

A Case Study of Kindergarten Teachers' Science Practices: Reflections of Knowledge and Attitude*

Nefise Özok Bulut^{a,*}, Meral Ören^b

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^{a,*} **Corresponding Author:** Nefise Özok Bulut, Assistant Professor, Department of Child Development, İstanbul Gedik University, İstanbul, Türkiye.
E-mail: nefise.ozok@gedik.edu.tr
ORCID: <https://orcid.org/0000-0002-2070-7797>

^b Meral Ören, Assistant Professor, Department of Early Childhood Education, Anadolu University, Eskişehir, Türkiye.
E-mail: moren@anadolu.edu.tr
ORCID: <https://orcid.org/0000-0003-1583-6874>

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Abstract

It is becoming increasingly recognized and accepted that providing children with quality science experiences during their early years can positively impact their science achievement and process skills in their later years. To provide such experiences, it is critical to explore how early childhood teachers' attitudes toward science and their level of knowledge in science impact their science teaching in the classroom. The study aimed to examine the science practices of kindergarten teachers with different levels of scientific knowledge and attitudes toward teaching science employing a holistic multiple-case study. The participants were two kindergarten teachers with different levels of scientific knowledge and attitudes toward teaching science. They were selected through an extreme case sampling method using the Early Childhood Teachers' Attitudes Toward Science Teaching Scale and the Achievement Test on Scientific Concepts results. The data were collected through interviews and observation; and analyzed through deductive thematic analysis. The results indicated that science knowledge and attitudes of teachers were related to; the frequency of science activities, the resources they used, planning processes, teaching methods, making accurate scientific explanations, and child involvement in science activities.

Keywords:

Early Childhood Education, Kindergarten Teachers, Science Education, Scientific Knowledge, Teachers' Attitudes Towards Teaching Science

Introduction

According to the results of the Programme for International Student Assessment (PISA) tests, Türkiye's performance in science literacy, though improving, continues to lag statistically behind the OECD average (OECD, 2019, 2022). This persistent gap underscores the critical need to enhance science education across all developmental stages, beginning with early childhood. Research findings, particularly from the Trends in International Mathematics and Science Study (TIMSS), affirm a positive correlation between the duration of preschool education and later science literacy outcomes (MoNE, 2016). Furthermore, quality, enriched science experiences provided in preschool are shown to be foundational for children's future scientific achievement and the development of essential scientific



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process skills (Genç-Kumtepe et al., 2009; Morgan et al., 2016).

Effective science instruction hinges upon the quality of the kindergarten teacher. While studies conducted in Türkiye consistently report that early childhood teachers generally hold positive attitudes toward teaching science, this enthusiasm often coexists with documented deficiencies in their science content knowledge (CK) and low professional self-efficacy (Mercan & Kutluca, 2021; Olgan, 2015; Polat et al., 2021). This disjuncture presents a primary challenge in the field: Although positive attitudes can be linked to a higher frequency of implementing science activities (Genç-Kumtepe et al., 2013), insufficient scientific knowledge often creates significant difficulties in executing these activities effectively and authentically (Akyol & Birinci-Konur, 2018; Babaroğlu & Okur-Metwalley, 2018). Crucially, the underlying reasons why teachers avoid or oversimplify science often extend beyond structural limitations to affective and self-efficacy-related barriers. Research suggests that early childhood educators frequently experience discomfort, anxiety, and a lack of confidence when teaching science, particularly when they perceive their science content knowledge as insufficient (Roberts & Collins, 2026; Simsar & Davidson, 2020). Such feelings of inadequacy may lead teachers to avoid science activities, postpone scientific investigations, or transform inquiry-based experiences into highly structured and predictable routines, thereby limiting children's opportunities for authentic scientific exploration (O'Connor et al., 2021; Roberts & Collins, 2026).

Much of the existing research primarily emphasizes that professional development should prioritize raising teachers' knowledge and attitudes, positing these factors as the necessary drivers for better science practice frequency and quality (Barenthien et al., 2020; Loxley et al., 2016; Oppermann et al., 2021; Pendergast et al., 2017). However, the complexity of this relationship is often overlooked. Training programs in Türkiye currently offer only one science education course, leading teachers to perceive their undergraduate preparation as insufficient (Mercan & Kutluca, 2021). Studies show that exposure to more methods courses or professional development is linked to greater proficiency and frequency of science integration (Oppermann et al., 2021; Sağkes, 2014). Crucially, given that early childhood teachers can inadvertently transmit scientific misconceptions, they must possess both content knowledge (CK) and pedagogical knowledge (PK) for science (Gerde et al., 2018; Greenfield et al., 2009; Kallery & Psillos, 2001; McCray & Chen, 2012).

Grounded in Gudmundsdottir and Shulman's (1987) PCK model, this study examines how early

childhood teachers transform subject matter into teachable content. Within this model, PCK functions as an integrated framework encompassing core components: deep content knowledge, specialized pedagogical techniques, and learner-tailored instructional strategies that accommodate children's developmental readiness and preconceptions (Nilsson & Loughran, 2012; Park & Oliver, 2008). In early childhood science, these components dictate how a teacher moves beyond generic teaching methods to deploy domain-specific scaffolding. Scientific knowledge and attitudes serve as critical precursors to this process; deficits in either inevitably constrain PCK, replacing genuine inquiry with superficial, recipe-following activities. Consequently, this research investigates not merely the presence of these elements, but how they interact to shape enacted PCK in the classroom. Crucially, because a teacher's enacted PCK directly delineates the boundaries of the classroom learning environment, it fundamentally shapes child outcomes—determining whether children exhibit active inquiry and high agency or succumb to passive disengagement and reinforced misconceptions during science experiences.

Furthermore, these classroom enactments do not occur in a vacuum but are highly influenced by the shifting curriculum and socio-cultural environment. While the recent curriculum revisions by the Ministry of National Education (MoNE) aim to modernize early childhood practices (MoNE, 2024), contemporary literature highlights that the post-COVID-19 digital transformation and the introduction of hybrid learning approaches have fundamentally reshaped early childhood science landscapes in Türkiye, creating additional demands for techno-pedagogical PCK readiness (Aktaş, 2024; Öztürk, 2025). Concurrently, the unique socio-cultural dynamics of school-family relationships in the Turkish context introduce a distinct mechanism of parental delegation or pedagogical compensation. In many local communities, parents heavily delegate scientific and academic accountability to the school, expecting early childhood teachers to act as the primary or sole source of formal knowledge acquisition. This cultural adaptation places an immense implicit pressure on teachers' enacted PCK, making their perceived scientific competence and classroom practices a critical junction for both institutional and familial expectations (Snape & Fox, 2021), particularly within localized private and institutional early childhood sectors where consumerist parental demands are highly pronounced.

While prior quantitative studies consistently map the correlation between teacher characteristics (CK, self-efficacy, and attitudes) and the frequency of science instruction (Mercan & Kutluca, 2021; Olgan, 2015; Polat et al., 2021), there is a profound critical gap

in understanding the qualitative, contextual dynamics of this relationship. The field currently lacks in-depth, systematic case studies that move beyond self-reports to analyze how knowledge and attitudinal deficiencies are reflected in the nuanced processes of planning, pedagogical choices, and real-time interaction with children during science lessons.

To address this critical gap, the purpose of this qualitative comparative case study is to examine, in-depth, the science planning and implementation practices of two kindergarten teachers possessing distinctly different profiles of science content knowledge and professional self-efficacy, while concurrently exploring how these disparate pedagogical environments shape kindergarteners' classroom reactions. The results are expected to contribute significantly to the refinement of pre-service teacher training programs, guide context-specific in-service training efforts, and inform curriculum development studies by providing rich data. To achieve this objective, the study addresses the following research questions:

1. How do kindergarten teachers with different levels of science knowledge and attitudes towards science education:
 - a. Plan science activities?
 - b. Implement science activities?
2. How do kindergarteners react during the science practices of kindergarten teachers?

Method

Research Design

The research design for this study employed a holistic multiple-case study design. This approach was selected to provide an intensive, contextual examination of a contemporary phenomenon (the relationship between teacher characteristics and practice) within its real-life setting (Creswell & Creswell, 2018). The decision to utilize a multiple-case study was methodologically driven by the need to explore variations and similarities in science teaching practices across distinctly different profiles of teacher knowledge and attitude.

In accordance with Yin's (2018) framework, a holistic design was applied to analyze each teacher-school context as a single, unified case, explicitly examining how individual subject matter boundaries, pedagogical content knowledge (PCK), and parental interactions intersect in daily instruction. Because the first author operated as a participant observer over a 16-week period, potential researcher influence and interpretive bias were meticulously managed through rigorous reflexivity. The researcher maintained a detailed diary of analytical memos to intentionally bracket a priori professional assumptions, ensuring

that findings remained closely grounded in the participants' authentic experiences rather than the researcher's expectations (Gray, 2004). Consequently, the resulting qualitative conclusions are presented non-definitively and with scientific caution, acknowledging that these bounded cases illuminate complex pedagogical dynamics rather than offering universal generalizations.

Participants

To select the cases, 119 volunteering teachers from schools in three districts of Istanbul, one of the major cities in Türkiye, completed the Early Childhood Teachers' Attitudes Toward Science Teaching Scale and the Achievement Test on Scientific Concepts. Using the scale scores, one teacher from both ends was selected through extreme case sampling using purposeful sampling methods. An extreme case sampling strategy (Silverman, 2015), a form of purposeful sampling, was employed to maximize the variation in teacher practices and enable the analysis of contrasting cases. To guide the reader, the teacher with the highest scores in the study is given the pseudonym 'Hale', starting with the initials of the word 'high', whereas the teacher with low scores is given the pseudonym 'Leyla', which begins with the initial letter of the word 'low'. All participants were provided with a participant information statement and informed consent.

Leyla was strategically selected to represent a profile slightly below the group average, deliberately avoiding extreme low-scoring outliers whose practices may be idiosyncratic. By focusing on this 'moderate but insufficient' profile, the study captures the reality of a substantial segment of the teacher population, thereby enhancing the contextual transferability of the findings regarding typical challenges. Table 1 presents Hale and Leyla's scores relative to the larger cohort ($N = 119$).

Table 1.
Participants' achievement test and attitude scale scores

	Hale	Leyla	Minimum	Maximum	Average
Attitude scale score	62	47	29	65	47.67
Achievement test score	19	7	7	19	13.47

Hale received the highest scores on both scales, while Leyla scored well below average on the Achievement Test on Scientific Concepts and had an average score on the Early Childhood Teachers' Attitudes Toward Science Teaching Scale. The characteristics of the teachers are demonstrated in Table 2.

Table 2.
Characteristics of the participants

	Hale	Leyla
Gender	Female	Female
Institution	Kindergarten	Kindergarten
Number of children in the class	23	23
Age	38	36
Professional experience	6	15
Undergraduate program	Early childhood education	Early childhood education

Both teachers operated within public primary schools adhering to the national MoNE (Ministry of National Education) curriculum. Kindergarten in this paper refers to the final year of formal schooling before first grade, as commonly used in the USA context, serving children aged 57-68 months at enrollment. Both schools were economically located in lower-middle-class neighborhoods and had a class size of approximately 25-28 students.

Schools with similar physical characteristics and resources were selected as they could influence science practices. However, some differences exist in science practices. Hale conducts formal science activities three to four times a week, often utilizing hands-on materials. Leyla conducts science activities two to three times a week, and her practices were observed to rely more on readily available classroom materials rather than specialized science resources.

Data Collection and Procedures

Two instruments guided the selection of case study participants. First, the Early Childhood Teachers' Attitudes towards Science Teaching Scale (Cho et al., 2003; adapted by Ünal et al., 2010) was used to assess self-development and self-efficacy. Reliability coefficients were high for both the original adaptation ($\alpha = 0.84$) and the current study ($\alpha = 0.89$). Second, the Achievement Test on Scientific Concepts (Güney, 2016) measured content knowledge. While the original test demonstrated a reliability of $\alpha = 0.77$, the current study yielded a coefficient of $\alpha = 0.67$.

Following participant selection, data were collected through 16 weeks of classroom observations and interviews (November 2019 – February 2020). Weekly semi-structured micro-interviews (Merriam, 2018) were conducted immediately before and after observations. The interview questions and prompts were developed based on a comprehensive literature review focusing on teacher self-efficacy (Bandura, 1997) and PCK dimensions (Gudmundsdottir & Shulman, 1987). To ensure content validity and pedagogical appropriateness, the initial draft of the questions was evaluated by three independent experts holding

doctoral degrees in early childhood education. Following their feedback, minor adjustments were made to the phrasing of the questions to enhance clarity. A pilot application was subsequently conducted with one non-participating preschool teacher to test the flow, comprehensibility, and duration of the micro-interviews, which confirmed the instrument's readiness for the field. These brief sessions (<10 mins) captured in-the-moment planning rationales and immediate reflections on practice (e.g., "Which science topics cause you anxiety?" or "How do you handle unanswerable questions from children?"). The first author utilized a participant observer technique, engaging in free play but remaining an observer during science activities. The focus extended beyond the teacher to include the verbal and nonverbal behaviors of interacting children.

Due to school administration policies, institutional research ethics, and strict child privacy regulations within early childhood settings in Türkiye, video recording of the children and classroom environments was not permitted. Consequently, data triangulation was rigorously implemented to ensure trustworthiness. Audio recordings of the interviews were transcribed verbatim and supplemented by detailed, chronological field notes capturing non-verbal cues (e.g., body language, attention shifts) observed during the classroom sessions. Additionally, a researcher's diary was maintained to record analytical memos and facilitate reflexivity (Gray, 2004). This process involved bracketing a priori beliefs to ensure interpretations remained grounded in the participants' perspectives rather than the researcher's assumptions.

Data Analysis

Qualitative data were analyzed using thematic analysis following the six-phase framework outlined by Braun and Clarke (2006). To balance theoretical coherence with empirical sensitivity, a hybrid coding strategy was employed:

Major themes were established a priori based on the study's research questions and the PCK framework (e.g., planning process, teaching process). This structure anchored the findings within the established theoretical scope.

Sub-themes and specific codes emerged organically from the data. Through deep immersion in verbatim transcripts and observation notes, codes such as difficulties encountered or children's reactions were derived directly from participants' experiences, capturing nuances not explicitly dictated by the PCK model. This dual approach ensured that the analysis remained theoretically grounded while being open to context-specific phenomena.

Validity and Reliability

To maximize the trustworthiness of this qualitative research, we implemented multiple methodological procedures (Creswell & Creswell, 2018; Merriam, 2018), addressing all four key criteria:

Established through data triangulation (cross-referencing interviews, observation notes, and the researcher's journal) and long-term engagement (16 observations per case). Furthermore, member checking was conducted by sending detailed summaries to Hale and Leyla for review and confirmation of accuracy.

Ensured via inter-coder reliability. A second, independent coder analyzed 10% of the total transcriptions. The agreement rate was calculated using the formula by Miles and Huberman (1994) across 75 total coding instances, yielding a final reliability score of 92%. Discrepancies were resolved through discussion to reach a consensus.

Supported by providing thick descriptions of the teachers' practices and the detailed account of the research context. Enhanced through researcher reflexivity, involving the systematic examination of the researcher's a priori beliefs and positionality, as maintained in the researcher's diary.

To further ensure transparency, the first author's positionality and potential observer effects must be critically explicated. As a doctoral researcher well-versed in early childhood science education, the first author entered the field with an a priori assumption that high-quality, inquiry-based science is critical for young children, which initially created a subjective expectation toward witnessing inquiry-driven practices. Acknowledging this bias, the researcher rigorously utilized analytical memos to bracket these personal expectations during data analysis. Furthermore, the prolonged 16-week presence of the researcher inevitably introduced subtle observer effects on classroom dynamics.

Most notably, the teacher with limited science expertise explicitly increased the frequency of her science activities during the initial weeks of the observation period, demonstrating a clear reaction to being observed. Rather than discarding this reactivity, the researcher treated this behavioral shift as an empirical finding in itself, documenting how the teacher initially relied on structured, internet-sourced demonstration kits to artificially meet the perceived professional expectations of the ongoing study. Over the extended timeline, however, this acute observer effect gradually diminished; the prolonged presence allowed the researcher to become a familiar, non-threatening element of the classroom environment. This long-term immersion eventually prompted both

teachers to revert to their authentic pedagogical routines, exposing the deep-seated pedagogical gaps, anxieties, and compensatory behaviors (such as relying on the 'parent of the week') that form the core of this study's findings. By critically reporting these reflexive shifts, the study embraces researcher-participant dynamics as a transparent dimension of qualitative rigor.

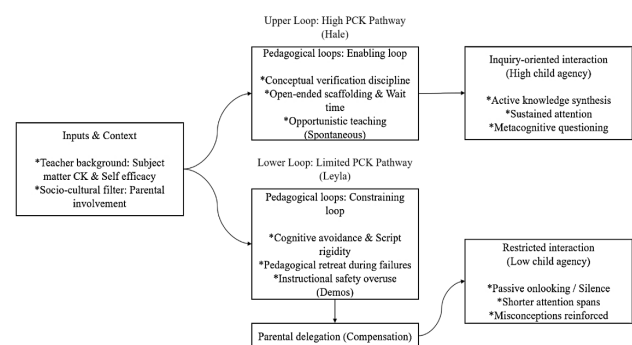
Ethical Procedures

This study was approved by the Anadolu University Social and Human Sciences Scientific Research and Publication Ethics Committee (Date: March 28, 2019, Protocol Number: 22483). Institutional permissions were secured from the participating private preschool administrations prior to data collection. Written informed consent was obtained from both participating teachers, and written parental consent alongside verbal child assent was secured for all participating children to ensure strict compliance with ethical standards and absolute confidentiality.

Results

As a result of the analysis obtained through micro-interviews, systematic observations, and the researcher's diary, the findings were inductively grouped under two main themes and eight sub-themes. To make the operational complexity of these qualitative findings immediately digestible for the reader, a comprehensive conceptual framework summarizing the relationship between the teachers' Pedagogical Content Knowledge (PCK) levels and the resulting classroom child interactions is illustrated in Figure 1. This model visually bifurcates the data into two distinct pedagogical pathways based on teacher competence.

Figure 1.
Conceptual framework of PCK pathways and child interaction dynamics



As a result of the analysis obtained through interviews and observations, the findings were grouped under two main themes and eight sub-themes as shown in Table 3.

The data analysis, based on a comprehensive set of micro-interviews, systematic observations, and researcher's diary yielded a rich comparative understanding of the two teachers' science teaching practices. The findings were inductively grouped into two main themes and eight sub-themes, as outlined in Table 3. Furthermore, to immediately provide the reader with a clear structural overview of the key comparisons, the core analytic distinctions between Hale and Leyla are summarized in Table 4, which precedes the thematic presentation.

The following sections detail the findings across the established themes, incorporating direct quotations with source codes (e.g., Observation, Interview, Researcher's diary) to ensure the study's confirmability and analytic rigor.

Table 3.

Themes, sub-themes and codes

Themes	Sub-themes	Codes
Planning process	Resources used	Books, magazines, documentaries, Internet, social media, plans from different sources
	Preparations	Controlling the accuracy of the information, Adapting children's level, Making modifications to ensure active participation of children, Making connections to previous learnings, Preparing interesting materials and learning environments
	Frequency	Two times a week, Three times a week, Four times a week, Unplanned science activities
	Topics	Physical science, earth and space science, life science
	Scientific process skills	Prediction, recall, making associations with background information, cause-and-effect relationships, inference, classification, measurement
Teaching process	Teaching methods and techniques	Question-and-answer, lecture, experiment, demonstration, inquiry
	Difficulties encountered	Attracting children's attention, Making transitions between activities, Classroom management, Adapting information to children's level, Creating a supportive learning environment, Integrating science with other activities
	Children's reactions	Active participation, remaining passive, focusing attention on the activity, answering questions, asking questions, remaining unresponsive, distraction,

Table 4.

Comparative analytical summary of findings

	Hale (Strengths: High Self-Efficacy / Extensive CK)	Leyla (Limitations: Low Self-Efficacy / Limited CK)
Planning and preparation	Conceptual verification discipline: Rigorous checking of information accuracy and use of multiple sources.	Reliance on ready-made materials: Tendency to use pre-made plans with minimal adaptation
Implementation and spontaneity	Opportunistic teaching: Ability to spontaneously convert moments of child interest into conceptual inquiry.	Pedagogical avoidance: Ignoring spontaneous moments that involve uncertainty or move beyond planned content.
Questioning technique	Open-ended inquiry: Providing sufficient wait time and guiding children towards hypothesis generation.	Closed-ended/self-answering: Prioritizing quick closure; answering her own questions; restricting deeper thinking
Questioning technique / Risk management	High conceptual confidence: Unworried about being asked unanswerable questions; actively connecting complex concepts to prior learning	Conceptual gaps: Transmitting inaccurate information due to lack of knowledge and retreating during conceptual failure.
Compensation/Support mechanism	Parental enrichment: Integrating parent-led content into her own inquiry framework.	Parental delegation: Strategically delegating life science activities to parents to reduce personal instructional burden.
Impact on child participation	High agency: Fostering active participation where children exhibit knowledge synthesis and metacognition.	Low agency: Discouraging curiosity and confirming scientific misconceptions through silence or incomplete answers.

Planning Process

Under this theme, the findings related to two sub-themes, namely the resources used by the teachers in the planning process and the preparations they make before the science activities, are given respectively. The findings indicate that differences in teacher competence significantly determined the depth of research and the discipline of conceptual validation.

During the interviews, Hale stated that she explores various sources, including books, magazines, documentaries, the internet, and social media for science activity plan ideas; and mostly plans science activities herself, but sometimes uses the plans from different sources by adapting if necessary. Leyla, on the other hand, stated during the interviews

that she uses magazines, documentaries, and the internet about science, and that she usually uses plans from different sources rather than planning herself. To prepare for the activities, Hale stated that she controls the accuracy of the information, adapts children's level, makes modifications to ensure active participation of children, and makes connections to previous learnings:

"I check the accuracy of the information from a theoretical perspective. I make adaptations according to the age and developmental characteristics of children... I remind them of the knowledge they have already learned. I try to ensure that children participate actively, depending on the activity (Interview)."

Observations indicated that Hale maintained this conceptual verification discipline even when activities were presented by the child of the week. This commitment reflects Hale's high self-efficacy and her professional standard of validating all content introduced into the classroom.

During a "the paper that doesn't get wet" experiment led by a child, Hale did not simply observe. She asked the children, "Do you remember what made the ping-pong ball bounce when we played?" thereby deliberately anchoring the experiment in the previously discussed concept of air pressure (Observation). This proactive intervention exemplifies Hale's ability to instantaneously connect a demonstration to prior learning and a coherent scientific framework.

In contrast, Leyla mentioned preparing interesting materials and learning environments (Interview), but did not specify any attempts to acquire deep conceptual knowledge about the topics she addressed. Researcher's diary entries strongly suggest that this deficiency led to pedagogical retreat when errors occurred:

"Leyla's failure to secure conceptual knowledge increased the risk of conceptual error and diminished her capacity for pedagogical recovery (Researcher's Diary)."

"During a non-exploding balloon experiment, Leyla failed to put enough water in the balloon, causing it to burst. Crucially, she did not discuss the reason for the burst with the children but immediately took a new balloon and repeated the experiment. This demonstrates her avoidance of spontaneously engaging with conceptual failure (Researcher's Diary)."

It was further observed that Leyla did not acquire knowledge regarding the science activities implemented by families, nor did she take an active role. Her presence during a bird-themed activity conducted by a mother was purely observational (Observation), and she admitted in the interview to lacking sufficient knowledge about animal care and characteristics (Interview). This behavior is interpreted

as an early manifestation of her compensatory strategy, where parental delegation is used to manage professional inadequacy.

Teaching Process

Under this theme, findings related to six sub-themes are presented: the frequency of teachers' implementation of science activities, the topics they address, scientific process skills, the teaching methods and techniques they use, the difficulties encountered by teachers, and the reactions of children.

The frequency of implementing science activities

Hale conducts science activities three to four times a week, and in one of these activities, a child does an experiment taught by his/her parents. Hale video records the process while she guides the child, asks questions to the children, and teaches related content knowledge. This practice shows that Hale uses this situation as a source of enrichment.

Leyla conducted science activities two to three times a week. She reported in the interviews that the researcher's presence encouraged her to practice more regularly (Interview). Crucially, Leyla openly stated that she engaged families to perform various science activities "to reduce the subject load and relieve her burden" (Interview). This finding confirms Leyla's use of parental delegation as a core professional compensatory strategy. Each week, this delegation involved the parent of the week conducting a demonstration experiment and teaching about an animal or a plant on a separate day.

A critical distinction emerged in the teachers' ability to leverage incidental teaching opportunities. Both teachers verbally acknowledged the value of capitalizing on objects or events that capture children's attention (Interview). However, observations showed a significant gap in their implementation capability.

Hale consistently demonstrated the pedagogical flexibility necessary to implement unplanned science activities in response to emergent interest. Her ability to teach opportunistically stemmed from her readily available content knowledge, allowing her to connect phenomena to core concepts in real-time.

Hale noticed that the leaves of one of two identical plants were wilting. She immediately gathered the children around and initiated an unplanned investigation, asking them a series of open-ended, diagnostic questions. A child pointed to the dry soil and stated, "That one looks sad because it's thirsty!" (Observation). Hale used this spontaneous contribution to structure a comparative experiment on plant needs, allowing the children to discover the wilting

cause themselves, thus maintaining child agency in the scientific process.

Conversely, throughout the 13-week observation period, Leyla failed to capitalize on any emergent learning moments, rigidly adhering to her scheduled script. Her limited CK seemed to result in cognitive avoidance, preventing her from engaging with spontaneous inquiries that might lead to unknown conceptual territory.

Leyla picked up a fallen aloe vera leaf and showed the liquid coming out to the children. The plant instantly attracted the children's attention; several children rushed forward, asking, "Is it medicine? Is it juice?" (Observation). Instead of seizing this moment to discuss plant function, moisture, or adaptation, Leyla simply left the leaf with them and walked away. This inability to transition from a behavioral description (showing the liquid) to a conceptual inquiry highlights how low CK restricts pedagogical improvisation.

This marked difference emphasizes that content knowledge in this context is not merely about having information, but about possessing the cognitive capacity to improvise instruction and manage the inherent uncertainty of an inquiry-based environment

Topics

Hale's topic selection was driven by a desire to "stir the curiosity of the children," prioritizing subjects that would support the development of scientific process skills and concepts adaptable to their level (Interview). Leyla, conversely, prioritized familiar concepts and events children encounter in their daily lives, aligning with a lower-risk instructional approach (Interview).

Both teachers covered physical science, Earth and space science, and life science. However, a pattern of competence-based specialization and delegation emerged: Leyla primarily covered physical science (often as demonstrations), while life science topics were consistently delegated to parents. This suggests a strategic avoidance of life science, where her self-reported inadequacy was highest. Hale allocated proportionally more coverage to Earth and space science, reflecting her broad comfort level.

The most significant distinction lay in the teachers' self-efficacy regarding potential conceptual challenges. Hale reported feeling proficient in science subjects and stated she was not worried about children asking unanswerable questions (Interview). This high self-efficacy is a cognitive factor that allowed her to teach more opportunistically.

Leyla, however, admitted to feeling inadequate concerning plants, animals, and physical science, stating directly that she worries when faced with

potential conceptual questions (Interview). While both teachers claimed they would investigate unknown questions, observations indicated Leyla's anxiety led to clear instances of avoiding critical conceptual engagement. Leyla's anxiety and low self-efficacy translated into a risk management strategy of ignoring complex or spontaneous inquiry, thereby protecting her perceived competence level.

During a 'sinking/non-sinking tangerine experiment' (conducted as a demonstration), a child asked a conceptually demanding question: "The ships do not sink because they are big. Is that so, teacher?" Leyla bypassed this question entirely and proceeded with the activity without answering or acknowledging the child's complex hypothesis (Observation). This behavioral pattern demonstrates that Leyla's lack of knowledge inhibited her ability to provide satisfactory answers, directly limiting children's questioning skills and discouraging the natural development of scientific inquiry.

Hale systematically integrated science activities with literacy and music, frequently using picture books to deepen conceptual understanding (Observation). Leyla mostly presented science as a fragmented and isolated activity (Observation). Despite the national curriculum's emphasis on using the environment, both teachers conducted all science activities indoors and did not utilize the outdoor space (Observation). This highlights a persistent systemic/contextual limitation within the school setting that transcends individual teacher competence.

Scientific process skills

The two teachers exhibited starkly different approaches to fostering scientific process skills. Hale actively nurtured skills such as prediction, recall, association, cause-and-effect reasoning, and inference, though she supported classification and measurement less frequently. Leyla's practices, constrained by her self-reported lack of knowledge, generally failed to create an environment conducive to skills development. Notably, neither teacher supported the crucial step of data recording after experiments.

Hale utilized questioning and material manipulation to move children from mere observation to structured inquiry. Her practice was characterized by intentional sequencing to develop measurement skills and foster conceptual discovery.

Hale held a white and a brown egg, initiating a conversation on their similarities and differences. After placing the eggs in the children's hands to facilitate tactile observation, she asked, "They feel different, but how can we know for sure which one is heavier?". A child responded, "We can weigh them, like the flour we used for cookies!". The class then transitioned to using the scale in the science center, demonstrating how Hale's questions successfully prompted children

to propose a testable measurement method based on prior experience (Observation).

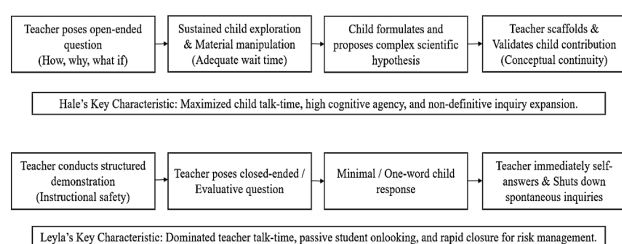
Leyla's instructional style was characterized by a tendency toward conceptual closure and immediate delivery of answers, often bypassing the necessity of active child exploration. This behavior is directly linked to her low self-efficacy, serving as a defense mechanism against spontaneous inquiry. In activities designed to teach scientific concepts, Leyla often employed a "telling" methodology instead of a "discovery" one. In an activity teaching 'hot, warm, and cold' concept, Leyla stated the outcome before the process: "Look, children, this water is a little hot, this water is cold, this water is warm. Now you will come one by one and touch the waters." (Observation). This approach prevents children from formulating hypotheses or engaging in self-regulation of the experiment, reducing the activity to passive sensory exercise.

Furthermore, Leyla demonstrated a lack of pedagogical content knowledge that resulted in the transmission of misinformation. Leyla's attempt to use an analogy to teach freezing failed due to a fundamental conceptual error, which she reinforced by avoiding an experiential follow-up. During a discussion on water melting/freezing, Leyla claimed: "When I put the water in the freezer, it froze. Does everything I put in the freezer freeze? For example, cheese, olives, and jam do not freeze." (Observation). Not only did Leyla fail to wait for children's answers, but she also did not plan to put these materials in the freezer to allow for observation. Most critically, she provided incorrect information by asserting that the water contained in these foods would not freeze, reinforcing a conceptual misunderstanding among the children due to her own lack of sufficient content knowledge.

In comparison, while both teachers included scientific process skills in their plans, Hale consistently created environments that scaffolded true scientific inquiry and discovery. On the other hand, Leyla's need for certainty led her to prioritize instructional efficiency over the development of inquiry skills.

Figure 2.

Behavioral flow models of classroom interaction sequences



Leyla predominantly employed the demonstration experiment technique, which she perceived as the default method for science: "in fact, we always do experiments according to the subject, everything is an experiment" (Interview). This overuse suggests an over-reliance on a structured format that minimizes spontaneous inquiry. Hale, possessing broader content competence, utilized a wider range of methods, integrating more discussion and exploratory activities, even for topics like animals and plants. Furthermore, Hale consciously built conceptual continuity by guiding children to connect current topics to previous ones, a practice Leyla completely omitted.

A stark difference emerged in the level of child engagement permitted during experiments. Hale frequently created an environment that supported active experimentation and true inquiry. In contrast, Leyla relied on demonstration experiments in which children were positioned merely as onlookers.

Leyla's preference for demonstrations extended to experiments that were not only safe but could have been easily adapted for active, hands-on learning (e.g., the non-sinking orange/tangerine experiments). This choice is interpreted as a pedagogical control strategy; by maintaining control over the materials, Leyla limited the potential for unpredictable outcomes or complex spontaneous questions that might expose her conceptual gaps. She even conducted potentially unsafe experiments (e.g., those involving candles, fast reactions) without appropriate safety precautions or conceptual grounding.

The most compelling difference lay in the teachers' use of questioning. Hale consistently employed open-ended questions (e.g., 'how,' 'why,' and 'what if') and practiced excellent scaffolding skills. She ensured children received adequate wait time to formulate complex responses, provided tips, and ensured active participation.

Before reading a book on rain, Hale asked children about the rainy weather. After establishing the fact that it was raining, she moved the inquiry to reasoning by asking, "How did you understand this and what did you see outside?". Later, to explain water vapor, she instructed them to breathe onto the windowpane, using the resulting condensation as a tangible, shared concept (Observation). Hale's practice exemplifies how high pedagogical content knowledge enables the teacher to manage the cognitive load of the lesson while promoting child agency.

In sharp contrast, Leyla relied predominantly on closed-ended questions, offered insufficient time for children to think, and often answered her own questions. This pattern reflects Leyla's lower CK, which increases her own cognitive load during instruction, leading her to avoid demanding, open-ended discourse.

Leyla attempted to teach measurement by placing her foot next to a child's foot and asking the class: "Which one of us has a longer foot? Mine is longer, isn't it?". A child responded, "Yours is longer because you are older?". Leyla immediately affirmed her own statement ("Mine is longer, isn't it?"), shutting down child's attempt to introduce the complex variable of age (Observation). Leyla's closed questioning and quick self-answering prioritized compliance and speed over the development of critical thinking and hypothesis generation.

In summary, Hale utilized a combination of teacher-centered and child-centered methods to create active, inquiry-based environments. Leyla, constrained by her low self-efficacy and limited knowledge, relied almost exclusively on teacher-centered methods and demonstration, prioritizing instructional safety over conceptual depth.

Difficulties encountered

This sub-theme details the challenges experienced by the teachers, which can be categorized into shared pedagogical challenges (classroom environment/transitions) and competence-specific challenges (content adaptation/integration).

Both teachers exhibited difficulties in attracting and maintaining children's attention and ensuring smooth transitions between activities. These challenges were largely linked to structural issues: materials were often prepared only after children had settled for the activity, leading to immediate disengagement. Furthermore, the lack of transition activities, such as finger plays, songs, or rhymes, resulted in recurring classroom management problems for both Hale and Leyla.

The teachers' individual difficulties were directly linked to their core competency levels. Hale's difficulty sometimes arose from her attempt to provide too much detail or over-adapt complex scientific information to the children's level. This led to cognitive overload for children. Hale's high content knowledge sometimes resulted in pedagogical overreach, where her detailed, accurate explanation surpassed the young children's capacity for sustained abstract reasoning.

Explaining the 'bouncing ping-pong ball experiment,' Hale provided a lengthy, multi-step explanation: "You said there was air between this ball and the bottle... When I quickly dropped the ball into the water, there was air in the space under the ball, and thanks to the water flowing into the container, the air there bounced the ball up." Hale repeated this detailed explanation several times, but the children began to get distracted and lose focus (Observation).

Leyla's difficulties were structural, involving a general failure to create an environment that fostered scientific process skills and, critically, an inability to integrate

science with other domains. Her activities were observed as being randomly sequenced and lacking any pedagogical bridge. Leyla's activity sequencing demonstrated a significant lack of pedagogical coherence. The juxtaposition of activities (motor game, experiment, math worksheet) without any intentional connection suggests instruction driven by a checklist rather than a unifying conceptual goal or theme.

"First, Leyla had children play a motor game... Afterward, a 'balloon popping experiment with orange peel' was carried out. Finally, the children painted worksheets with five monkeys and the number 5 (Observation)."

Moreover, Leyla's most profound difficulty was that her limitations in scientific knowledge frequently led to incorrect or incomplete explanations during the experiment, directly compromising the accuracy of the content delivered. This problem was pervasive across activities where she lacked prior conceptual preparation.

Children's reactions during science activities

The final findings provide compelling evidence of how the teachers' pedagogical competence directly shapes the quality of children's participation—a core research question of this study.

Children in Hale's class exhibited active participation, sustained attention, and frequent questioning. This active role was directly influenced by Hale's use of open-ended questions, her provision of sufficient wait time and hints, and her consistent validation of children's responses. This creates a classroom culture of intellectual safety, encouraging children to take risks in inquiry. Hale actively cultivated conceptual continuity by asking questions that required the children to retrieve and synthesize prior knowledge.

In a discussion about eggs, Hale built upon the children's initial answers ("Birds and butterflies, we learned the other day") to pose a more complex, inferential question: "There was a living being in ancient times, but it has not survived to this day. What was its name?" The children successfully retrieved the concept ("dinosaur"), with one child justifying their answer: "Teacher, they had eggs, too. You read us a book; we saw it there." (Observation). This dialogue demonstrates how Hale's scaffolding facilitates knowledge synthesis and metacognition (the ability to reflect on how they know something).

However, consistent with previous observations, Hale's occasional difficulty in adapting complex information led to temporary disengagement (as exemplified by the detailed 'bouncing ping-pong ball experiment' explanation), causing children to become distracted (Observation).

Children in Leyla's class were notably more passive, responding less frequently, asking fewer questions, and exhibiting shorter attention spans. This diminished engagement is attributed to Leyla's limiting behaviors, such as answering her own questions and failing to follow up on children's inquiries. Crucially, Leyla's limitations in scientific knowledge not only hampered participation but also directly contributed to the development and reinforcement of scientific misconceptions among the children.

During a hot/cold/warm water demonstration, Leyla focused on safety by telling children to stay away from the table due to the hot water. When a child observed the rising steam and hypothesized, "It must be really hot; there is smoke coming out," Leyla failed to intervene (Observation). This inaction represents a missed opportunity to correct the common misconception that steam is smoke—a failure stemming from either a lack of conceptual vigilance (PCK deficit) or a prioritization of classroom management over conceptual clarity.

This finding strongly suggests that Leyla's instructional deficiencies created a low-risk, low-gain learning environment, discouraging participation and inadvertently allowing scientifically inaccurate beliefs to be validated through teacher silence.

Discussion and Conclusion

The purpose of this research was to compare the planning and implementation of science activities by two kindergarten teachers: one with a strong background in scientific knowledge and a positive attitude toward science education, and the other with considerably less expertise. The results indicate that the teachers had differences in both the planning and implementation processes.

The teacher with stronger scientific knowledge demonstrated a systematic approach to planning, actively researching topics and gathering children's literature and resources. In contrast, the teacher with limited science knowledge relied primarily on demonstration experiments sourced from the internet, often without a deeper understanding of the concepts involved. This difference can be interpreted through the lens of pedagogical content knowledge and teacher self-efficacy theories (Bandura, 1997; Gudmundsdottir & Shulman, 1987). Teachers with insufficient content knowledge may experience reduced self-efficacy, leading them to adopt safer, more structured teaching methods—such as demonstrations—where the potential for conceptual error is minimized. Similar observations have been made in previous research, indicating that teachers' limited understanding of science inhibits their willingness to explore inquiry-based learning environments (Bilaloğlu et al., 2008; Greenfield et al., 2009; Tu, 2006).

A particularly original finding of this study concerns how the teacher with limited expertise compensated for her lack of scientific knowledge by involving parents. She delegated science activities to the "parent of the week," who conducted them during class. This practice, while increasing the number of activities, did not ensure pedagogical coherence or inquiry-oriented interaction. However, it offers valuable insight into how early childhood teachers in Türkiye may navigate professional challenges. From a sociocultural perspective, this behavior reflects adaptive compensation—teachers drawing on family participation as a contextual resource to overcome their own professional limitations. In many Western contexts, family engagement is conceptualized as a collaborative partnership (Epstein & Miller, 2011), whereas in this study it functioned as a compensatory mechanism for pedagogical gaps. Consequently, the 'parent-teacher-child' triangle in the Turkish educational ecosystem structurally diverges from Western frameworks by repositioning the parent from an external learning partner into an active instructional substitute. This specific cultural adaptation highlights how intense parental expectations and institutional pressures in a centralized system can prompt teachers to utilize family resources to manage their own professional anxieties and content knowledge deficits. This finding fills a notable gap in the international literature by illustrating how cultural expectations around family participation can intersect with teacher competencies and instructional practices.

The relationship between teachers' science knowledge and their questioning techniques also emerged as a critical finding. The teacher with stronger science knowledge frequently used open-ended questions (why, how, and what if) that stimulated reasoning, while the teacher with limited knowledge relied predominantly on closed-ended questions. This pattern can be explained by cognitive load theory: when teachers lack sufficient conceptual understanding, their working memory is occupied with managing the activity itself, leaving limited capacity for spontaneous inquiry (Sweller, 2011). As a result, they avoid cognitively demanding questioning. This finding reinforces earlier reports that 95% of early childhood teachers' questions tend to be closed-ended (Bilaloğlu et al., 2017; Siraj-Blatchford & Manni, 2008), and that teachers' questioning quality is strongly linked to their confidence in subject matter knowledge.

Furthermore, the teacher with stronger science knowledge demonstrated an ability to respond to unplanned "teachable moments" by recognizing children's spontaneous questions and extending them into meaningful inquiry. Such responsiveness is central to reflective practice (Schön, 2017) and inquiry-based learning, both of which require teachers to continuously adapt instruction based on children's

curiosity and prior experiences (McCray & Chen, 2012; Oppermann et al., 2021). The other teacher's inability to capitalize on these moments highlights the pedagogical limitations that arise when content knowledge is shallow and rigidly scripted.

Integration across domains also distinguished the two teachers. The teacher with higher science competence connected science activities to literacy, art, and mathematics, which aligns with research showing that interdisciplinary approaches enhance children's cognitive flexibility and holistic development (Bevan et al., 2020; Pella, 2022). In contrast, the other teacher's activities remained fragmented and isolated. This suggests that understanding the interconnectedness of disciplines is not merely desirable—it is foundational to effective early childhood science education (Edwards & Loveridge, 2011; French, 2004).

Another critical finding was that the teacher with limited science knowledge provided inaccurate explanations, particularly in physical sciences. Misinterpretations of scientific phenomena—such as using demonstrations without explaining underlying principles—can foster misconceptions that persist into later education (Binns & Popp, 2013; Gerde et al., 2018; Kallery & Psillos, 2001). Children's misconceptions often arise not from curiosity but from teachers' oversimplifications or conceptual errors. Hence, teacher preparation programs should focus not only on what to teach but also on how to represent concepts in developmentally appropriate ways (Akyol & Birinci-Konur, 2018; Dağlı & Dağlıoğlu, 2020).

Several methodological limitations should be acknowledged. First, the study relied on observations of two teachers, and video recording was not permitted. Second, the researcher was the sole observer, which may have introduced interpretive bias. Third, the observation period was limited. Fourth, because this investigation was situated exclusively within private preschools in a major metropolitan center (Istanbul), the findings predominantly illustrate urban early childhood dynamics. The enacted pedagogical content knowledge, resource availability, and classroom science practices may manifest differently among educators working in rural, remote, or socio-economically disadvantaged regions of Türkiye, thereby bounding the immediate transferability of these outcomes to non-metropolitan environments. Nevertheless, the study remains valuable because it provides rich qualitative insights into authentic classroom practices that are rarely captured in early childhood science education research in Türkiye. Despite these constraints, the findings offer a nuanced understanding of how teachers with differing science backgrounds enact, adapt, and compensate within real educational contexts. To strengthen early childhood science education, several actionable steps can be derived from these findings:

Undergraduate early childhood programs in Türkiye currently offer only one science education course. This structural brevity creates a substantial gap when contrasted with international best practices and professional standards. For instance, the National Association for the Education of Young Children (NAEYC) guidelines emphasize that high-quality teacher preparation must integrate continuous, multi-semester science and STEM pedagogy interwoven with active field practicums (NAEYC, 2020). Integrating foundational physical and biological science courses—similar to those in the Missouri State University Early Childhood Program (2025)—can build stronger conceptual understanding and practical confidence. Restructuring the national curriculum to shift from a single-course model to a consecutive, inquiry-based science methodology track is imperative to equip pre-service teachers with sustainable Pedagogical Content Knowledge (PCK).

In-service training should move beyond content delivery to include mentoring, microteaching, and reflective feedback components that develop teachers' inquiry-based instructional skills.

Given the observed reliance on family support, schools should design structured, pedagogically guided family engagement models that treat parents as learning partners rather than substitutes for teacher expertise.

Although the Turkish Early Childhood Education Program (MoNE, 2024) emphasizes outdoor learning, both teachers confined activities indoors. Future training should include modules on using outdoor spaces for inquiry-based exploration (Loxley et al., 2016).

In conclusion, this study demonstrates that teachers' levels of scientific knowledge and attitudes toward science directly influence the frequency, quality, and pedagogical richness of science activities in early childhood education. Teachers with stronger scientific backgrounds fostered more inquiry-oriented, integrated, and responsive learning environments, whereas those with limited knowledge depended on structured demonstrations and external support. Importantly, the finding that teachers compensate for their lack of knowledge through family involvement contributes a novel cultural and pedagogical perspective to the global literature on teacher competence. Addressing these challenges through enriched coursework, reflective professional learning, and structured family partnerships will be crucial to advancing the quality and equity of early childhood science education in Türkiye and beyond.

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During the preparation of the manuscript, the authors used Google Gemini to assist with English translation

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