainty, fear of making mistakes, and concern about classroom management. In the Greek educational system, where initial teacher education has traditionally placed limited emphasis on physics content and educational technology, these challenges are particularly pronounced. Research indicates that many preschool and primary teachers have had minimal formal preparation in magnetism and related physical science topics, relying instead on textbooks and personal experience [3].

Teacher change is not a linear or purely rational process. Changing theories in education emphasize that adopting new practices involves cognitive, emotional, and social dimensions. Teachers must not only learn new strategies but also renegotiate their beliefs, identities, and relationships. Fullan's work on educational change highlights the importance of meaning-making, arguing that reforms succeed only when teachers understand and internalize the purposes behind new initiatives. In the absence of such meaning-making, change is often superficial or short-lived. In the context of magnetism teaching, teachers may comply with curricular directives to integrate STEM or robotics without fundamentally altering their pedagogical approach, resulting in activity without conceptual depth [16, 13].

Sociocultural perspectives on teacher learning further emphasize that change is situated within communities of practice. Teachers learn not only through formal training but through interaction with colleagues, participation in professional networks, and engagement with institutional cultures. Norms, expectations, and power relations within schools shape what is considered legitimate practice. In environments where innovation is supported by leadership,

collaboration, and resources, teachers are more likely to experiment and take risks. In contrast, in contexts characterized by rigid curricula, high workload, and limited support, teachers may prioritize survival over innovation [4, 5]. Understanding teachers' experiences with magnetism teaching through STEM, robotics, and AI therefore requires attention to the broader institutional and cultural landscape. Beliefs about students also play a significant role in shaping teachers' practices. Teachers who view young children as capable thinkers are more likely to engage them in inquiry, problem solving, and conceptual discussion. Those who hold deficit-oriented views may simplify content, avoid challenge, and limit opportunities for exploration. Research in early science education shows that teachers' expectations of students' abilities influence the depth and quality of instruction [17]. In the case of magnetism, teachers who underestimate children's capacity for abstract reasoning may restrict activities to play without conceptual focus, thereby limiting learning opportunities.

The integration of AI introduces additional theoretical considerations related to authority, agency, and control. Teachers must negotiate the role of AI as a source of information and feedback, balancing its potential benefits with concerns about reliability and appropriateness. This negotiation intersects with teachers' beliefs about their own authority and responsibility in the classroom. Studies suggest that some teachers experience AI as a threat to professional autonomy, while others view it as a supportive partner [9, 13]. These perceptions shape how AI is framed and used in practice.

Taken together, these theoretical perspectives underscore that teachers' perceptions, readiness, and challenges are not merely individual attributes but are embedded in complex systems of belief, identity, experience, and context. In the teaching of magnetism through STEM, educational robotics, and AI, these systems intersect in particularly intricate ways. Teachers must navigate conceptual difficulty, technological novelty, and institutional expectations simultaneously. Theoretical frameworks that foreground beliefs, self-efficacy, identity, and sociocultural context therefore provide essential tools for interpreting empirical findings and for designing interventions that support meaningful change.

This theoretical grounding prepares the way for the empirical sections that follow, which examine preschool and primary teachers' perceptions of STEM integration, educational robotics, and AI in the teaching of magnetism. By situating these perceptions within a broader theoretical landscape, the article seeks to move beyond descriptive accounts toward a deeper understanding of the dynamics that enable or constrain pedagogical innovation in early physics education.

### **Teachers' Perceptions of STEM in Magnetism Teaching**

This section examines preschool and primary teachers' perceptions of STEM integration in magnetism teaching, with particular attention to perceived pedagogical benefits, practical challenges, and contextual constraints. Teachers' perceptions of STEM integration in the teaching of magnetism are shaped by a complex interplay of pedagogical beliefs, content knowledge, prior experience, and institutional context. In early childhood and primary education, STEM is often associated with innovation, interdisciplinarity, and active learning, and many teachers

express positive attitudes toward its potential to enhance engagement and relevance. In the Greek educational context, survey and qualitative studies indicate that preschool and primary teachers generally perceive STEM as a promising framework for enriching science instruction and for connecting abstract concepts to real-world applications [3, 4]. This positive orientation is particularly evident in relation to magnetism, which teachers frequently describe as a topic that benefits from hands-on, exploratory approaches. Teachers commonly report that STEM activities make magnetism more accessible and meaningful for young learners by embedding magnetic phenomena within purposeful tasks and problem-solving contexts, particularly when inquiry-based activities are used to support knowledge construction and skill development in early science learning [18, 19]. Rather than treating magnetism as a set of isolated facts, STEM integration allows teachers to situate it within engineering challenges, design projects, and everyday scenarios. For example, teachers describe activities in which children design simple vehicles, sorting systems, or games that rely on magnetic interactions, noting that such contexts help students see magnets as functional components rather than mysterious objects [20]. This functional framing aligns with teachers' beliefs about the importance of experiential learning and supports their sense that STEM can make difficult concepts more tangible.

At the same time, teachers' perceptions reveal a nuanced understanding of the demands that STEM integration places on their practice. While many express enthusiasm for interdisciplinary teaching, they also report uncertainty about how to balance multiple curricular goals, manage time, and assess learning within STEM projects. In magnetism teaching, this uncertainty is compounded by the conceptual difficulty of the content. Teachers acknowledge that designing STEM activities that are both engaging and conceptually meaningful is challenging, particularly when they lack strong background knowledge in physics [13, 10]. As a result, some teachers restrict STEM integration to superficial applications, such as simple crafts or demonstrations, without fully exploiting its potential for conceptual development.

Research suggests that teachers' perceptions of STEM are strongly influenced by their prior experiences with professional development and collaborative projects. Teachers who have participated in STEM training programs or school-based initiatives tend to report greater confidence and more sophisticated understandings of how STEM can support magnetism learning [5, 4]. They describe STEM not merely as an add-on but as a coherent pedagogical approach that integrates inquiry, design, and reflection. In contrast, teachers with limited exposure to STEM often view it as an additional burden or as a set of isolated activities, expressing concern about workload and classroom management. This variation highlights the role of professional learning in shaping perceptions and underscores the importance of sustained support.

Teachers also perceive STEM as a means of addressing student diversity. Many note that interdisciplinary, hands-on activities allow children with different learning styles and abilities to participate meaningfully. In magnetism lessons, for instance, children who struggle with verbal expression can demonstrate understanding through design and construction, while those who are more verbally inclined can articulate explanations and hypotheses. Teachers report

that such multimodal participation fosters inclusion and increases motivation <sup>[12]</sup>. However, they also caution that managing diverse groups within complex projects requires careful planning and support.

Institutional factors play a significant role in shaping teachers' perceptions. In contexts where school leadership supports innovation, provides resources, and values interdisciplinary work, teachers are more likely to view STEM integration positively and to experiment with new approaches <sup>[4, 5]</sup>. Conversely, in schools characterized by rigid schedules, heavy curriculum demands, and limited infrastructure, teachers often perceive STEM as unrealistic or impractical. In the Greek educational system, where curricula are often dense and assessment pressures high, some teachers express frustration at the lack of flexibility to implement extended STEM projects, particularly in early childhood settings.

Teachers' perceptions of STEM are also shaped by their beliefs about the nature of science and learning. Those who view science as a process of inquiry and problem solving are more likely to embrace STEM integration as congruent with their pedagogical philosophy. In contrast, teachers who conceptualize science primarily as a body of knowledge to be transmitted may struggle to reconcile STEM's open-ended, exploratory nature with their expectations of classroom order and control <sup>[3, 16]</sup>. In magnetism teaching, this tension can manifest in reluctance to allow students to explore freely or to tolerate uncertainty and error.

The literature further indicates that teachers' perceptions of STEM are dynamic and can evolve through experience. Longitudinal studies and qualitative accounts show that initial apprehension often gives way to greater confidence as teachers gain familiarity with STEM practices and observe positive student outcomes <sup>[20, 5]</sup>. In magnetism lessons, teachers report that witnessing students' excitement and conceptual progress reinforces their commitment to STEM integration, even in the face of challenges. This suggests that perceptions are not fixed but are shaped by ongoing interaction between beliefs, experience, and context.

Despite generally positive attitudes, teachers also articulate specific concerns related to assessment. Many express uncertainty about how to evaluate learning within STEM projects, particularly when outcomes are diverse and processes are as important as products. In magnetism teaching, where conceptual understanding may be implicit or embedded in action, teachers worry about how to document and justify learning, especially in systems that emphasize standardized assessment <sup>[17]</sup>. This concern can lead to cautious implementation or reliance on traditional assessment methods that may not capture the full range of learning.

Overall, teachers' perceptions of STEM in magnetism teaching are characterized by a combination of optimism and ambivalence. Teachers recognize the potential of STEM to make learning more engaging, relevant, and meaningful, particularly in a conceptually challenging domain. At the same time, they are acutely aware of the demands that STEM integrate places on their time, knowledge, and pedagogical skills. These perceptions are shaped by personal beliefs, professional experience, institutional context, and broader cultural narratives about education and technology. Understanding this complexity is essential for designing professional development, curricular frameworks, and support structures that respond to teachers' realities rather

than idealized models of innovation.

While STEM integration is often perceived by teachers as a pedagogical framework rather than a specific technological tool, its perceived challenges and affordances closely anticipate those reported for educational robotics and artificial intelligence. Across all three approaches, teachers articulate a recurring tension between pedagogical aspiration and practical feasibility, shaped by content knowledge, time constraints, and institutional conditions.

Compared to robotics and AI, STEM is generally perceived as less threatening to teachers' professional identities, as it aligns more closely with familiar inquiry-based and interdisciplinary practices. However, the challenges associated with STEM—such as balancing curricular demands, managing open-ended inquiry, and assessing learning—mirror those later intensified in robotics- and AI-supported instruction. In this sense, STEM functions as a conceptual gateway through which teachers first encounter the epistemic and pedagogical shifts demanded by technology-enhanced magnetism teaching.

Importantly, teachers' experiences with STEM appear to condition their openness to robotics and AI. Educators who report positive and supported experiences with STEM integration tend to approach robotics and AI with greater confidence, viewing them as extensions of inquiry-based pedagogy rather than disruptive innovations. Conversely, unresolved tensions at the STEM level often resurface more acutely in robotics and AI contexts, where technological complexity amplifies existing insecurities.

This cross-sectional perspective suggests that teachers' perceptions of STEM, robotics, and AI should not be treated as separate phenomena but as interconnected stages within a broader process of pedagogical change. Understanding this continuity is essential for designing professional development pathways that build progressively on teachers' experiences rather than introducing innovations in isolation.

### **Teachers' Perceptions of Educational Robotics in Magnetism Teaching**

This section focuses on teachers' perceptions of educational robotics as a mediating tool for magnetism learning, highlighting both its motivational affordances and the professional challenges it introduces. Educational robotics occupies a particularly visible and symbolically powerful position in contemporary discourses of educational innovation. For preschool and primary teachers, robotics is often associated with creativity, play, and technological advancement, and many educators perceive it as a motivating tool that can capture children's interest and support active learning. In the context of magnetism teaching, robotics is frequently viewed as a means of making invisible forces tangible and dynamic, thereby enhancing experiential understanding. Research in the Greek educational context consistently shows that teachers express positive attitudes toward the use of educational robotics in early science education, associating it with increased student engagement, enjoyment, and participation <sup>[20, 21]</sup>.

Teachers commonly describe robotics as an effective bridge between abstract concepts and concrete experience. In magnetism lessons, robots equipped with magnetic components or sensors allow children to observe the functional consequences of magnetic interactions, such as movement, stopping, or triggering actions. Teachers report that such activities help students see magnets not as static

objects but as active agents within systems, supporting the development of causal and relational reasoning <sup>[22, 20]</sup>. This functional framing resonates strongly with teachers' pedagogical beliefs about the value of hands-on learning and aligns with their desire to make science meaningful and accessible.

At the same time, teachers' perceptions of educational robotics are characterized by ambivalence and tension. While many express enthusiasm, they also articulate significant concerns related to technical competence, classroom management, and pedagogical alignment. A recurring theme in the literature is teachers' anxiety about their own lack of training and confidence in using robotics platforms. Preschool and primary teachers often report limited prior exposure to robotics during their initial education and professional development, leading to feelings of inadequacy and fear of failure <sup>[4, 5]</sup>. In magnetism teaching, where content itself may be perceived as difficult, this technological insecurity can be amplified.

Teachers frequently express concern about the time required to prepare, implement, and troubleshoot robotics activities. They note that setting up equipment, managing materials, and resolving technical issues can consume valuable instructional time, making robotics appear impractical within tight schedules. In early childhood settings, where routines and transitions are carefully structured, teachers worry that robotics activities may disrupt classroom flow and challenge behavioral management <sup>[12]</sup>. These practical considerations shape teachers' perceptions of feasibility and can limit their willingness to experiment with robotics, even when they recognize its pedagogical value.

Pedagogical alignment is another area of concern. Some teachers report uncertainty about how to integrate robotics meaningfully into magnetism lessons without reducing activities to play for play's sake. They express a desire to ensure that robotics supports conceptual learning rather than merely providing entertainment. This concern reflects deeper beliefs about the purpose of education and the role of play in learning. In early childhood contexts, teachers may struggle to reconcile playful robotics activities with expectations of curricular coverage and conceptual rigor <sup>[21, 16]</sup>. When teachers lack clear models or examples of conceptually grounded robotics integration, they may default to superficial use or avoid robotics altogether.

Research also indicates that teachers' perceptions of robotics are influenced by their beliefs about children's capabilities. Teachers who view young learners as capable of complex reasoning are more likely to see robotics as an appropriate and valuable tool for magnetism teaching. They describe children as curious, persistent, and able to engage with problem solving when supported appropriately. In contrast, teachers who hold more conservative views of children's abilities may perceive robotics as too complex or cognitively demanding for early learners <sup>[12, 23]</sup>. These beliefs shape not only whether robotics is used but how it is framed and scaffolded.

Institutional and infrastructural factors further mediate teachers' perceptions. Access to equipment, technical support, and administrative encouragement significantly influences whether teachers view robotics as an opportunity or a burden. In schools where robotics kits are readily available and supported by leadership, teachers report greater confidence and more positive experiences <sup>[4]</sup>. Conversely, in contexts where resources are scarce or shared

among many classes, teachers may perceive robotics as unrealistic or inequitable. These material conditions intersect with teachers' beliefs and experiences, shaping their overall stance toward robotics integration.

Teachers' perceptions also evolve through practice. Qualitative studies indicate that initial apprehension often gives way to increased confidence and appreciation as teachers gain experience with robotics and observe positive student outcomes <sup>[21]</sup>. In magnetism lessons, teachers report that seeing children formulate hypotheses, test ideas, and revise explanations reinforces their belief in the value of robotics as a learning tool. This experiential dimension is critical, as it suggests that perceptions are not fixed but can be transformed through supported practice.

However, the literature also documents cases in which negative experiences, such as technical failures or classroom management difficulties, reinforce resistance and avoidance. Teachers who encounter repeated challenges without adequate support may conclude that robotics is impractical or inappropriate, particularly in early childhood settings <sup>[5]</sup>. This underscores the importance of providing ongoing professional development, mentoring, and technical assistance to sustain positive perceptions and practices.

In relation to magnetism specifically, teachers often highlight the potential of robotics to make learning more dynamic and interactive. They note that robots can illustrate magnetic attraction and repulsion in ways that static demonstrations cannot, enabling children to see immediate consequences of their actions. At the same time, teachers emphasize the need for careful scaffolding to ensure that students attend to the underlying phenomena rather than focusing solely on the robot as a novelty object. This concern reflects an awareness of the risk of technological distraction and a desire to maintain conceptual focus <sup>[16, 21]</sup>.

Overall, teachers' perceptions of educational robotics in magnetism teaching are characterized by a productive tension between enthusiasm and caution. Teachers recognize robotics as a powerful tool for engagement and experiential learning, particularly in a conceptually challenging domain. At the same time, they are acutely aware of the demands that robotics places on their knowledge, skills, time, and classroom management. These perceptions are shaped by beliefs about teaching and learning, views of children's capabilities, prior experience, and institutional context. Understanding this complexity is essential for designing professional development and support structures that address teachers' concerns and build on their aspirations.

### **Teachers' Perceptions of Artificial Intelligence in Magnetism Teaching**

This section explores teachers' perceptions of artificial intelligence in magnetism teaching, emphasizing conceptual ambiguity, ethical concerns, and implications for pedagogical authority. Artificial intelligence represents the most recent—and for many preschool and primary teachers, the most conceptually ambiguous—innovation considered in this review. In educational discourse, the term AI is often used as an umbrella concept encompassing a wide range of digital tools with varying degrees of autonomy, adaptivity, and pedagogical function. This conceptual breadth contributes to teachers' uncertainty and complicates meaningful pedagogical integration, particularly in early childhood and primary science education.

For analytical clarity, the present review distinguishes between three pedagogically relevant forms of AI in the context of magnetism teaching:

- (a) AI-supported visualizations and simulations that dynamically represent magnetic interactions and invisible processes;
- (b) AI-driven adaptive or dialogic systems that provide feedback, prompts, or differentiated support during inquiry activities; and
- (c) AI tools that support teachers' instructional planning and orchestration, including lesson design, experiment planning, and formative assessment support. These forms differ substantially in their epistemic role, degree of autonomy, and implications for teacher authority and classroom interaction.

Teachers' perceptions of AI are shaped not only by the perceived affordances of these tools but also by their alignment with inquiry-based pedagogy and developmental appropriateness. AI-supported simulations are often viewed as the most accessible and least disruptive form, as they extend familiar practices of visualization and representation in physics teaching. In contrast, adaptive and dialogic AI systems raise more profound pedagogical and ethical questions related to authority, trust, and the distribution of epistemic responsibility between teacher, learner, and algorithm. AI tools that support teachers' planning tend to be perceived as less visible to students and, consequently, less threatening to established classroom relationships.

This differentiation allows for a more nuanced interpretation of teachers' ambivalent attitudes toward AI. Rather than reflecting a generalized resistance to innovation, teachers' hesitations often correspond to specific forms of AI and to concerns about control, transparency, and the preservation of relational and inquiry-oriented dimensions of early science education.<sup>[13, 9]</sup>

Research in the educational context indicates that many preschool and primary teachers view AI as a potentially valuable tool for supporting individualized learning, providing feedback, and visualizing abstract phenomena<sup>[24]</sup>. Teachers often associate AI with adaptive learning systems, intelligent tutoring, and interactive applications that can respond to students' input in real time. In magnetism lessons, teachers recognize that AI could help children explore invisible processes, test predictions, and receive guidance when they encounter difficulties. This perceived potential aligns with teachers' desire to support diverse learners and to scaffold understanding in a conceptually demanding domain<sup>[13]</sup>.

At the same time, teachers' perceptions are characterized by significant uncertainty. Many report limited understanding of what AI actually entails and how it differs from more familiar digital tools. This lack of conceptual clarity can generate anxiety and hesitation. Teachers express concern about their own preparedness to use AI responsibly and effectively, particularly with young children. In early childhood contexts, where relationships, emotional security, and human interaction are central, some teachers worry that AI might undermine the relational dimension of teaching or reduce opportunities for social interaction<sup>[9, 13]</sup>. These concerns reflect deeper beliefs about the nature of education and the role of the teacher.

Ethical considerations feature prominently in teachers' perceptions. Teachers raise questions about data privacy, the safety of children's information, and the transparency of AI

systems. They express unease about who controls AI applications, how data are used, and whether algorithms may introduce bias. In magnetism teaching, where AI might be used to track responses or guide inquiry, teachers are particularly sensitive to issues of surveillance and control. These ethical concerns are often intensified by a lack of clear institutional guidelines and training, leaving teachers to navigate complex issues without adequate support<sup>[9]</sup>.

Teachers also negotiate questions of authority and agency in relation to AI. Some express concern that AI could be perceived by students as an authoritative source of knowledge, potentially undermining the teacher's role as mediator and guide, while others emphasize its potential as a supportive instructional resource when appropriately integrated into science teaching<sup>[25]</sup>. This is particularly salient in early education, where teachers play a central role in shaping epistemic norms and relationships of trust. Teachers worry that children may attribute undue authority to AI-generated feedback or explanations, leading to uncritical acceptance. Others, however, view AI as a supportive partner that can enhance their teaching and provide additional scaffolding, particularly in large or diverse classrooms<sup>[13, 9]</sup>. These divergent perceptions reflect differences in teachers' professional identities and beliefs about control and responsibility.

In relation to magnetism specifically, teachers perceive AI as offering unique opportunities for visualization and representation. Because magnetic fields and forces are invisible, teachers recognize the potential of AI-supported simulations and dynamic representations to make relational structures more explicit, particularly when accompanied by structured lesson plans and pedagogical guidance<sup>[26]</sup>. They describe the possibility of using AI tools to show how attraction varies with distance, how orientation affects interaction, or how different materials respond to magnets. Such representations are seen as potentially valuable for supporting conceptual understanding, particularly for students who struggle with abstract reasoning<sup>[10, 13]</sup>. However, teachers also express concern that students may focus on the visual effects without understanding underlying mechanisms, underscoring the need for careful pedagogical framing.

Teachers' perceptions of AI are also influenced by their broader experiences with digital technologies. Those who feel confident using computers, tablets, and interactive software are more likely to view AI as an extension of existing practice and to express curiosity and openness. In contrast, teachers with limited technological confidence often perceive AI as intimidating and beyond their competence<sup>[4]</sup>. This pattern mirrors findings in the literature on technology adoption, which highlight the role of self-efficacy in shaping attitudes and practices.

Institutional context again plays a decisive role. In schools where digital innovation is encouraged and supported, teachers report more positive perceptions and greater willingness to experiment with AI applications. Where infrastructure is limited, training is scarce, or leadership is cautious, teachers are more likely to view AI as unrealistic or inappropriate. In the Greek educational system, where AI integration in early education is still emerging, many teachers report a lack of clear policy direction and practical guidance, contributing to uncertainty and cautious attitudes<sup>[13]</sup>.

Teachers also express concerns about developmental appropriateness. Some question whether AI applications are suitable for young children, given their cognitive and emotional development. They worry about screen time, reduced physical activity, and the potential for over-reliance on technology. In magnetism teaching, where hands-on exploration is traditionally valued, teachers emphasize the importance of maintaining physical manipulation of materials and social interaction, viewing AI as a supplementary rather than central tool [23]. This perspective reflects a desire to balance innovation with pedagogical values rooted in play, embodiment, and human connection.

Despite these concerns, evidence from the literature suggests that teachers' perceptions of AI are not static but evolve through experience, support, and reflective practice. Studies indicate that when teachers participate in professional development focused on AI and observe positive student responses, their confidence and openness increase [13, 9]. In magnetism lessons, teachers who have experimented with AI-supported activities report that students are engaged, ask questions, and show curiosity about underlying processes. These experiences can challenge initial skepticism and foster more nuanced views of AI as a pedagogical resource.

However, the literature also highlights the risk of superficial adoption. Teachers may use AI tools in limited or decorative ways, without integrating them meaningfully into conceptual learning. This risk is heightened when teachers lack clear pedagogical models or when AI is introduced through top-down mandates rather than collaborative exploration [16, 13]. In such cases, teachers' perceptions may remain ambivalent or negative, reinforcing resistance.

Overall, teachers' perceptions of AI in magnetism teaching are characterized by a dynamic interplay of hope and hesitation. Teachers recognize the potential of AI to support visualization, differentiation, and inquiry in a conceptually challenging domain. At the same time, they express concerns about ethics, authority, developmental appropriateness, and their own preparedness. These perceptions are shaped by beliefs, professional identity, technological confidence, and institutional context. Understanding this complexity is essential for designing professional development, policy frameworks, and support structures that enable teachers to engage with AI in informed and confident ways.

### **Teachers' Readiness, Challenges, and Barriers in Implementing STEM, Educational Robotics, and AI in Magnetism Teaching**

While teachers' perceptions of STEM, educational robotics, and AI are an important indicator of openness to innovation, perceptions alone do not determine practice. The translation of positive attitudes into sustained pedagogical action is mediated by teachers' readiness and by a range of structural, professional, and cultural barriers. In the teaching of magnetism, these dynamics are particularly salient because teachers must negotiate conceptual difficulty, technological complexity, and institutional constraints simultaneously. Research consistently shows that readiness is not a single attribute but a multidimensional construct encompassing content knowledge, pedagogical competence, technological confidence, and professional identity [27].

One of the most persistent challenges identified in the literature is limited content knowledge in physics, and

magnetism in particular. Many preschool and primary teachers report that they feel inadequately prepared to teach magnetism in depth, often relying on textbook explanations or simple demonstrations. Studies indicate that some teachers hold misconceptions similar to those of their students, such as overgeneralizing magnetic properties to all metals or conceptualizing magnetism as a static property rather than a relational interaction [10, 11]. When teachers lack confidence in their own understanding, they are less likely to design inquiry-based activities, facilitate open discussion, or respond flexibly to students' questions. This epistemic insecurity constitutes a fundamental barrier to innovative practice.

Pedagogical readiness is another critical dimension. STEM integration, robotics-supported learning, and AI-mediated inquiry all require shifts from transmissive to facilitative teaching roles. Teachers must design open-ended tasks, manage group work, scaffold inquiries, and tolerate uncertainty. For many educators, particularly those trained in more traditional pedagogies, these shifts are challenging. Research in the Greek context suggests that while teachers often endorse inquiry-based learning in principle, they struggle to enact it in practice, particularly when working with abstract content such as magnetism [1]. The tension between curriculum coverage and exploratory learning further complicates pedagogical decision-making.

Technological readiness constitutes a third major dimension of challenge. Many preschool and primary teachers report limited experience with educational robotics platforms and AI applications. This lack of familiarity generates anxiety and reduces willingness to experiment. Teachers express fear of technical failure, concern about losing classroom control, and uncertainty about troubleshooting [20, 22]. In magnetism teaching, where robotics and AI are often introduced as means of making invisible phenomena visible, technological insecurity can undermine the very pedagogical strategies intended to support understanding.

Time constraints emerge as a recurrent barrier across studies. Teachers report that planning STEM projects, preparing robotics activities, and exploring AI tools require significant time investment. In educational systems characterized by dense curricula and heavy administrative workload, teachers struggle to find space for extended inquiry or design-based learning [5, 4]. In early childhood settings, where routines and transitions are tightly scheduled, the introduction of complex activities is perceived as disruptive. This structural constraint often leads teachers to prioritize familiar, low-risk practices over innovative but time-consuming approaches.

Resource limitations further constrain implementation. Access to robotics kits, digital infrastructure, and AI applications is uneven, both across schools and within schools. Teachers in well-resourced environments report greater readiness and confidence, while those in under-resourced contexts express frustration and resignation [20, 5]. In the Greek educational system, disparities in infrastructure and funding shape teachers' perceptions of feasibility and equity. When resources are scarce, teachers may view STEM, robotics, and AI as luxuries rather than necessities, limiting their integration into everyday practice.

Institutional support is another decisive factor. Teachers are more likely to experiment with innovative approaches when school leadership encourages risk-taking, provides resources, and values professional learning, particularly

within the context of inquiry-based curriculum reforms that place new demands on assessment practices and digital innovation [28]. Conversely, in environments characterized by rigid hierarchies, emphasis on standardized assessment, and limited collaboration, teachers often perceive innovation as risky or unsupported [4]. In magnetism teaching, where conceptual understanding may not be easily assessed through traditional tests, teachers worry about accountability and external evaluation, which can discourage experimentation.

Professional development is widely recognized as a key lever for enhancing readiness, yet the literature reveals significant gaps in the availability and quality of training, particularly in relation to emerging technologies such as artificial intelligence, which require support for both pedagogical planning and classroom enactment [24]. Many teachers report that professional development related to STEM, robotics, and AI is sporadic, theoretical, or disconnected from classroom realities [5, 20]. Teachers express a desire for hands-on, practice-oriented training that addresses both content knowledge and pedagogical strategies. In magnetism teaching, they seek concrete examples of activities, opportunities to observe experienced colleagues, and guidance on how to scaffold inquiry and manage technology. The absence of sustained, coherent professional development limits teachers' capacity to move beyond initial experimentation.

Emotional factors also play a significant role in shaping readiness and practice. Teachers' narratives reveal feelings of anxiety, vulnerability, and fear of failure in relation to technological innovation. These emotions are particularly pronounced among teachers who identify strongly with traditional images of the caring, nurturing educator and who fear that technology may disrupt established relationships [12]. At the same time, teachers who have positive experiences with innovation report feelings of excitement, professional renewal, and increased self-efficacy. These emotional dynamics underscore that readiness is not purely cognitive but deeply affective.

In Greece, as in many countries, early childhood education has historically emphasized socialization and care, with limited emphasis on physics or engineering content, despite recent curricular reforms that formally foreground inquiry-based science learning in primary education [29]. In contexts where academic achievement is narrowly defined and innovation is viewed with suspicion; teachers may experience pressure to conform to traditional practices. In Greece, as in many countries, early childhood education has historically emphasized socialization and care, with limited emphasis on physics or engineering content. The introduction of STEM, robotics, and AI into this context can therefore be perceived as incongruent with established norms, creating additional barriers to acceptance [3, 4].

The intersection of these challenges is particularly evident in magnetism teaching. Teachers must navigate a concept that is epistemically demanding, a set of pedagogies that require significant shifts in practice, and technologies that demand new skills. When these demands accumulate without adequate support, readiness is undermined and innovation stalls. Conversely, when teachers receive coherent professional development, institutional support, and opportunities for collaborative learning, they are more likely to overcome initial barriers and develop confidence [5].

Importantly, the literature also highlights teachers' resilience and agency. Despite challenges, many teachers demonstrate creativity, persistence, and commitment to improving their practice. They adapt activities to their contexts, seek out resources, and learn through trial and error. In magnetism lessons, teachers describe experimenting with simple materials, modifying robotics tasks, and gradually incorporating AI tools as their confidence grows. These accounts underscore that teachers are not passive recipients of reform but active agents who negotiate innovation within their professional realities.

Overall, teachers' readiness, challenges, and barriers in implementing STEM, educational robotics, and AI in magnetism teaching are shaped by a complex interplay of knowledge, beliefs, emotions, resources, and institutional context. Addressing these factors requires systemic approaches that combine professional development, resource provision, leadership support, and curricular flexibility. Without such support, innovation risks remain episodic and superficial. With it, teachers can develop the confidence and competence needed to transform magnetism teaching in meaningful and sustainable ways.

### **Implications for Teacher Education and Professional Development**

The analysis of preschool and primary teachers' perceptions, readiness, challenges, and barriers in teaching magnetism through STEM, educational robotics, and AI has profound implications for teacher education and professional development. The findings reviewed in this article make clear that innovation in early physics education cannot be reduced to the provision of new tools or the dissemination of curricular guidelines. Rather, it requires sustained investment in teachers' conceptual understanding, pedagogical reasoning, technological confidence, and professional identity. Teacher education must therefore be reconceptualized as a process of epistemic and pedagogical transformation rather than technical training.

A central implication concerns the role of content knowledge in early childhood and primary teacher preparation. The persistent insecurity reported by teachers in relation to magnetism highlights longstanding gaps in physics preparation within early education programs. Many teachers enter the profession with limited exposure to physical science beyond basic survey courses, and magnetism is often treated superficially or not at all, a pattern already evident at the pre-service stage in relation to physics teaching self-efficacy [15]. As a result, teachers may rely on intuitive or everyday explanations that are insufficient for supporting conceptual change in learners [10]. Teacher education programs must therefore place greater emphasis on deep, conceptually oriented engagement with physical science, including opportunities to explore phenomena, confront misconceptions, and construct coherent explanatory models. This does not imply transforming early childhood teachers into physicists, but it does require recognizing that epistemic confidence is a prerequisite for pedagogical innovation.

Pedagogical preparation is equally critical. The integration of STEM, robotics, and AI demands that teachers move beyond transmissive models of instruction and adopt inquiry-oriented, design-based, and dialogic practices. However, many teachers report that their initial training

emphasized classroom management and routine planning rather than the orchestration of open-ended inquiry [3, 4]. Professional development must therefore focus on pedagogical reasoning: how to design tasks that elicit learners' ideas, scaffold exploration, support explanation, and foster reflection. In magnetism teaching, this includes learning how to sequence activities to generate cognitive conflict, how to use representations effectively, and how to facilitate discussion around invisible processes.

Technological preparation must also be reframed. Too often, professional development in educational technology focuses on the mechanics of tool use rather than on pedagogical integration, neglecting opportunities for teachers to engage with artificial intelligence as a tool for instructional design, classroom orchestration, and reflective practice [25]. Teachers learn how to operate robotics kits or digital platforms but receive little guidance on how to align these tools with conceptual goals. The literature reviewed here suggests that such fragmented training contributes to superficial adoption and technological distraction [16, 21]. Effective professional development should therefore integrate content, pedagogy, and technology, enabling teachers to see how robotics and AI can mediate specific learning processes in magnetism. This requires moving beyond one-off workshops toward sustained, practice-based learning that supports teachers in planning, implementing, and reflecting on physics activities with the aid of intelligent tools [24].

The importance of experiential learning in teacher education emerges as a recurring theme. Teachers' perceptions of STEM, robotics, and AI become more positive and nuanced when they have opportunities to engage with these approaches as learners, to experiment in low-risk environments, and to reflect on their experiences [5]. Professional development programs should therefore include hands-on activities, collaborative design tasks, and opportunities to observe and discuss classroom implementations. In magnetism education, this might involve teachers designing and testing their own STEM activities, building simple robotic systems, or exploring AI-supported simulations. Such experiences can support both conceptual understanding and pedagogical confidence.

Collaboration and community building are also essential. Sociocultural theories of learning emphasize that professional growth is situated within communities of practice. Teachers learn through interaction, dialogue, and shared problem solving. The isolation reported by many teachers, particularly in relation to innovative practices, undermines readiness and resilience [4, 5]. Professional development initiatives should therefore foster collaborative cultures, providing spaces for teachers to share experiences, discuss challenges, and co-construct solutions. In magnetism teaching, collaborative planning and reflection can help teachers navigate conceptual difficulty and technological complexity.

Mentoring and coaching models offer additional promise. Teachers who have access to experienced mentors or instructional coaches are more likely to persist in innovation and to refine their practice over time. Mentors can provide feedback, model strategies, and support reflection, helping teachers move beyond initial experimentation toward more sophisticated practice. In contexts where formal mentoring is not available, peer mentoring and professional learning communities can serve similar functions [20].

The analysis also points to the importance of addressing emotional dimensions of teacher learning. Anxiety, fear of failure, and vulnerability are common in relation to technological innovation, particularly among teachers who identify strongly with traditional professional identities [12]. Professional development must therefore be psychologically safe, valuing experimentation, acknowledging difficulty, and normalizing struggle. When teachers feel supported rather than judged, they are more likely to take risks and engage deeply with new approaches.

Institutional support is a further critical factor. Teacher education and professional development cannot compensate for unsupportive organizational contexts. School leadership plays a key role in shaping norms, allocating resources, and signaling the value of innovation. Leaders who encourage inquiry, provide time for collaboration, and invest in resources create conditions in which professional learning can flourish [4]. In magnetism teaching, where extended inquiry and design-based projects require time and flexibility, such support is indispensable.

Finally, the implications extend to policy. Educational policies that mandate innovation without providing resources, training, and support risk generating compliance without commitment. Policymakers must recognize that integrating STEM, robotics, and AI into early physics education is a complex process that requires systemic investment. This includes funding for resources, time for professional development, and alignment of curricula and assessment with inquiry-oriented practices. Without such alignment, teachers are placed in untenable positions, expected to innovate within structures that reward conformity.

In sum, the findings of this article suggest that teacher education and professional development must be reoriented toward deep conceptual engagement, pedagogical reasoning, integrated technological understanding, and professional identity formation. Magnetism, as a conceptually demanding domain, highlights the consequences of neglecting these dimensions. If early physics education is to be transformed into meaningful and sustainable ways, teachers must be supported not only as implementers of innovation but as reflective practitioners and co-constructors of pedagogical knowledge.

## Conclusions and Future Research Directions

This review has highlighted that preschool and primary teachers' engagement with STEM integration, educational robotics, and artificial intelligence in the teaching of magnetism is shaped by a complex interplay of beliefs, epistemic confidence, emotional experience, and institutional context. Teachers' perceptions are neither uniformly resistant nor uncritically enthusiastic; rather, they reflect a productive tension between pedagogical aspiration and perceived professional vulnerability. Magnetism, as an invisible and relational physical phenomenon, brings these tensions into sharp relief, revealing both the promise and the fragility of technology-enhanced inquiry in the early years.

A central contribution of this article is the argument that meaningful innovation in early physics education cannot be understood as the simple adoption of tools or frameworks. Instead, it must be conceptualized as a progressive process of pedagogical change, in which STEM functions as an initial epistemic and pedagogical entry point, educational

robotics intensifies demands on classroom orchestration and teacher competence, and artificial intelligence introduces deeper questions of authority, ethics, and epistemic agency. Teachers' experiences across these approaches are interconnected rather than discrete, suggesting the need for coherent and cumulative professional development pathways.

From a research perspective, the review identifies several important gaps. First, there is a need for longitudinal studies that trace how teachers' perceptions, self-efficacy, and practices evolve over time as they engage with STEM, robotics, and AI in magnetism teaching. Such studies would help move beyond snapshot accounts of attitudes toward a more dynamic understanding of teacher change. Second, design-based research is needed to explore how specific pedagogical designs—particularly those integrating inquiry, physical manipulation, and digital representations—support both teacher learning and students' conceptual understanding of magnetism. Third, future research should more explicitly examine the relationship between teachers' epistemic confidence and students' learning outcomes, an area that remains underexplored in early physics education. Further research is also required to investigate how teachers negotiate ethical and developmental concerns related to AI use in early childhood contexts, particularly with regard to authority, transparency, and the preservation of relational dimensions of teaching. Comparative studies across educational systems would be especially valuable in identifying how policy, curriculum, and institutional culture shape teachers' readiness and agency.

In conclusion, transforming magnetism teaching in early childhood and primary education is not primarily a technological challenge but a pedagogical, professional, and institutional one. Sustainable change depends on recognizing teachers as reflective practitioners and co-constructors of innovation, supported through coherent teacher education, collaborative professional cultures, and aligned policy frameworks. By foregrounding teachers' perceptions and experiences, this article contributes to ongoing debates about how early physics education can become epistemically rich, inclusive, and responsive to the realities of classroom practice.

## References

1. Samara V, Kotsis KT. The use of new technologies and robotics (STEM) in the teaching of sciences in primary education: The concept of magnetism: A bibliographic review. *Eur J Educ Stud.* 2023; 10(2):51-64. Doi: <https://doi.org/10.46827/ejes.v10i2.4652>
2. Samara V, Kotsis KT. Primary school teachers' perceptions of using STEM in the classroom: Attitudes, obstacles, and suggestions: A literature review. *Contemp Math Sci Educ.* 2023; 4(2):ep23018. Doi: <https://doi.org/10.30935/conmaths/13298>
3. Gavrilas L, Kotsis KT, Papanikolaou MS. Exploration of the prospective utilization of educational robotics by preschool and primary education teachers. *Pedagog Res.* 2024; 9(1):article-em0181. Doi: <https://doi.org/10.29333/pr/14049>
4. Gavrilas L, Kotsis KT. Investigating perceptions of primary and preschool educators regarding incorporation of educational robotics into STEM education. *Contemp Math Sci Educ.* 2024; 5(1):ep24003. Doi: <https://doi.org/10.30935/conmaths/14384>
5. Samara V, Kotsis KT. Profile of Greek primary education teachers regarding their attitude towards STEM. *Int J Prof Dev Learn Learn.* 2025; 7(1):e2507. Doi: <https://doi.org/10.30935/ijpdll/15805>
6. Ammar M, Al-Thani NJ, Ahmad Z. Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Soc Sci Humanit Open.* 2023; 9:100839. Doi: <https://doi.org/10.1016/j.ssaho.2024.100839>
7. Bybee RW. *The case for STEM education: Challenges and opportunities.* Arlington, VA: NSTA Press, 2013.
8. English LD. STEM education K-12: Perspectives on integration. *Int J STEM Educ.* 2016; 3(1):1-8. Doi: <https://doi.org/10.1186/s40594-016-0036-1>
9. Fayzullina AR, Filippova AA, Garnova NY, Astakhov DV, Kalmazova N, Zaripova ZF. Artificial intelligence in science education: A systematic review of applications, impacts, and challenges. *Contemp Educ Technol.* 2025; 17(4):ep613. Doi: <https://doi.org/10.30935/cedtech/17519>
10. Mbonyiryivuze A, Yadav LL, Amadalo MM. Physics students' conceptual understanding of electricity and magnetism in nine-year basic education in Rwanda. *Eur J Educ Res.* 2022; 11(1):83-101. Doi: <https://doi.org/10.12973/eu-jer.11.1.83>
11. Samara V, Kotsis KT. Research on kindergarten and primary school students' magnetic misconceptions and how to plan educational activities. *EIKI J Eff Teach Methods.* 2024; 2(2):10-14. Doi: <https://doi.org/10.59652/jetm.v2i2.124>
12. Bers MU. *Coding as a playground: Programming and computational thinking in the early childhood classroom.* 2nd ed. Routledge, 2020. Doi: <https://doi.org/10.4324/9781003022602>
13. Samara V, Kotsis KT. Use of the artificial intelligence in teaching the concept of magnetism in preschool education. *J Digit Educ Technol.* 2024; 4(2):ep2419. Doi: <https://doi.org/10.30935/jdet/14864>
14. Kotsis KT. Alternative ideas about concepts of physics are a timelessly valuable tool for physics education. *Eurasian J Sci Environ Educ.* 2023; 3(2):83-97. Doi: <https://doi.org/10.30935/ejsee/13776>
15. Stylos G, Kamtsios S, Kotsis KT. Assessment of Greek pre-service primary teachers' efficacy beliefs in physics teaching. *J Sci Teach Educ.* 2022; 34(1):44-62. Doi: <https://doi.org/10.1080/1046560X.2021.2023959>
16. Portillo-Blanco A, Guisasola J, Zuza K. Integrated STEM education: Addressing theoretical ambiguities and practical applications. *Front Educ.* 2025; 10:1568885. Doi: <https://doi.org/10.3389/feduc.2025.1568885>
17. Zviel-Girshin R, Rosenberg N. Enhancing early STEM engagement: The impact of inquiry-based robotics projects on problem-solving self-efficacy and collaborative attitudes in early childhood education. *Educ Sci.* 2025; 15(10):1404. Doi: <https://doi.org/10.3390/educsci15101404>
18. Wang G, Chen S. Integrating STEM principles into kindergarten science education: Effects of inquiry-based activities on knowledge acquisition and skills development. *Int J Knowl Manag.* 2025; 21(1):Article 383964. Doi: <https://doi.org/10.4018/IJKM.383964>
19. Samara V, Kotsis KT. A teaching intervention for

- magnetism using STEM in kindergarten. *Int J Prof Dev Learn Learn.* 2023; 5(2):ep2312. Doi: <https://doi.org/10.30935/ijpdll/13667>
20. Gavrilas L, Kotsis KT, Papanikolaou MS. Assessing teacher readiness for educational robotics integration in primary and preschool education. *Education.* 2024, 3-13. Doi: <https://doi.org/10.1080/03004279.2023.2300699>
  21. Samara V, Kotsis KT. Educational robotics in primary education in Greece: Methodological approaches and attitudes of teachers. A bibliographic review. *Eur J Educ Pedag.* 2023; 4(2):194-204. Doi: <https://doi.org/10.24018/ejedu.2023.4.2.629>
  22. Samara V, Kotsis KT. The use of STEM as a tool for teaching the concept of magnetism in kindergarten. *J Res Environ Sci Educ.* 2025; 2(1):1-17. Doi: <https://doi.org/10.70232/jrese.v2i1.1>
  23. Samara V, Kotsis KT. Robotic Christmas activities with Beebot: A STEM application for preschool education. *J Sci Educ Res.* 2025; 9(1):21-31. Doi: <https://doi.org/10.21831/jser.v9i1.77862>
  24. Kotsis KT. Artificial intelligence helps primary school teachers to plan and execute physics classroom experiments. *EIKI J Eff Teach Methods.* 2024; 2(2):1-9. Doi: <https://doi.org/10.59652/jetm.v2i2.158>
  25. Kotsis KT. Integration of artificial intelligence in science teaching in primary education: Applications for teachers. *Eur J Contemp Educ E-Learn.* 2024; 2(3):27-43. Doi: [https://doi.org/10.59324/ejceel.2024.2\(3\).04](https://doi.org/10.59324/ejceel.2024.2(3).04)
  26. Vakarou G, Stylos G, Kotsis KT. AI for enhancing physics education: Practical tools and lesson plans. *Int J Sci Math Technol Learn.* 2024; 31(2):159-176. Doi: <https://doi.org/10.18848/2327-7971/CGP/v31i02/159-176>
  27. Mandrikas A, Stefanidou C. Greek primary teachers' views about STEM education. *Eur J Sci Math Educ.* 2025; 13(2):119-136. Doi: <https://doi.org/10.30935/scimath/16162>
  28. Kotsis KT. Implementing the new inquiry-based science curriculum in Greece: Challenges for teachers, assessment, and digital innovation. *Int J Adv Multidiscip Res Stud.* 2025; 5(6):254-259. Doi: <https://doi.org/10.62225/2583049X.2025.5.6.5203>
  29. Kotsis KT, Gikopoulou O, Patrinos M, Kapotis E, Kalkanis GT. The new Greek inquiry-based learning science curriculum for primary education. *J Math Sci Teach.* 2025; 5(3):em83. Doi: <https://doi.org/10.29333/mathsciteacher/16846>