



A Comprehensive Overview of the Role of Mentoring in Science Education: Perspectives from Countries around the World and Türkiye

Özgür ÖZÜNLÜ¹

¹Dr., Ankara Yıldırım Beyazıt University, ozgurozunlu@aybu.edu.tr, ORCID ID: 0000-0001-7841-4869

ABSTRACT

Mentorship within the science education ecosystem serves a critical function, ranging from helping students acquire scientific process skills to shaping academic career maps. This study aims to evaluate the phenomenon of mentorship through a systematic literature review, tracing its origins from Ancient Greece to contemporary organizations, examining its theoretical foundations (both formal and informal approaches), and analyzing its concrete manifestations in science education (such as TÜBİTAK project guidance, STEM/STEAM programs, and virtual mentoring platforms). Research findings indicate that the mentor-mentee relationship—built on volunteerism, mutual trust, and interaction—can yield significant outcomes, including enhanced academic performance, the development of critical-thinking capacity, and support for professional identity formation. Nevertheless, the efficacy of the mentoring process is hindered by various obstacles, including communication breakdowns between parties, inadequate institutional resources, and a lack of systematic training for mentors. To overcome these challenges, this study proposes standardizing mentor preparation programs, effectively utilizing digital mentoring tools, and strengthening institutional support mechanisms to enhance the quality of science education. It is suggested that future research focus on the long-term academic and professional impacts of mentoring activities, as well as how digitalization adds a new dimension to mentoring dynamics.

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Fen Eđitiminde Mentorluđun Rolüne Kapsamlı Bir Genel Bakış: Dünya ve Türkiye'den Perspektifler

ÖZET

Fen eđitimi ekosisteminde mentorluk, öğrencilerin bilimsel süreç becerilerini kazanmasından akademisyenlerin profesyonel kariyer yollarının şekillenmesine kadar kritik bir işlev görmektedir. Bu çalışma, mentorluk olgusunu sistematik bir literatür taraması yoluyla değerlendirmeyi, kökenlerini Antik Yunan'dan çağdaş kuruluşlara kadar izlemeyi, teorik temellerini (hem resmi hem de gayri resmi yaklaşımlar) incelemeyi ve fen eđitimindeki somut çıktılarını (TÜBİTAK proje rehberliđi, STEM/STEAM programları ve sanal mentorluk platformları gibi) analiz etmeyi amaçlamaktadır. Araştırma bulguları, gönüllülük, karşılıklı güven ve etkileşim üzerine kurulu mentor-menti ilişkisinin akademik performansın artırılması, eleştirel düşünme kapasitesinin geliştirilmesi ve profesyonel kimlik oluşumunun desteklenmesi de dahil olmak üzere önemli sonuçlar doğurabileceđini göstermektedir. Bununla birlikte, mentorluk sürecinin etkinliđi, taraflar arasındaki iletişim kopuklukları, yetersiz kurumsal kaynaklar ve mentorlar için sistematik eđitim eksikliđi gibi çeşitli engellerle karşı karşıyadır. Bu zorlukların üstesinden gelmek için bu çalışma, mentor hazırlık programlarının standardizasyonunu, dijital mentorluk araçlarının etkin kullanımını ve fen eđitiminin kalitesini artırmak amacıyla kurumsal destek mekanizmalarının güçlendirilmesini

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önermektedir. Gelecekteki arařtırmaların mentorluk faaliyetlerinin uzun vadeli akademik ve mesleki etkilerine ve dijitalleşmenin mentorluk dinamiklerine nasıl yeni bir boyut kattığına odaklanması önerilmektedir.

Introduction

In today's era, often referred to as the Information Age, science education is of strategic importance to the sustainable development of societies. However, to achieve the expected efficiency from science education, it is not sufficient to merely equip students with theoretical knowledge; they must also acquire scientific process skills, develop critical thinking abilities, and grow as scientifically literate individuals (Ormancı & Çepni, 2022). At this juncture, mentoring practices that guide learning processes play a key role in enhancing the quality of science education.

Although the concept of mentorship finds its roots in Ancient Greek mythology (Greek: Mentor–Advisor) (Nkrumah & Scott, 2022), it has gained a more structured and systematic dimension in contemporary educational systems. Particularly in an interdisciplinary field such as science education, mentorship influences not only students' academic development but also their professional identity formation and socio-emotional growth. In this context, innovative approaches—such as TÜBİTAK projects, STEM/STEAM applications, and digital mentoring platforms—serve as vital mechanisms to enhance the effectiveness of mentoring processes (Pérez-Cruz et al., 2025; Tariq, 2025; Workforce et al., 2019).

Undoubtedly, one of the primary factors determining the success of the mentoring process is the mentor themselves. If the necessary care regarding the competencies a mentor must possess is not demonstrated, it is not possible to achieve the expected efficiency in the process in question (Workforce et al., 2019). On the other hand, mentorship has a dynamic relational structure, and the effectiveness of this process depends on the quality of the mutual interaction between the parties (Pfund et al., 2016). Therefore, to establish effective mentorship, both the mentor and the mentee must undertake specific roles and responsibilities (Yeung et al., 2010).

This study aims to comprehensively examine the theoretical foundations, historical development, and current application areas of mentoring practices in science education. Furthermore, by addressing the challenges encountered and the impacts of mentoring processes on students, prospective teachers, and academics, this study seeks to provide a holistic perspective on the subject. Accordingly, this study aims to draw significant implications for mentoring practices in science education through a systematic review and analysis of the existing literature.

Methodology

This study is based on a comprehensive document review and literature search, examining mentoring practices in science education from multiple perspectives. The research was conducted using a qualitative design that did not rely on empirical data collection; instead, document analysis was employed as the primary method for data collection and analysis. Literature searches were conducted between January and March 2025 using Web of Science, Scopus, ERIC, and Google Scholar databases. Keywords included "mentoring", "education", "science education", "mentor-mentee relationship", "STEM mentoring", "teacher mentoring", and "e-mentoring". Studies published in English between 2000 and 2025 were included.

Document analysis, also referred to as "documentary research" in the literature, aims to obtain data through the systematic examination of existing records and documents (Bowen, 2009). This method involves the stages of locating, reading, noting, and critically evaluating resources toward a specific objective (Sak et al., 2021). In other words, document analysis encompasses the process of examining and interpreting materials available in either printed or electronic formats—whether computer-based or online (Bowen, 2009). Furthermore, it is defined as the process of analyzing written materials that provide information about the phenomenon or phenomena under investigation (Sak et al., 2021).

During the document analysis process, the researchers systematically scanned national and international academic articles, books, reports, and conference proceedings focusing on mentorship in education. The literature selection process was guided by the principles of transparency, rigor, and reproducibility commonly recommended for review studies. To ensure the relevance and quality of the evidence base, explicit inclusion and exclusion criteria were established before the search.

The review focused on studies published between 2000 and 2025 that addressed mentoring practices, models, or frameworks within science education contexts. Eligible studies included peer-reviewed empirical research articles, systematic literature reviews, and conceptual papers that contributed to the understanding of mentoring processes in educational settings. Studies were required to be published in English and to provide sufficient methodological or theoretical detail relevant to mentoring practices.

A systematic search was conducted across major academic databases using combinations of keywords related to mentoring, mentorship, science education, teacher development, and professional learning. The initial search yielded 74 records. Following the removal of duplicate publications, the titles and abstracts of the remaining studies were screened for relevance. This preliminary screening resulted in the retention of 62 articles for full-text assessment. Subsequently, full-text articles were evaluated against the predefined eligibility criteria. As a result of this process, 30 peer-reviewed studies published in national and international journals were selected for inclusion in the final review.

Several exclusion criteria were applied during the screening process. Studies were excluded if they focused primarily on technical, engineering, or disciplinary content without explicit educational or pedagogical implications. Opinion papers, editorials, and publications lacking a clear empirical or theoretical foundation were also excluded. Furthermore, studies conducted exclusively in higher education settings were generally omitted unless they offered conceptual models, mentoring frameworks, or findings that could be meaningfully transferred to K–12 science education contexts. To enhance the transparency and replicability of the review, only studies available through open-access platforms or institutional database subscriptions were included.

The study selection procedure followed four successive stages: identification, screening, eligibility assessment, and inclusion. This process ensured that only studies meeting the established quality and relevance criteria contributed to the synthesis of findings presented in this review.

In this respect, this review aims to answer the following research questions:

RQ1. How has the concept of mentorship emerged and developed historically within education, and what position does it occupy in contemporary educational thought?

RQ2. How is the mentor–mentee relationship characterized, and through which processes does it evolve from the traditional apprentice–master model into contemporary mentoring?

RQ3. What does the peer-reviewed literature published between 2000 and 2025 reveal about how mentoring in science education is studied, including the countries in which the research was conducted, the methods employed, and the research foci addressed?

RQ4. How is mentoring implemented in science education practice, and what are the characteristic features of its application models—namely, academic research-based mentoring, TÜBİTAK project advising, interdisciplinary mentoring in STEM/STEAM projects, and digital mentoring?

RQ5. What contributions does the mentoring process produce for mentees, mentors, and the field of science education?

RQ6. What challenges are encountered in mentoring processes in science education, and what suggestions are offered to overcome these challenges?

Data Collection Instruments

The retrieved studies were examined in detail and presented holistically regarding mentorship and mentees in education—specifically in science education—as well as the implementation process and its contributions. The research methodology involved the systematic scanning, analysis, and

synthesis of current and foundational academic resources on the subject. In addition to international databases such as Web of Science, Scopus, and ERIC, the study included national academic publications.

Data Analysis

The reviewed literature was analyzed thematically, with attention to the historical development of mentorship, its theoretical foundations, application models, and role in science education. The analysis explored how mentorship functions at different levels of science education—including among students, prospective teachers, and academics—and the outcomes it produces.

Following the four-stage selection procedure described in the Methodology, the final corpus comprised 30 peer-reviewed studies published in national and international journals between 2000 and 2025. Each study was read in full and examined through systematic descriptive and thematic analyses. To make the evidence base transparent and comparable, the studies were coded and summarized across five dimensions: (a) authors and publication details, (b) stated purpose, (c) research method and design, (d) key findings, and (e) principal conclusions. An additional column records the country or countries in which each study was conducted, allowing the national contexts discussed in the Findings section to be linked to the studies they are based on.

The descriptive synthesis is presented in a consolidated table in the appendices and in a supplementary Excel file. Each row corresponds to one study. This two-part approach—thematic synthesis in the main text and a study-by-study descriptive table in the appendices—was adopted to support the transparency, rigor, and reproducibility expected of review studies and to enable readers and future researchers to examine the corpus independently.

This study aims to provide a holistic perspective on mentoring practices in science education by synthesizing existing knowledge and guiding future research.

Validity and Reliability

Because document analysis has been repeatedly criticized for the insufficient detail with which its procedures are reported, and because the credibility of review findings depends on the explicit naming of the assumptions and analytic decisions that underpin them, the present study adopted a set of strategies for validity and reliability drawn from the methodological literature on documentary and qualitative research (Kıral, 2020; Wood et al., 2020). In qualitative inquiry, these two conventional concepts are addressed through the broader notion of trustworthiness, operationalized by the criteria of credibility (truth value), transferability (applicability), dependability (consistency), and confirmability (neutrality) (Ahmed, 2024); these criteria respectively correspond to the quantitative notions of internal validity, external validity, reliability and objectivity (Lemon & Hayes, 2020).

Validity was addressed first during the document selection stage. In document analysis, the researcher is required to evaluate candidate documents against four criteria: authenticity (the extent to which a document is genuine), credibility (the extent to which it is free from error and distortion), representativeness (how typical the document is of the material it represents), and meaning (the significance and clarity of its content) (Morgan, 2022). Accordingly, objective inclusion and exclusion criteria were established for the documents before the analysis; the authenticity and verifiability of each source were confirmed using its bibliographic identifiers; and the corpus time interval was set to 2000–2025, as determined by the research questions. Maximum document variety was pursued by drawing on journal articles, program reports, and theoretical works, enabling the phenomenon to be examined across multiple documentary types. Credibility was further strengthened through triangulation and persistent engagement with the material, which are among the principal means of establishing truth value in qualitative research (Ahmed, 2024); in this sense, documentary analysis is valued precisely because it permits methodological and data triangulation (Cardno et al., 2017). The

framework of the analysis was made explicit rather than left implicit, in line with the requirement that document analysis be anchored in a stated, advanced conceptual and epistemological position.

Reliability was addressed through an audit trail and through systematic documentation of every step of the process, so that the analytic path from the corpus to the themes could be retraced by an external reader (Wood et al., 2020). The inclusion and exclusion decisions, the coding of each study along the dimensions of the descriptive analysis, and the derivation of the thematic headings were recorded as written evidence, since dependability rests on rigorous documentation rather than on the reproducibility of a single interpretive act (Ahmed, 2024). In addition, the derivation of the themes was reported alongside the studies on which each theme rests, making the inferential step from data to findings visible and thereby open to scrutiny (Wood et al., 2020). Where the construction of a theme required verification, the source documents were consulted again — a form of producer confirmation by which researchers obtain correction, direction, and feedback from those who produced the documents (Alshurafat, 2019). Transferability was supported by describing the corpus, country contexts, and methodological characteristics of each study in sufficient detail to enable readers to assess the applicability of the findings to other settings (Hayashi et al., 2019).

Findings

The Concept of Mentorship and Its Place in Education

Ancient Greek culture and mythology shaped the historical roots of mentorship. The eponym of the concept is Mentor, the friend to whom King Odysseus, in Homer's epic *The Odyssey*, entrusted the education and upbringing of his son, Telemachus, before departing for the Trojan War. In this narrative, Mentor is not merely an instructor but a guardian and advisor figure who assumes a holistic guiding role in the young prince's moral, intellectual, and physical development. This mythological foundation provides the theoretical framework for positioning the mentor as a trustworthy, wise, and guiding character (Abiddin & Hassan, 2011; Hobson & Sharp, 2004; Vierstraete, 2005).

In contemporary contexts, mentorship—particularly within organizational and professional settings—has become more structured and functional. In its modern definition, it is a form of relationship in which an individual with extensive experience in a specific field (the mentor) provides systematic support to the developmental process of an individual (the mentee) who is pursuing the same professional path and is in the early stages of their career (Hudson, 2016).

This support mechanism encompasses a comprehensive interaction aimed at the mentee's development of personal and professional competence, going beyond knowledge transfer, coaching, role modeling, and encouragement (Desselle et al., 2020). In contemporary organizations, this interaction transforms into a multidimensional learning partnership that can emerge within the framework of formal (official programs) or informal (spontaneous) dynamics.

Mentorship relationships can generally be classified into two types: formal and informal. Formal mentoring refers to structured programs designed by institutions with specific objectives, where participants are systematically paired. In contrast, informal mentoring is a more flexible and organic relationship that develops of its own accord, through the parties' own volition, without any formal programming. The distinction between these two categories becomes evident through parameters such as the level of structurality, duration, mutual commitment, and the intensity of interaction (Bagnoli & Estache, 2021; Khojah & Asif, 2020).

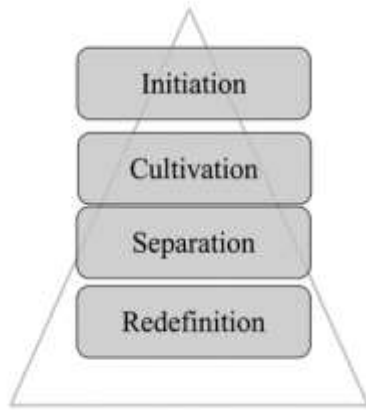
There are various models in the literature regarding the stages of the mentoring process. Kram (1983) conceptualized this process as a developmental cycle consisting of four phases:

A dynamic interaction based on volunteerism and mutual trust forms the foundation of the mentoring process. This relational process is inherently cyclical and incremental, progressing through specific stages, each containing its own unique dynamics. A visual representation of these stages (Lovatón & México, 2019) illustrates the progression from the initial meeting to the eventual redefinition of the relationship.

In Figure 1, this model identifies four distinct moments in the mentor-mentee encounter: initiation, cultivation, separation, and redefinition (García-Cardo et al., 2023).

Figure 1

Stages of Mentoring (Haddock-Millar, 2017)



1. **Initiation:** This initial phase involves mutual Overcoming and the construction of a foundation based on trust. During this period, the mentor and mentee work to understand each other's character traits, expectations, and work styles while defining the boundaries and rules of their interaction. The care invested in this stage directly determines the quality and efficiency of the relationship in later phases (Brown et al., 2020).
2. **Cultivation:** This is the productivity phase where previous efforts transform into concrete outcomes. Lasting between two and five years, this stage sees the mentee gaining increased self-confidence and the ability to make autonomous career decisions. As the mentee's individual competencies improve, their professional dependence on the mentor decreases.
3. **Separation:** Usually triggered by the mentee's newfound autonomy or factors related to the mentor, this stage involves the formal conclusion of the relationship. Healthy separation requires transparent planning and mutual agreement through open communication. Poorly managed or premature separation can lead to a loss of self-confidence for the mentee, whereas a well-timed departure leaves a positive professional foundation for both parties.
4. **Redefinition:** The final phase marks the transformation of the relationship into a peer-like dynamic based on mutual respect and friendship. As the mentee reaches professional maturity, the traditional hierarchy dissolves into a lasting professional bond where both parties interact as equals.

Beyond relational cycles, formal mentorship programs often follow a structured managerial model consisting of four key phases:

1. **Preparation Phase:** Mentors and mentees are trained regarding their specific roles and expectations.
2. **Matching Phase:** Participants are systematically paired as partners based on common goals and personality compatibility.
3. **Interaction Phase:** This is the core implementation period during which the actual transfer of knowledge, experience, and skills takes place.
4. **Termination Phase:** This stage involves the structured conclusion of the formal relationship and the final evaluation of the process.

Mentorship in education spans a wide spectrum, from guiding students through their academic journeys to helping prospective teachers develop pedagogical competence and supporting

new academics in their research. It provides a holistic contribution by offering moral support, aiding the formation of professional self-perception, and providing career management strategies alongside psychological support.

Mentor-Mentee Relationship

The realization of the expected benefits from a mentoring relationship primarily depends on the mentor's capacity to fulfill their role. Research in this field demonstrates a significant link between program success and mentors' knowledge base, behavioral tendencies, and practical skills (Deng & Turner, 2023). Consequently, in an environment where the mentor lacks the necessary qualities, the likelihood that the process will achieve its intended outcomes diminishes substantially.

At the core of effective mentoring lies a dynamic, positive relationship between the parties. The healthy functioning of this relationship depends on a set of fundamental principles. Foremost among these are the voluntary formation of the relationship, mutual unconditional respect, and a solid bond of trust built over time. On this foundation, the mentor is obligated to go beyond merely sharing their existing knowledge to create a learning environment that recognizes the mentee's individual characteristics and fosters their progress (Pfund et al., 2016). In educational settings, this mutual interaction can take various forms, such as dialogue among a cooperating teacher and a teacher candidate, a thesis advisor and a graduate student, or an experienced instructor and a student.

In this context, mentoring is inherently a dialectical process rather than a one-sided form of guidance. Accordingly, the effectiveness of the process is not limited solely to the mentor's qualifications; it is also directly related to the extent to which the mentee engages in this interaction and meets the expected competencies (Young & Perrewé, 2000). Indeed, an optimally functioning mentoring relationship requires that both parties have a clear understanding of their roles and can translate this understanding into mutual synergy (Ambrosetti & Dekkers, 2010).

Consequently, the internalization of relational boundaries, performance expectations, and interaction dynamics by both the mentor and the mentee is a primary determinant of process efficiency (Pfund et al., 2016).

The effects of mentoring activities on individual and professional development are multi-layered. The literature indicates that these processes not only nurture creative thinking but also expand career opportunities, allow individuals to discover their latent talents, serve the maturation of personal values, and lay the groundwork for building meaningful professional networks. The effectiveness of the process is also directly linked to specific behavioral patterns exhibited by mentors. Mentoring practices such as encouragement, recognition of potential, and role modeling reinforce individuals' self-confidence, self-esteem, and perception of self-worth (Garman et al., 2001).

The literature indicates that the mentoring relationship serves a constructive function in the professional and psychological development of mentees (Kram, 1983). Particularly for individuals in the early stages of their careers, mentor behaviors such as role modeling, unconditional acceptance, instilling confidence, and professional solidarity emerge as critical psychosocial mechanisms that support the formation of competence perception, self-confidence, and professional identity in mentees (Kram, 1983; Roberts, 2000).

From the Apprentice-Master Model to Mentoring

Historically, mentoring practices have largely been shaped by the master-apprentice paradigm. While the traditional approach focused on the transfer of skills and knowledge through direct interaction, the contemporary understanding of mentoring offers a much more inclusive structure. Today, this process goes beyond mere knowledge transmission, aiming to develop multifaceted competencies such as critical thinking, problem-solving, the ability to conduct independent research, and a system of ethical values (Jacobi, 1991).

In modern educational paradigms, mentoring supports not only an individual's cognitive development but also their socio-emotional growth. This holistic approach is particularly important in fields such as science education, where interdisciplinary connections and higher-order thinking skills are central. Within this process, the mentor evolves from the traditional role of a one-way knowledge transmitter into a guide who activates the learner's intrinsic potential (Hudson, 2016).

In light of these developments, mentoring has become a strategic mechanism in the contemporary educational ecosystem that enriches individuals' learning journeys, supports their professional development, and enhances their levels of scientific literacy. Specifically in science education, this mechanism is of vital importance across a wide spectrum, ranging from students' acquisition of scientific process skills to the pedagogical formation of teacher candidates and the research careers of academics.

Mentoring in Science Education

Science education encompasses fundamental approaches aimed at developing individuals' abilities to comprehend scientific phenomena, analyze them critically, and draw new inferences by integrating diverse data. In this context, epistemological approaches—individuals' basic perceptions of the origin, validity, limitations, and methods of knowledge transmission—play a decisive role (Hofer & Pintrich, 1997).

The existential rationale for science education extends far beyond mere knowledge transfer; the primary goal is for individuals to adopt the scientific methodology as a way of thinking, gain a reflex for critical inquiry, and maintain a solution-oriented stance in the face of authentic problems. At this point, mentoring acts as a catalyst across the developmental spectrum from student to academic. Indeed, an examination of the relevant literature emphasizes that mentoring activities not only contribute to the academic success of actors in science education but also influence their identity formation as scientists, the mapping of their career trajectories, and ultimately, their integration into the scientific community (Deanna et al., 2022; Robnett et al., 2018).

From the Student's Perspective

As one of the key factors shaping student success in science education, mentoring support has a direct and decisive role in educational quality (Masalimova et al., 2024). The developmental gains of students under the guidance of a mentor can be systematized as follows:

Acquisition of Scientific Methodology Skills. Under the guidance of mentors, students gain hands-on experience in scientific process skills such as hypothesis development, experimental design, and data analysis. This process enhances students' critical thinking capacities (Nelson et al., 2018) and increases their scientific literacy.

Enrichment of Applied Learning Experiences. Mentor support in structured activities, such as project-based learning and laboratory work, encourages students' active participation in the learning process. Structured feedback from mentors allows students to engage in original experimentation without the fear of making mistakes, thereby strengthening their academic self-confidence (Beals et al., 2021).

Establishment of Career Roadmaps. Students with career goals in STEM fields gain access to strategic information regarding academic opportunities, research projects, and internships through mentors. This guidance contributes to the early shaping of students' professional orientations (Fiss et al., 2024).

Development of Academic Motivation and Sense of Community. The mentoring relationship reinforces students' belief that they are valuable members of the academic community.

This situation increases intrinsic motivation toward science education and strengthens students' commitment to the discipline (Silva et al., 2026).

These comprehensive mentoring interactions aim to support both the cognitive and affective development of students in science education, cultivating them as self-confident individuals equipped with the systematic approach to scientific thought (Silva et al., 2026).

From the Perspective of Teacher Candidates

The effectiveness of science education is directly related not only to students' levels but also to the mentoring activities implemented during the training of teacher candidates. The fundamental contributions provided by structured mentoring activities in pre-service teacher education programs can be summarized as follows:

Development of In-Class Implementation Skills. Mentor teachers guide candidates in coping with pedagogical challenges encountered in the classroom, designing methods appropriate to students' needs, and developing effective instructional materials (Valencia et al., 2006).

Professional Socialization Process. Under the facilitation of experienced mentors, teacher candidates build their professional identities and gain the self-confidence necessary for the transition into the teaching role (Izadinia, 2016).

Habit of Reflective Practice. The critical feedback mechanism provided by mentors allows candidates to systematically analyze their own teaching practices, thereby reinforcing a mindset of continuous professional development (Frick et al., 2010).

Establishment of Professional Networks. The mentoring experience accelerates teacher candidates' integration into professional communities and provides a foundation for establishing professional connections that support their career development (McIntyre & Hobson, 2015).

Information on Mentoring Practices in Teacher Education in Some Countries is provided in Table 1.

Table 1

Mentoring Practices in Teacher Education in Some Countries

Countries	Applications
USA / New York	It is envisaged that teacher candidates undergo a full-time, one-year on-the-job training period during their induction into the profession. During this integration phase, these teachers receive both coaching and mentoring support, with the responsibilities and functions of each role clearly distinguished. To ensure the effective execution of the process, mentors are required to participate in the "Mentor Academy" program and take an active role in professional sharing forums.
Japan	Newly appointed teacher candidates are subject to a one-year preparatory program consisting of two distinct stages. The first stage comprises a 25-working-day training period covering theoretical course content and practical workshops. In contrast, the second stage involves a minimum of 300 hours of practical training conducted within the school environment under the supervision of a mentor.

Finland	Although induction training exists, it lacks the characteristics of a structured program, including a standardized curriculum, systematic supervision, or objective assessment and evaluation methods. The current model functions primarily as a facilitation approach, in which colleagues gather once a month to share professional experiences and practical examples.
South Korea	Newly appointed teacher candidates first participate in a two-week school orientation program. Following this initial stage, participants are enrolled in a comprehensive professional preparatory training program lasting six months.
Canada / Ontario	Following their appointment to teaching positions, the "Teacher Candidate Training Program," which all candidate teachers are required to attend for one year, comes into effect. Within the scope of this program, systematic mentoring services are provided to newly appointed teachers by experienced educators in their respective fields.
Singapore	Following the appointment process, teachers are required to participate in professional orientation activities organized as the "Induction Program for Beginning Teachers." Following this initial phase, it is projected that candidate teachers will be included in a systematic guidance process within the framework of a "Structured Mentoring Program" during the first two years of their professional careers.

From the Perspective of Academic Research

Mentoring has become a widely recognized field of study aimed at positively influencing undergraduate students, creating an effective mechanism to improve their academic performance, ensuring retention in specific disciplines such as science, technology, engineering, and mathematics (STEM) in universities, and facilitating interdisciplinary transitions (Lunsford et al., 2017). The majority of the literature on mentoring in higher education institutions focuses on the relationship between the mentor and the student. For many faculty members, advising students constitutes an essential component of academic counseling. Research indicates that one-on-one faculty-student mentoring has a significant and positive impact on students (Pascarella, 1980). From the standpoint of academic research, the types of mentoring are as follows:

Thesis Advising. In academic literature, mentors are tasked with supporting students' development, motivating them, and guiding their educational processes (Grant et al., 2014). In addition to serving as role models for students, these academics fulfill various responsibilities, including conducting instructional activities, observing students, encouraging development, providing counseling, and supervising processes.

Research Ethics and Scientific Values. Ethics is essentially a branch of philosophy that examines human behavior from a moral perspective. This discipline systematically analyzes the values that guide interpersonal relationships, as well as the criteria and rationales for characterizing actions as good or bad, right or wrong (Çabuk & Işgüden, 2006). In the context of academic mentoring, these principles have a concrete counterpart; mentors play a key role in ensuring that students maintain integrity in their scientific work, internalize ethical rules, and develop a robust awareness regarding procedures related to academic publishing (Swain, 2023).

Scientific Collaborations. Mentors expand the academic networks of young researchers by involving them in national and international projects (Swain, 2023).

Career Guidance. Research mentoring provides critical contributions to post-doctoral academic or industrial career planning (Martins & Faciola, 2025).

In summary, mentoring in science education is a comprehensive process that supports the development of all stakeholders, from students to academics. By taking education and instruction beyond the individual level, it both enhances the capacity of scientific communities and establishes a foundation for enduring scientific productivity.

Mentoring Practices in Science Education

The positioning of the concept of mentoring within the science education ecosystem is not limited to a purely theoretical perspective; rather, it gains operational functionality through embodied curriculum programs, project-oriented pedagogical interventions, and application sequences designed systematically. This structured integration provides a dynamic platform that enables a wide range of stakeholders—from student profiles to experienced academics—to participate effectively in the production, dissemination, and evaluation of scientific knowledge (Schwartz et al., 2016; Ünver et al., 2022).

In this context, it is evident from empirical data that different mentoring paradigms, developed at both the national and global levels, serve as a significant catalyst for the development of qualified human capital—a cornerstone of science education—and for rooting scientific rationality within the social fabric. Ultimately, these institutional frameworks have the potential not only to ensure the sustainability of scientific activity but also to herald an epistemological transformation by fostering a collective consciousness (Nikkhah, 2011; Tuma & Dolan, 2024).

TÜBİTAK Project Advising

When examining the mentoring ecosystem in the field of science education in Turkey, the Research Project Competitions for Secondary School Students and the support programs coded 2204-A and 2204-B, implemented within TÜBİTAK, stand out as highly structured institutional models. These programs are strategic initiatives that enable high school-level researchers to conduct original research under the guidance of advisor teachers or academic mentors at universities.

In this system, mentors move beyond a traditional instructor role and serve as guides, accompanying students on their individual journeys of discovery. The support process encompasses a holistic cycle, from the emergence of the project idea to the presentation of the final report. The mentor not only provides guidance on technical issues, such as literature review or data analysis, but also aims to instill qualities that form the basis of a researcher's identity, such as critical thinking, systematic work discipline, principles of academic integrity, and scientific ethics (Sergeyeva et al., 2021)

As a result, such structured mentoring platforms do not limit young individuals solely to competition or project-based processes. On the contrary, by introducing them to the methodological and ethical dimensions of scientific knowledge production at an early stage, this approach contributes to the formation of a solid scientific foundation in the long run (Silva et al., 2026). This situation is a concrete indicator of how vital a function mentoring serves in achieving sustainable learning outcomes in science education.

Interdisciplinary Mentoring in STEM/STEAM Projects

Mentoring is of decisive importance to the development of students' intellectual and practical skills in STEM (Science, Technology, Engineering, Mathematics) projects, which are interdisciplinary, and in STEAM projects, which incorporate art into this framework. Mentors involved in these projects provide systematic guidance that extends beyond the transfer of technical knowledge; they also direct students in establishing interdisciplinary connections, activating creative thinking, and developing innovative products through original solutions.

In this context, Science and Art Centers in Turkey stand out as significant educational institutions where the mentoring mechanism is functionally applied, particularly in the education of gifted students. In these centers, through project-based learning processes, students are supported in mastering scientific research methodologies and developing an academic perspective through contributions from academics at universities and field experts from relevant sectors.

Digital Mentoring

Digital mentoring, also known as e-mentoring, is a contemporary guidance paradigm that has emerged from the reflections of digital transformation in education and guidance, responding to the changing needs of the modern era (Seękin et al., 2021). This practice is expressed in the academic literature through a range of terms, including online guidance, remote coaching, virtual counseling, internet-based mentoring, and digitally mediated guidance (Neely et al., 2017; Rowland, 2012). This terminological diversity essentially points to a new interaction model that transcends the geographical and temporal boundaries of the traditional mentoring relationship. Despite this richness in the conceptual framework, the common denominator across these definitions is a structured relational mechanism in which communication, interaction, and information-sharing activities—the core components of mentoring processes—are largely conducted through internet-based digital platforms.

When evaluated from an inclusive, multidimensional perspective, this digitally based approach can be defined as a systematic model that brings together individuals with diverse experiential backgrounds for meaningful mentoring dialogue. It is a process that is customized to individual needs, focused on producing tangible outcomes, and progressing through dynamic, synchronous interaction (Tabar & Zadhasn, 2023). Furthermore, it encourages a holistic developmental process, maximizes accessibility by eliminating geographical and physical barriers, and ultimately offers sustainable guidance and support (Chong et al., 2019).

Contributions of the Mentoring Process

The value of mentoring practices in science education transcends individual development, serving as a strategic investment that has lasting effects on the quality of the educational system, the productivity of the academic community, and social progress. From this perspective, the positive outcomes of effectively designed mentor-mentee relationships can be systematized into four fundamental dimensions: academic success, scientific literacy, professional development in the teaching profession, and social impact.

Impact on Academic Success

Numerous studies have demonstrated that students involved in the mentoring process exhibit increased academic success. Students receiving mentor guidance achieve higher in courses, participate more actively in research projects, and integrate more easily into scientific publishing processes (Nasser & Alkhateeb, 2012). Mentor support enables students to improve their learning strategies, increase their motivation, and reach their academic goals more systematically.

Undoubtedly, at the foundation of an effective mentoring process lies the mentor's voluntary assumption of the role and their active commitment to it. This state of voluntariness and commitment points to intrinsic motivation, the driving force behind mentoring activities (Kühn et al., 2023). Indeed, being intrinsically motivated enables the mentor to fulfill their mentoring responsibilities more effectively, engage in more constructive practices, and exhibit positive behaviors. This motivational background ensures that the mentor shifts their focus from the mere completion of organizational tasks toward supporting the mentee's professional growth and personal development, ultimately preparing the ground for the mentor to derive deep professional satisfaction from the mentee's achievements.

Development of Scientific Literacy and Critical Thinking

Scientific literacy, which stands out among the primary goals of science education, is defined as a multi-dimensional concept encompassing the capacity of individuals to approach problems encountered in daily life from a scientific perspective, to generate solutions using critical thinking skills, and to make informed choices accordingly. In this context, mentoring practices provide significant contributions to the development of these literacy skills by offering students the opportunity to experience scientific research processes firsthand (Zhou et al., 2025). Research projects conducted under mentor supervision and requiring a systematic approach not only enhance students' analytical thinking capacities but also increase their competencies in data analysis and interpretation, while reinforcing their skills in presenting scientific findings effectively.

Professional Development in the Teaching Profession

Mentoring plays a critical role in the professional preparation process for science teacher candidates. Candidates working with mentor teachers during the pre-service period gain experience in lesson planning, assessment and evaluation, and classroom management. Furthermore, feedback from mentors enables candidates to develop their pedagogical knowledge and skills (Barnett & Friedrichsen, 2015).

Positive Impact in the Student-Teacher-Society Triangle

Mentoring practices in science education have a transformative function at the societal level beyond individual gains. Students raised with mentor support actively participate in scientific communities and develop solutions to social problems. Teacher candidates, on the other hand, ensure educational continuity by passing on the mentoring experience they acquired during their professional formation to future generations. This situation contributes to the dissemination of scientific culture, the socialization of scientific knowledge, and the development of innovative approaches (Davies et al., 2021).

Challenges Encountered in the Mentoring Process

In practice, it is not always possible for mentoring processes in science education to proceed under the ideal conditions envisioned in theory. The dynamic nature of mentor-mentee relationships can be susceptible to problems arising from communication disruptions, role ambiguities, or mismatches in expectations. Furthermore, systemic deficiencies at the institutional level (such as inadequate planning and monitoring-evaluation mechanisms) and resource constraints (time, financial support, and educational materials) emerge as factors that significantly limit the effectiveness of these processes. These obstacles are the fundamental reasons it is difficult for mentoring to achieve its goals of both individual development and societal benefit.

The mentoring relationship requires mutual harmony. However, in some cases, communication problems, differing expectations, or low motivation may arise between the mentor and the mentee. This situation reduces the process's effectiveness and negatively affects the mentee's development (MacCallum et al., 2017).

Science education requires intensive time and resources due to laboratory applications, project work, and research activities. An excessive workload or inadequate financial resources may prevent mentors from allocating sufficient time to the mentoring process. This, in turn, can decrease the efficiency of the process. Mentoring requires specific skills and pedagogical competence. The inadequacy of mentors who lack sufficient training can undermine mentees' motivation and development.

Discussion

The purpose of this review was to map, through document analysis, how mentoring has developed and is currently practiced in science education. The corpus of 30 studies published between 2000 and 2025 reveals a field that has moved decisively from a perception of mentoring as an

incidental, individual favor exchanged between colleagues towards an explicitly designed, institutionally supported, and increasingly theorized developmental process. The findings of the present review, discussed under the six research questions that guided the analysis, converge on a coherent picture while also exposing persistent structural gaps between what the literature knows about effective mentoring and what is actually practiced.

The reviewed literature confirms that the semantic and moral roots of the concept lie in the mythological figure of Mentor, whose role was not instructional in a narrow sense but custodial and developmental, encompassing the moral, intellectual, and physical formation of the young (Cojocar, 2023). Consequently, contemporary definitions retain this holistic emphasis: mentoring is characterised as a nurturing process in which a more experienced person serves as a role model and teaches, sponsors, encourages, counsels and befriends a less experienced person to promote the latter's professional and personal development, and it is carried out within the context of an ongoing caring relationship rather than as a mere exercise in skills improvement (Desselle et al., 2020). Historical analyses likewise emphasize that conversations around the term moved from social settings into school cultures, and that the term has never settled into a single definition, functioning alternately as meaningful interaction and as program implementation, such as faculty mentoring or apprenticeship models (Nkrumah & Scott, 2022). The contribution of the documentary corpus of this review is that this conceptual stretching is visible in practice as well: while the historical works in the corpus conceptualised the relationship as a four-phase developmental cycle of initiation, cultivation, separation and redefinition (Kram, 1983), contemporary studies in science education describe mentoring as an evolving partnership in which the mentor is expected to generate more qualified educators than themselves rather than to transmit what is already known (Nikkhah, 2011).

The analysis showed that effectiveness is not a property of the mentor alone. Several studies foreground the mutual, dialectical character of the relationship: mentors perceive relationship effectiveness and trust more positively when mentees are open to advisement and put effort into their required work, and mentees develop higher trust and perceptions of effectiveness when mentors provide sufficient social support behaviors that meet their expectations (Young & Perrewé, 2000). A further recurring finding concerns preparation: mentoring knowledge and skills can be developed, and bringing mentors and mentees together on the assumption that they already possess the required skills is described as not only naive but also advantageous to mentee populations that already hold the social capital to form such relationships (Pfund et al., 2016). The corpus also documents the reverse of this relationship pattern. Studies of research apprenticeships report that mentors who engage in higher levels of negative mentoring produce undergraduates with lower levels of scientist identity. In contrast, instrumental and socioemotional mentoring are associated with higher levels of scientist identity (Robnett et al., 2018). This is a consequential finding for science education because it indicates that the relationship is not merely a vehicle for support but a mechanism for identity formation that can also work in reverse when mentoring is practiced carelessly.

A striking observation from the descriptive synthesis presented in the Appendix Table is the uneven geographical and methodological distribution of the evidence. Across the 30 studies, qualitative case studies and small-scale designs predominate, large-scale survey analyses are rare, and genuinely comparative designs constitute a small minority (Luft et al., 2002, 2011; Roehrig & Luft, 2006). The country-level patterns reveal three distinct configurations of mentoring in teacher induction. First, Türkiye exhibits a paradox of recognition without regulation: the literature acknowledges a mentor-like guidance role for candidate teachers while simultaneously reporting that its functional implementation remains unclear (İlđan, 2021), that a substantial proportion of participants reported not receiving a large majority of the mentoring practices examined (Uřak et al., 2010), and that only in more recent regulatory documents are mentor duties defined in greater detail (Yılmaz & G nbey, 2024). Second, Singapore and Japan illustrate highly structured, centrally regulated induction arrangements, with Singapore's framework designed precisely to standardise practices that had varied from school to school (Kee, 2006), and with Japanese mentoring shaped by cultural expectations and by the short duration of professional development — a comparison that

emerged repeatedly when Japan was set against Canada, where mentoring is more limited and teachers work in greater isolation (Asada, 2012; Howe, 2005, 2008). Third, Finland represents a fundamentally different philosophy, in which peer-group mentoring positions all participants concurrently as both mentors and mentees and foregrounds non-evaluative, collaborative self-development and well-being, while contending with constraints of time and national regulation (Pennanen et al., 2018; Tynjälä et al., 2019). Finally, the studies conducted in the United States document a large-scale, associationally robust pattern: the presence of a mentor from the same field and participation in collective induction activities were associated with beginning teachers' decisions about remaining in or leaving the profession (Smith & Ingersoll, 2004), and induction mentoring and professional development were reported to support retention among new STEM teachers (Hutchison, 2012). Comparative and international analyses converge on the same design features – collaboration, reflection, specially trained mentors, and support rather than assessment (Howe, 2006). Taken together, these configurations suggest that the dominant variable is not culture as such but the degree to which mentoring is structurally embedded, resourced, and separated from evaluation.

The review identified four distinguishable models through which mentoring is realized in science education: mentoring embedded in academic research, TÜBİTAK project advising, interdisciplinary mentoring in STEM/STEAM projects, and digital mentoring. The evidence on the last of these is instructive. Digital and e-mentoring are described as responding to the location barriers, disciplinary diversity and collaborative demands that STEM mentoring programmes face, with synchronously and asynchronously communicating platforms offering the prospect of more inclusive and scalable mentoring (Pérez-Cruz et al., 2025); they are characterised as individualised processes focused on tangible outcomes that eliminate geographical and physical obstacles and thus provide sustainable guidance and as programmes whose defining features are flexibility, adaptability and the incorporation of technology (Tariq, 2025). At the same time, the broader literature cautions that mentorship should not be left to chance or idiosyncratic implementation and identifies a persistent gap between what is known about effective mentoring and how it is practiced (Workforce et al., 2019). The four models, therefore, differ less in their pedagogical logic than in their infrastructural demands: all four require trained mentors, defined roles, and adequate time; the digital model also requires technological capacity.

The contributions reported across the corpus can be grouped into four dimensions that emerged consistently: academic achievement, scientific literacy and critical thinking, professional development in teaching, and wider social impact. Students who participate in mentoring programs have been reported to show improved academic performance, higher engagement, and greater confidence in career planning than their non-mentored peers (Uwimana et al., 2024), and mentoring is described as a catalyst capable of unleashing potential for discovery, curiosity and participation in STEMM and of improving the training environment in which that potential is fostered (Workforce et al., 2019). A particularly important finding for the science education context is that mentoring can develop the mentors themselves: undergraduate mentors in a STEM outreach program significantly outperformed matched non-mentor peers on post-test critical thinking, with gains in analysis, inference, and numeracy (Nelson et al., 2018). The literature also documents cognitive and affective gains under mentor supervision in authentic research processes and project-based settings (Beals et al., 2021), as well as the formation of scientific identity through instrumental and socioemotional mentoring (Robnett et al., 2018). In programs designed for researchers, structured mentorship supported by tools such as individual development plans and mentor–mentee compacts has been linked to improved student satisfaction and reduced attrition, with mentors distinguished from advisors by their focus on long-term personal and career development rather than short-term academic objectives (Martins & Faciola, 2025). At the systemic level, mentorship is increasingly framed not as a private relationship but as a fundamental element in efforts to transform scientific culture, to the extent that funding agencies in several countries now incorporate such contributions into the evaluation of researchers (Davies et al., 2021). The corpus from Türkiye and South Korea adds an important qualification to this generally positive picture: the benefits reported in mentoring

arrangements are conditional on the availability of qualified mentors and on a supportive interaction environment (Lee, 2013), with studies documenting benefits in conceptual, affective, and career-related domains (Çiğdemoglu et al., 2019).

The challenges identified in the corpus are remarkably consistent across national contexts and can be organized into relational, competency-related, and systemic categories. At the relational level, the principal factors reported when mentoring relationships fail are communication difficulties or an inability to establish a connection, mentor intervention style, insufficient mentor expertise and skills, perceived lack of mentee motivation, unfulfilled expectations of the program, the mentor being too busy or abandoning the mentee, scheduling problems, and inadequate program or family support (MacCallum et al., 2017). At the competency level, the shortage of trained mentors is repeatedly identified: historically, few mentors have been trained in effective mentoring methods, and even fewer mentees have been trained in how to guide their mentoring relationships (Pfund et al., 2016), while systematic reviews of teacher education mentorship identify lack of mentor preparation, role ambiguity, and inconsistent quality of feedback as persisting problems. At the systemic level, the corpus reports workload and financial constraints that prevent mentors from allocating sufficient time, role conflict arising when mentoring is coupled with evaluation (McDonough, 2018), and the absence of standardized curricula, systematic supervision, and objective assessment methods in some national induction arrangements. These findings qualify the optimism of the contributions literature in an important way: the benefits of mentoring are not automatic consequences of placing an experienced and an inexperienced person in a relationship, but the product of deliberate design.

Three limitations should be acknowledged. First, the corpus is bounded by the 2000–2025 interval and by the search strings and databases described in the Methodology section; publications outside this window or indexed under terminology not captured by the search terms may have been missed. Second, the requirement that studies be available in English or through accessible national databases means that the review is likely to under-represent scholarship published in other languages, which is a relevant constraint given the considerable output on mentoring in Türkiye, Finland, and East Asia. Third, as a document analysis, the study is necessarily dependent on what the selected documents report; where primary studies omitted information on duration, intensity, or mentor preparation, that information could not be reconstructed.

Conclusion and Recommendations

This review set out from the observation that, although the mythological and conceptual roots of mentorship are ancient, the systematization of mentoring in science education is a recent and still incomplete project. The document analysis of 30 studies published between 2000 and 2025 supports four principal conclusions.

First, mentoring in science education has been reconceptualized from a one-directional transmission relationship into a developmental partnership built on voluntariness, mutual trust, and shared responsibility; the literature no longer treats mentee attributes as passive background variables but recognizes them as co-determinants of relational effectiveness (Pfund et al., 2016; Young & Perrewé, 2000).

Second, the evidence base confirms that mentoring yields measurable and multi-layered benefits — for academic achievement and career confidence (Uwimana et al., 2024), for critical thinking, including in the mentors themselves (Nelson et al., 2018), for the formation of scientific identity (Robnett et al., 2018), for teacher retention in structurally supported systems (Smith & Ingersoll, 2004), and for the wider scientific culture (Davies et al., 2021). Because mentorship can be so influential in shaping the future scientific workforce, its occurrence should not be left to chance or idiosyncratic implementation (Workforce et al., 2019).

Third, comparisons across national contexts suggest that institutional design influences mentoring practices (Shanks et al., 2020). Across the induction programs compared, formal support

and protected time are recurring features, while implementation still depends on the school context (Howe, 2006; Shanks et al., 2020).

Fourth, the challenges reported in the corpus — relational breakdowns (MacCallum et al., 2017), insufficient mentor preparation (HS, 2026; Pfund et al., 2016), and resource and workload constraints — are not incidental implementation defects but structural features of systems that assign mentoring responsibilities without equipping mentors for them.

In sum, mentoring is one of the most effective available strategies for improving the quality of science education. Still, its effectiveness is contingent, and that contingency is a matter of educational policy rather than of individual goodwill.

Systems should treat mentoring as an infrastructural component of teacher induction rather than as an informal collegial courtesy. This implies three concrete measures: mentoring should be structurally embedded in induction with defined duration and intensity, since duration and frequency are documented drivers of programme effectiveness and cost (Bagnoli & Estache, 2021); mentoring responsibilities should be formally distinguished from evaluative duties, given the documented tension between assessment and developmental support, and the consistent finding that effective programmes emphasise support rather than assessment (Hobson & Malderez, 2013); and mentor workload should be recognised and compensated, since time constraints are among the most frequently reported barriers. Where induction arrangements currently lack a standardized curriculum, systematic supervision, or objective assessment methods, these elements should be developed rather than left to local variation (Helms-Lorenz et al., 2015).

Mentor training should be standardized and made a precondition of the mentoring role. Programs should aim at the competencies the corpus identifies as decisive, including the ability to align expectations, provide constructive and meaningful feedback, maintain regular contact, and recognize when the relationship requires renegotiation or respectful termination (MacCallum et al., 2017; Swain, 2023). Because the knowledge and skills needed for a relationship to function effectively can be developed, but bringing mentors and mentees together without training advantages those who already possess social capital (Pfund et al., 2016), training should be designed explicitly to widen access rather than to confirm existing advantage. Mentors should also be trained to distinguish advising from mentoring, since the former addresses short-term academic objectives while the latter fosters long-term personal and career development (Martins & Faciola, 2025). Finally, preparation should support the shift from hierarchical assessment towards developmental partnering based on trust, dialogic reflection, and inquiry, which is the direction advocated for teacher education mentorship.

Practice recommendations follow directly from the implementation models discussed above. In research-based and TÜBİTAK-style mentoring, role expectations, meeting schedules, and mutual responsibilities should be made explicit at the outset, for example, through a written agreement, since clarity of roles and agreed goals are repeatedly associated with effective relationships (Swain, 2023). In STEM/STEAM projects, mentors should be supported to guide interdisciplinary connections and creative thinking, rather than limiting their contributions to technical transfer. In digital mentoring, technological capacity should be planned alongside pedagogical capacity: digital platforms offer the prospect of inclusive and scalable mentoring by removing geographical and physical barriers (Pérez-Cruz et al., 2025), but they require flexibility and adaptability in program design, and they do not compensate for the absence of mentor preparation or of clear relational boundaries.

Four directions emerge from the gaps identified in the corpus. First, longitudinal designs are needed to track the persistence of mentoring outcomes beyond the induction period, as existing evidence is heavily weighted towards short-term and case-based designs. Second, research should examine the effects on mentors and on the students of mentored teachers, not only on mentees, since evidence that mentors themselves gain in critical thinking (Nelson et al., 2018) suggests that the returns of mentoring are broader than current designs capture. Third, genuinely comparative, cross-national studies remain scarce; the studies that compare national contexts are among the most conceptually productive in the corpus (Asada, 2012; Howe, 2005, 2008), and the field would benefit

from further systematic comparison of how structural embedding, mentor training, and evaluation pressures interact across systems. Fourth, the digitalization of mentoring requires dedicated investigation: how the shift from face-to-face to digitally mediated interaction alters relational dynamics, trust formation, and the quality of feedback is not yet documented in the science education literature (Hussain et al., 2025), and this is likely to become the most rapidly developing strand of the field. Finally, in the Turkish context specifically, further research should address the functional implementation of the mentor role in candidate teacher education (Ateř et al., 2019) and the empirical effects of structured programs such as T  B  TAK project advising and Science and Art Center mentoring on young researchers' scientific identity and career trajectories.

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Appendix: Article table examined for work

	Country	Author(s)	Purpose	Method / Design	Finding	Conclusion
1	Türkiye	Alp (2022)	To develop pre-service science teachers' mentoring skills through interdisciplinary projects	Concurrent triangulation mixed-methods: weak experimental design + action research; science teaching undergraduates at a state university in İstanbul; 13 mentors, 63 mentees; household solid-waste management projects	Mentoring in interdisciplinary science projects contributed positively to mentees' conceptual learning; mentors improved mentoring skills in pedagogical knowledge/personal characteristics, system requirements, and modeling and feedback; no significant difference in environmental awareness or attitudes, but a positive change in environmental behavior and sustainable consumption in some sub-dimensions	Both mentors and mentees reported that the practice was beneficial for their professional development.
2	Türkiye	Oğuz Ünver, Okulu, Muslu et al. (2022)	To examine and evaluate a professional development model using online mentoring (e-scaffolding) supported by scientific inquiry, and to reveal the readiness of stakeholders (teachers and mentors)	Part of the TÜBİTAK 1001-Grant 220K080 project "Designing and Evaluation of the Effectiveness of Scientific Inquiry Supported by Online Mentoring (e-scaffolding) in In-service Teacher Training"; strategies include mentorship, coaching, peer learning, and collaboration	Teachers held positive views on the importance of science-based inquiry learning and teaching; their expectations of professional development programs varied with their levels of experience.	Designing professional development in line with teachers' expectations is important for making teachers' voices heard.

3	Türkiye	Çiğdemoğlu, TekeLi & Köse (2019)	To reveal the effects of mentoring process on a teacher participating in the BILMER project workshops that support the integration of extracurricular learning environments (science centers) into school curricula, and the effect of mentoring on her students.	Case study: qualitative data from the teacher and her students; a chemistry teacher followed through the mentoring period and observed during project-based activities	Students achieved significant gains in conceptual and affective aspects, understanding of the nature of science, interdisciplinary aspects, and environmental awareness; student diaries showed changes in career planning, career choices, and future perspectives.	Providing mentorship support to teachers in professional development programs is important in many respects, helping ensure the programs are effective and sustainable.
4	Türkiye	Uşak, Hudson & Savran-Gencer (2010)	To benchmark mentoring practices by measuring mentees' perceptions of their mentoring in primary science	Survey of 34 research-based mentoring practices administered to 304 pre-service teachers in Turkey	The majority of mentees perceived that they had received mentoring practices; however, 20% or more reported they had not received 24 of the 34 practices.	Establishing benchmarks for mentoring practices may help educators identify needs and develop programs to address them.
5	Türkiye	İlğan (2021)	To construct a conceptual framework for teachers' professional development and draw implications for the Turkish education system	Conceptual review	Turkey assigns a mentor-like role (rehber öğretmen) to candidate teachers, though it is difficult to say that this is implemented in practice.	Identifying mentor candidates, training and certifying them, and ensuring intensive interaction with candidate teachers can facilitate professional orientation

6	Türkiye	Yılmaz & Günbey (2024)	To examine mentoring practices in the candidate-teacher training process based on legal documents	Qualitative document analysis of 11 legal documents (laws, regulations, guides, directives, circulars) enacted between 1983 and 2022	Early documents emphasized practices to be completed rather than the mentor-candidate relationship; later documents addressed how the process should be carried out and the scope of roles and responsibilities; current documents define mentors' duties in greater detail.	Mentoring is recognized in current legal documents as an important approach in the training of candidate teachers.
7	South Korea	Nam, Seung & Go (2011)	To investigate how a five collaborative mentoring program influenced beginning science teachers' inquiry-based teaching and reflection on practice	One-year program: a five one-on-one mentoring meetings, weekly science education seminars, weekly mentoring group discussions, and self-evaluation activities; three beginning science teachers and three mentors at the middle-school level (grades 7–9) in an urban area; five lessons per teacher evaluated with the Reformed Teaching Observation Protocol	The program encouraged beginning teachers to reflect on their perceptions and teaching practice in inquiry-based science teaching, leading to changes in their practice; collaborative interaction between mentors and beginning teachers was highlighted.	A collaborative mentoring program focused on inquiry-based science teaching supports changes in beginning teachers' classroom practice.
8	South Korea	Kwak (2011)	To investigate ways of introducing a mentoring system to support beginning and experienced science teachers' professional development.	Group mentoring with three protégé-mentor teams; instructional consulting based on videotaped classroom teaching; video-based discussions and open-ended interviews	Teachers shared reflective experiences through collaborative investigations based on evidence revealed in the classroom teaching videos.	Conclusions and recommendations are offered regarding teachers' mentoring and the government's development of a mentoring system.

9	South Korea	Kwak (2010)	To examine the effect of a mentoring program implemented in beginning science teachers' classrooms to support their professional development	Three mentor-mentee pairs; mentors and mentees videotaped all lessons in the same unit; a consulting panel of six beginning and senior teachers cross-analyzed the lessons; open-ended interviews and regular group discussions.	Common teaching features of beginning teachers were analyzed in terms of classroom culture and management, classroom discourse, and science experiments. Through mentoring, mentees recognized that enriched classroom dialogue affected students' content understanding and acknowledged both the necessity of laboratory activities and the roles and ways of managing science activities.	Ways to support beginning teachers' development of instructional professionalism are discussed.
10	South Korea	Lee (2013)	To analyze the difficulties experienced by pre-service science teachers in an "inquiry mentoring" program developed to improve their inquiry-teaching ability.	Program implemented over 2.5 months; 45 pre-service science teachers mentored 44 high-school students; data from mentor diaries, mentoring reports, and individual interviews.	Mmentor-factor difficulties (mentors' own inadequacy: lack of cognitive, inquiry, and teaching ability) exceeded mentee-factor difficulties (student differences, lack of activity); interaction difficulties concerned physical and emotional distance, deciding the scope of guidance and online interaction; environmental	Implications are drawn for pre-service science education through the inquiry mentoring program.

					difficulties reflected an inadequate support system.	
.1 1	Japan	Asada (2012)	To communicate how Japanese culture affects mentoring in schools and to report a study of mentor–novice teacher dialogue.	Small study conducted June 2006–February 2007; dialogues between one female novice teacher and one male mentor with 27 years' experience were analyzed on three occasions; digital recorder and video camera; transcripts were subjected to morphological analysis; 46 teaching scenarios were analyzed.	Patterns of linguistic interaction between mentor and mentee were identified; the time novice teachers spend in Japanese schools is too short for mentoring to move beyond an apprenticeship model; in-group (uchi) and out-group (soto) culture affect novices' acceptance.	The initial teacher development period in Japanese schools could usefully be extended, and culture must be understood so that novice teachers can be accepted into the school's in-group

12	Japan & Canada	Howe (2005)	To examine Japan's teacher acculturation through cross-cultural teaching and research	Ethnographic narrative methods	Canada's teachers work largely in isolation, learning by trial and error, with little provision for mentorship and insufficient time to reflect; Japan's teachers have opportunities for reflection, collegiality, and collaboration, and effective induction practices have evolved gradually; undeveloped pre-service programs, one-way "top-down" pedagogical exchanges, and ineffective mentors remain contentious issues.	Japan's induction practices challenge teacher education to focus more on the needs of beginning teachers.
13	International (8 countries)	Howe (2006)	To identify common attributes and exceptional features of exemplary teacher induction programs	Comparative analysis of exemplary induction programs from Australia, Britain, Canada, France, Germany, Japan, New Zealand, and the United States	The most successful programs give experts and neophytes opportunities to learn together in a supportive environment promoting collaboration, reflection, and acculturation; region-specific practices include extended internships, specially trained mentors, comprehensive in-service training, and reduced teaching assignments, with	Exemplary induction programs share core features and offer transferable practices for teacher acculturation.

					an emphasis on assistance rather than assessment.	
14	Canada & Japan	Howe (2008)	To compare and evaluate teacher induction in Canada and Japan	Comparative study, following an overview of each educational system and an assessment of higher education in each region, draws on the author's personal teaching experience and research	Canada's strengths lie in well-developed pre-service teaching programs, but graduates are left to "sink or swim" in their critical first year; Japan's comprehensive yearlong internship offers an effective apprenticeship induction model with an emphasis on assistance rather than assessment	Teachers need opportunities to learn from one another and time for collaboration, planning, and reflection

15	USA	Smith & Ingersoll (2004)	To examine whether induction programs have a positive effect on the retention of beginning teachers	Analysis of the nationally representative 1999–2000 Schools and Staffing Survey	Beginning teachers provided with mentors from the same subject field and who participated in collective induction activities were less likely to move to other schools and less likely to leave the teaching occupation after their first year.	Induction and mentoring reduce beginning-teacher turnover.
16	USA	Hutchison (2012)	To examine the experiences of new STEM teachers who entered teaching through different pathways, focusing on mentoring effectiveness and the meaningfulness of professional development	Case-study analysis of three new STEM teachers	Mentoring and professional development during the induction year are important for promoting teacher persistence in the profession.	The study offers ideas for recruitment, instructional preparation, and STEM teacher retention practices.
17	USA	Luft, Roehrig & Patterson (2002)	To examine the impact of three different induction programs on secondary science teachers	Teachers matched by grade level across three groups (science-focused support, general support, and no formal support); monitored during the spring semester for teaching beliefs, instructional practices, and classroom experiences.	Secondary science teachers in the science-focused support program implemented more student-centered inquiry lessons, held beliefs aligned with student-centered practices, and felt fewer constraints in their teaching than the other two groups.	Reinforces the importance of induction programs and suggests that universities and school districts should work together to develop specialized support for beginning science teachers

18	USA	Roehrig & Luft (2006)	To examine the impact of a science-focused induction program on secondary science teachers from different preparation programs	16 first-year secondary science teachers who had graduated from one of four different teacher-preparation programs; all monitored during their first year of teaching	The preservice training of a science teacher influenced the type of support derived from the science-focused induction program; teachers from a program with an extended student-teaching experience and two science methods courses held student-centered beliefs and implemented more reform-based lessons	Reinforces the importance of induction programs and the need for specialized support programs for beginning science teachers
19	USA	Luft, Bang & Roehrig (2007)	To show how experienced and professionally active science teachers can support beginning science teachers	An article drawing on the authors' research on beginning-teacher development	A new science teacher needs five types of support — including logistical, instructional, conceptual, and psychological support; the support offered knowingly and unknowingly by the teacher next door is a critical factor; discussing events and ideas can foster professional growth.	The most immediate way to help new science teachers comes from nearby experienced teachers, since formal induction programs vary and rarely focus on developing science-teacher expertise.

20	USA	Luft, Firestone, Wong et al. (2011)	To examine the induction years of beginning content specialists and the changes in their beliefs, pedagogical content knowledge, and practices across different induction programs.	Two-year mixed-methods study of following secondary science teachers during their first and second year of teaching	First-year teachers who participated in science-specific induction programs strengthened their beliefs, PCK, and practices; by the end of the second year, most science teachers shared similar beliefs and PCK, yet those in science-specific programs continued to enact more interactive learning environments with more investigations and laboratories.	The induction of science specialists is an important area of work, and more research is needed into how beginning secondary science teachers learn and which induction experiences best support them.
21	USA	Donna & Roehrig (2024)	To develop a taxonomy of the challenges beginning science teachers face, to inform induction and professional development.	Study of beginning science teacher challenges: taxonomy developed for use in comprehensive induction programs	Beginning science teachers face a wide range of challenges, including those related to planning instruction; a generalist mentor can support many of these, while content-specific induction, with mentoring at its core, helps teachers explore challenges in the context of content.	The taxonomy can be used to design targeted, standards-aligned induction and professional development supports for beginning science teachers.

22	USA	Diehl, Harris, Barrios, O'Connor & Fong (2000)	To describe the development, design principles, and implementation of an on-site training and mentoring program for intern science teachers in urban schools, and to report the roles and experiences of those involved.	Descriptive program paper (symposium presented at the 2000 AERA Annual Meeting); partnership of the UC Berkeley Graduate School of Education, the San Francisco Unified School District, and the Lawrence Berkeley National Laboratory; four perspectives reported (intern teacher, first-year teacher, master practitioner/master teacher, lead teacher), supported by exit interviews	Exit interviews suggest that the program's innovative mentoring structure and other elements could improve the quality of science teaching and the number of prepared teachers in urban schools; however, there are not enough suitably trained science teachers who are able and willing to sustain their careers in urban high schools.	A partnership-based, school-site mentoring model is presented as a way to prepare and retain more qualified science teachers in urban schools.
23	USA	Luft (2025)	To comment on issues concerning teacher induction and to argue that induction practices for early career science teachers need to change.	Commentary/perspective article (non-empirical); draws on international reports on the science teacher supply.	UNESCO (2023) highlighted the declining number of individuals electing to enter the science teaching profession, along with a significant number of teachers leaving the field within their first 5 years; the global shortage of science and mathematics teachers is colliding with the need for talented and knowledgeable science teachers	Induction practices need to change, and the well-being of early-career science teachers must be supported and ensured.

24	Singapore	Yit Kee (2006)	To discuss mentoring as a strategy for inducting beginning teachers in Singapore schools, and to present the Structured Mentoring Program framework.	A program paper presenting the SMP framework and the mentoring recommendations and practices designed to support the beginning teacher	The SMP aims to level up induction and mentoring practices that currently vary across schools; the program was launched on 27 January 2006	The framework is designed to provide structured support for the beginning teacher
25	Singapore	Ng (2012)	To examine the practice of mentoring and coaching in the Singapore education system, the difference in philosophy between the two concepts, and the issues and challenges involved	Literature review and critical analysis of mentoring and coaching philosophies and schemes for different levels of educators	Mentoring and coaching are used in many areas of educators' professional development; inherent tensions exist between the appraisal connotations of some platforms and the encouragement of critical, reflective learning and innovation.	Empirical research is recommended on the impact of specific schemes, participants' experiences, mentor/coach supply, and the extent to which the system is too formalized to encourage innovation.

26	Singapore	Tan (2013)	To explore mentoring experience through a positioning theory lens, focusing on beginning teachers and mentors in a Singapore school.	Case study: data collected mainly through interviews with beginning teachers and mentors	Beginning teachers with an emotionally assuring experience had mentors positioned as emotional providers; those with a professionally fulfilling experience had mentors positioned beyond emotional support; less satisfying experiences involved mentors positioned as physically and emotionally unavailable; mentors with frustrating experiences had beginning teachers who challenged their positioning.	Schools should give more attention to mentor preparation, and it should not be a one-off exercise; a pre-mentoring session for both mentors and beginning teachers may be useful.
27	Singapore	Chin (2017)	To develop theoretical propositions about the perspectives primary school teachers hold on the mentoring of beginning teachers in Singapore primary schools	Qualitative study	Effective mentors exhibit specific attributes related to communication and mentoring approaches; a correlation was found between mentors' commitment level and their intent and perceived potential benefits of mentoring; conditions influencing the effectiveness of these mentor attributes were identified.	Effective mentoring depends on identifiable mentor attributes and on the conditions that enable them.

28	Finland	Pennanen, Heikkinen & Tynjälä (2018)	To examine the virtues of mentors and mentees in the Finnish model of teachers' peer-group mentoring	Analysis of the Finnish peer-group mentoring model and its social-theoretical foundations	In PGM, group members work as co-mentors and co-mentees to each other, sharing experiences and expertise; PGM involves no assessment, evaluation, or inspection, and participants are responsible for their own learning; social interaction is emphasized as central.	PGM is best described as collaborative self-development
29	Finland	Tynjälä, Pennanen, Markkanen et al. (2019)	To review research on the Finnish model of peer-group mentoring	Thematic review based on 46 peer-reviewed publications about PGM in Finland published in 2009–2019; qualitative approach dominant	Both mentors and mentees find PGM a useful tool for individual professional learning and well-being; indirect influences on the development of work communities were reported; the main challenges are the lack of national agreement on organizing PGM and on allocating mentors' and mentees' working time to it	PGM, as well as teachers' professional development as a whole, should be seen as an integral part of the educational ecosystem

30	Finland	Heikkinen (2020)	To describe the development of mentoring practices in Finland and to examine the main research findings on mentor and mentee experiences of the PGM model.	Review of PGM research and development over 15 years through an ecosystemic lens	F, inland's high-quality pre-service teacher education is widely recognized. In contrast, challenges in in-service teacher education have been acknowledged, and several researchers have highlighted the need for mentoring and induction.	Mentoring lives (or not) in a given ecological niche, understood as a relational space between initial teacher education and career-long professional development.
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