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Doctor's Learning Environment: Fostering Critical Thinking in 4-Year-Old Children

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Abstract

The development of critical thinking from an early age is essential in science education, and despite its importance, there is still little research in early childhood education. This exploratory study presents a learning environment around a daily life problem faced by preschoolers, related to the human body and health, carried out through role-play and inquiry, aimed at developing critical thinking within the knowledge application domain in 4-year-old children. The study involved a sample of 9 children from a preschool in Málaga (Spain). Data were collected through observations, dialogues, field notes, and children's productions. The assessment of progress in the application of scientific knowledge and understanding of science encompassed a comprehensive set of criteria aligned with Bloom's revised taxonomy. The findings indicate greater progress in the remembering compared to understanding. Specifically, 76.18% of the children reached the achieved level in listing, 72.21% in explaining, 62.50% in relating, and 58.33% in identifying. This suggests that, at early ages, learning environments designed around daily-life health contexts can contribute to the development of certain aspects of critical thinking.

Keywords: learning environment; critical thinking; early childhood education; daily life problem; human body; illness

1. Introduction

Learning today requires not only the ability to understand information but also the development of critical thinking skills that enable individuals to question sources, evaluate evidence, and actively resist misinformation, competencies that are essential for responsible participation in contemporary society (Brosseau-Liard, 2017; List et al., 2024; Redaelli et al., 2025).

Research in cognitive development indicates that even children are not passive recipients of information. By the age of three or four, children acquire vast amounts of knowledge from their social environment and begin to demonstrate emerging epistemic abilities: they can evaluate the reliability of informants, distinguish knowledgeable from ignorant speakers, and display selective trust (Harris, 2012). Although these early capacities provide important foundations for later critical thinking, they are still developing and highly context-sensitive (O'Reilly et al., 2022). Therefore, it becomes increasingly important to intentionally nurture and extend these emerging capacities through early childhood

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educational practices, as they will provide the foundation for the consolidation of critical thinking in the future.

The development of mature critical thinking involves complex cognitive processes such as analyzing and evaluating, which require higher levels of mental elaboration, which are not fully attained until adolescence (Halpern, 1997). However, these advanced skills are built progressively upon more foundational capacities—such as listing, explaining, relating and identifying—that are within children's reach and that lay the groundwork for more sophisticated forms of reasoning in later stages (Montano-Silva et al., 2025).

Despite growing theoretical recognition of children's epistemic potential, empirical research documenting critical thinking processes in authentic early childhood classroom contexts remains limited. This gap highlights the need to investigate pedagogical practices that may effectively foster critical thinking and to deepen our understanding of how these skills emerge and develop in preschool-aged children (O'Reilly et al., 2022).

Drawing on this framework, this exploratory and descriptive case study proposes an educational intervention aimed at providing a structured context to support the development of children's emerging epistemic capacities. Specifically, it examines the implementation of a learning environment centered on a daily-life problem related to the human body and illness in a classroom of four-year-old children. The study aims to explore how structured, play-based, and inquiry-oriented experiences may support the emergence of critical thinking within the domain of knowledge application in early childhood education.

1.1. Critical Thinking Models

Critical thinking is a complex construct whose precise definition is difficult to establish. It involves different skills and dispositions, which makes it challenging to arrive at a consensual definition in the literature. Kuhn's (1999) developmental model proposes that critical thinking is grounded in three forms of "meta-knowledge": metacognition, strategic metacognition, and epistemological understanding, which evolve from childhood through adolescence. Dwyer's integrated framework (Dwyer et al., 2014) conceptualizes critical thinking as a metacognitive process of reflective judgment, integrating educational objective taxonomies and cognitive models into a comprehensive learning outcomes framework for the twenty-first century. Jiménez-Aleixandre and Puig (2022) argue that critical thinking comprises a set of components related to deliberate judgment, particularly argumentation, as well as dimensions linked to citizenship education. This latter dimension involves the ability to develop independent opinions, question socially and culturally established ideas, and analyze and critique discourses that justify social inequalities.

In this study, we will employ the ENCIC-CT model proposed by Franco-Mariscal et al. (2024), which comprises four components. First, the initial layer represents the core of the model, which involves the use of socio-scientific issues or daily life problems (Bencze et al., 2020): real, complex, and unresolved problems that are intrinsically linked to the intersection between science, technology, and society. These issues are controversial and can be approached from multiple perspectives (social, ethical, economic, environmental, legal, political, etc.) (L. Chen & Xiao, 2021; Sadler & Zeidler, 2005).

The second layer encompasses the dimensions of critical thinking (Vieira & Tenreiro, 2016; Jiménez-Aleixandre & Puig, 2022; Halpern & Danna, 2023; Vila et al., 2023). Specifically, these dimensions are grouped into three domains: knowledge, skills, and dispositions. The knowledge domain includes Vision of Science and Knowledge Application; the skills domain includes Comprehensive Analysis of Problems, Critical Analysis of Information, Argumentation, Decision Making and Communicative Skills; and the dispositions domain includes Personal Autonomy/Metacognition/Reflection, Activism, and Emotional Engagement (Franco-Mariscal et al., 2024).

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The third layer involves scientific practices: argumentation, inquiry and modeling. Argumentation is the expression of rational judgment in which verbal articulation, in social contexts, reveals the reasons for accepting or rejecting a point of view or a set of ideas (Hahn & Oaksford, 2012). Inquiry is a multifaceted activity that involves observation, the formulation of questions, the collection of information from various sources, and the planning and design of investigations (National Research Council, 2000). Modeling is conceived as an integrated set of knowledge, metaknowledge, skills, and epistemic values necessary to carry out modelling tasks in a comprehensive way (Oliva et al., 2015).

The fourth layer comprises teaching strategies for the development of critical thinking. Some of these include role play (López-Fernández, 2024), controversy maps (España-Naveira et al., 2023), micro-debates (Cano-Iglesias, 2024), augmented reality (Moreno-Martínez & Franco-Mariscal, 2020), films and television series (Franco-Mariscal, 2024), audio stories (López-Fernández et al., 2024), and Learning Environments (hereinafter, LE) (O'Reilly et al., 2022).

1.2. Critical Thinking in Early Childhood Education

Critical thinking in early childhood is increasingly recognized as a foundational competence for lifelong learning and responsible participation in society (Facione, 2011; Lai, 2011; Lipman, 2003). However, despite this recognition, empirical research examining how critical thinking develops within authentic early childhood classroom contexts remains limited (Pollarolo et al., 2022). Recent reviews nevertheless suggest that it can be meaningfully fostered during the preschool years when educators deliberately promote appropriate cognitive and dialogic practices (Lipman, 2003; Schleihauf et al., 2022).

In early childhood education, critical thinking refers not to fully developed abstract reasoning but to the emergence of foundational epistemic abilities. By around four years of age, children begin to demonstrate reason-responsiveness: they can provide simple justifications, distinguish between stronger and weaker reasons, revise initial ideas when presented with better arguments, and engage in basic reflective dialogue (Schleihauf et al., 2022). Studies further indicate that children can formulate and respond to questions, explain their thinking in simple terms, and participate in structured conversations in which adults scaffold reasoning through open-ended prompts (Fernández-Santín & Feliu-Torruella, 2020; O'Reilly et al., 2022).

At this stage, exploratory play and inquiry-oriented activities are particularly relevant. Engagement with materials that stimulate observation and questioning, participation in story discussions where children critique characters' actions or propose alternative endings, and cooperative tasks that require negotiation and shared decision-making all create opportunities for the emergence of early critical thinking processes (O'Reilly et al., 2022; Pollarolo et al., 2022).

These emerging capacities can be understood through the revised Bloom's taxonomy (Anderson & Krathwohl, 2001), which organizes cognitive processes from remembering and understanding to analyzing, evaluating, and creating. In four-year-old children, thinking predominantly operates at the foundational levels, namely remembering and understanding: they can recall information, comprehend instructions, and apply knowledge in familiar contexts such as classification or problem-solving in play. Initial forms of analysis appear in simple comparisons and distinctions. Although higher-order processes remain incipient, systematic engagement at these foundational levels provides the cognitive basis for the later development of mature critical thinking.

Educationally, this implies that the objective in early childhood is not the attainment of fully developed critical thinking but the intentional cultivation of its underlying components. This includes supporting children in articulating reasons, relating ideas, interpreting

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situations, and making simple decisions based on shared inquiry experiences (National Research Council, 2012). In this sense, critical thinking builds upon conceptual knowledge and becomes evident when such knowledge is actively mobilized to explain, connect, and justify ideas.

Additionally, autonomy-supportive pedagogies play a central role in this process. When teachers act as facilitators—encouraging dialogue, shared problem-solving, and reflective participation—they create conditions that promote self-regulation and the gradual consolidation of critical thinking dispositions (Barrable, 2020).

The present study develops critical thinking in early childhood education through the ENCIC-CT model (Franco-Mariscal et al., 2024). It begins by considering the illness that affect children's bodies as daily life problems (layer 1), and then focuses on the knowledge application associated with this issue (layer 2). The study also incorporates inquiry as a scientific practice to explore specific aspects of the problem (layer 3), and role-play and LEs as teaching strategies in the classroom (layer 4). The following sections expand on each of these components.

1.3. The Human Body and Illness as Daily Life Problem

The development of skills for solving daily life problems is fundamental in early childhood education, as it prepares children to face challenges in their immediate environment and fosters their autonomy, critical thinking, and social adaptation (Pratiwi, 2023). Recent research highlights the importance of integrating everyday life experiences into the curriculum to strengthen these skills (Pratiwi, 2023; Wahyuningtyas, 2019). Moreover, the literature underscores not only the value of connecting learning with real and practical experiences, but also the key role of educators and the family environment in fostering these competencies (Farewell et al., 2021).

Daily life problems can range from difficulties in self-regulation, peer interactions, and personal hygiene to managing emotions and adapting to new routines. These situations allow children to practice self-help, communication, cooperation, and decision-making skills (Pratiwi, 2023).

The significance of an early childhood education LE focused on the human body is emphasized. Understanding the human body is the first stride in integrating health and well-being into education (Stewart et al., 1999). This objective aligns with the efforts of the World Health Organization, the European Union, and UNESCO's (2022) Sustainable Development Goal 3. Health education entails a blend of learning experiences that offer children opportunities to gain knowledge and decision-making skills concerning their health. In this context, LEs can integrate these activities to promote healthy behaviors (Lewallen et al., 2015).

1.4. Knowledge Application Involving the Human Body and Illness

A consensus regarding critical thinking is the need for specific contextual knowledge to evaluate particular references. The knowledge application in the ENCIC-CT model requires that children be able to use and apply scientific knowledge (Blanco-López et al., 2015).

In the daily life problem related to human body and illness, children need accurate knowledge of their bodies, including the names for body parts (Wurtele & Kenny, 2011). Acquiring the correct names for all body parts is not only a significant milestone in their language development but also contributes to fostering a positive and healthy body image (Khoori et al., 2022). By 30 months, children usually know more body part names (about 20) than they can point to on their own body (Patriau et al., 2022). Slaughter and Brownell (2011) suggested that this disparity arises from children observing and naming their own body parts with adult assistance.

Various studies have revealed that children's body representations may not fully develop until around the age of 10 (Slaughter & Brownell, 2011). Additionally, children, including teenagers, often lack precise terminology for their body parts and tend to use colloquial terms (Burrows et al., 2017).

Understanding body dimensions is essential, because studies reveal that 2–3-year-old children may not accurately assess their own size when trying to fit into small chairs or cars (DeLoache et al., 2004).

1.5. Inquiry-Based Learning

The scientific practice of inquiry, referred to in science education as Inquiry-Based Learning (IBL) or Inquiry-Based Science Education (IBSE), is understood as a set of cognitive skills that students need to develop. It encompasses the methods used by scientists, that is, the nature of scientific investigation (Franco-Mariscal et al., 2024). The activities should integrate scientific knowledge with the development of scientific skills such as observing, comparing, identifying, classifying, measuring, and communicating (Jirout & Zimmerman, 2015), promoting the construction of new knowledge within the constructivist framework.

There is a wide range of methodological approaches for implementing inquiry in the classroom (Rönnebeck et al., 2016). Among them, the 5E learning cycle proposed by Bybee et al. (2006) stands out as one of the most widely used. This model is particularly suitable for fostering inquiry in early childhood, as it structures instruction into five sequential stages: Engage, Explore, Explain, Elaborate, and Evaluate. The purpose of the Engage phase is to elicit students' prior knowledge, stimulate interest, and gather diagnostic data to inform teaching and learning. The Explore phase is characterized by opportunities for children to engage in hands-on learning and express their thoughts. During the Explain, students are supported in developing scientific explanations by drawing from their experiences and observations. The Elaborate phase offers children opportunities to apply their newfound knowledge to novel situations, fostering a deeper understanding of the concept and enhancing their science inquiry skills. Lastly, the Evaluate phase reviews the learning, as well as their new understanding and skills.

Cabrera and Colosi (2010) state that hands-on exploration fosters critical thinking, including differentiation, relationship recognition, system organization, and multi-perspective consideration. Various researchers concur that early childhood LE represent broader spheres of knowledge in which learning takes place (Rushton & Juola-Rushton, 2008).

1.6. Role Play as a Teaching Strategy

Role play is a simulation activity in which each participant assumes a specific role within the context of a simulated problem, following certain rules and interacting with the other participants (Cruz-Lorite et al., 2023). With this strategy, children accumulate experiences and perceive relationships between properties and elements in their surroundings, guiding further exploration and deeper interests (Dejonckheere et al., 2016).

Another important feature involves using play for learning (Elkind, 2007) because children accumulate experiences and perceive relationships between properties and elements in their surroundings, guiding further exploration and deeper interests (Dejonckheere et al., 2016; López-Fernández et al., 2021).

Play fosters children's creativity and imagination as they interact with their environment, promoting teamwork, the sharing of experiences and materials, and the development of decision-making and conflict resolution skills. Under adult supervision, play also teaches children to follow rules. Moreover, play accommodates diversity by catering to different interests and learning paces.

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Opportunities for written and oral language abound in such settings (Cleveland & Fisher, 2014). Literacy is further encouraged by incorporating signs with words, as environmental print represents the first type of text a child learns to "read" (Levitt & Red, 2013). Moreover, oral language can be promoted through dramatizing everyday situations. Åkerblom et al. (2019) observed significant improvements in preschool children's understanding of chemistry after participating in a dramatization.

This strategy not only supports the development of critical thinking in students but also offers teachers the opportunity to design and implement a variety of tasks aimed at fostering it. Moreover, such games provide a pedagogical alternative capable of increasing motivation and generating more meaningful learning experiences (Franco-Mariscal et al., 2023). In this context, the playful component becomes integrated with a clear educational purpose.

1.7. Learning Environments as a Teaching Strategy

Interacting with the environment can help children learn science and develop scientific skills and attitudes (Earle, 2022). Several studies illustrate how children aged three to six display advanced scientific thinking and participate in complex scientific practices (Jirout & Zimmerman, 2015). Creating LE for children to explore and play enhances their science understanding and interest (Barrable, 2020). The spatial setup significantly impacts teaching quality and learning. LE empowers children to decide when, where, what, and with whom to learn, allowing them to align their interests (Bamberger & Tal, 2007; Perry et al., 2023).

The Organization for Economic Cooperation and Development (OECD, 2013) defined a LE as an organic, holistic ecosystem, including the activity and the learning outcomes. It is a place where learners are engaged in self-directed and cooperative activities. Teachers have explored ways to make learning engaging, such as using LE or learning centers, where space, furniture, and materials are thoughtfully organized into well-defined zones with clear labels (Sáez-Bondía et al., 2024). These settings, often indoors but also in outdoor or natural environments, encourage learning activities and promote social development (Cetken-Aktas & Sevimli-Celik, 2023).

Research on the development of critical thinking within LEs in early childhood education is still scarce. However, some studies suggest that these settings can be effective in fostering critical thinking skills at early ages (O'Reilly et al., 2022). As well, different studies agree that high-quality LE are powerful tool for preschool teachers (H. Chen & Wang, 2018). A quality early childhood setting should incorporate learning centers that provide opportunities for hands-on interactive involvement, experimentation, and self-discovery (Jechura et al., 2016). These learning spaces empower children to choose materials for meaningful learning experiences, such as puzzles, construction items, and dress-up/sociodramatic play, fostering identification and context-based learning. Examples of such centers include block, library, art, and science centers.

LEs are characterized by the development of social skills, interaction, and cooperation (Ogu & Schmidt, 2013). On one hand, LE promotes child communication and group cohesion through shared tasks. Simultaneously, they facilitate student-teacher interactions as children seek assistance or information from both their peers and educators. These spaces offer opportunities for children to develop according to their characteristics (Arthur et al., 2017). Additionally, children also cultivate appreciation and respect for the materials.

Different studies show that LEs facilitate optimal brain stimulation in children (Jensen, 2013). During this process, a child's brain receives stimuli from the LE through the senses, which initiates chemical–electrical reactions that underpin all learning (Rushton & Juola-Rushton, 2008). Moreover, an effective LE should evoke emotions (Samuelsson & Kaga, 2008), which are enriched by social interactions. Children's pleasure and enthusiasm during the learning are indicators of their enjoyment. The absence of a LE in a preschool classroom can impede children's connection with their surroundings and the development of positive learning experiences.

2. Research Questions

This study focuses on the importance of fostering critical thinking from an early age and on the limited research conducted in early childhood education on health-related topics and critical thinking. Its aim is to illustrate the implementation of a LE centered on a daily life problem related to the human body and illness in a preschool classroom of 4-year-old children. The study addresses the following research questions (RQ):

- RQ1: How does a LE that focuses on the human body and illness as a daily-life problem and incorporates role-play and inquiry activities support the knowledge application domain of critical thinking in 4-year-old children?
- RQ2: What developmental patterns do 4-year-old children demonstrate within the knowledge application domain after participating in the LE?

3. Materials and Methods

3.1. Study Design

This exploratory study was conducted at a rural preschool, located in Málaga, Spain. The school followed the Spanish curriculum for 4-year-old children (Junta de Andalucía, 2023), which encourages children to explore and understand their environment through active engagement in activities such as manipulation, observation, investigation, exploration, etc. These activities enable children to gather information to interpret and comprehend the world around them.

3.2. Participants

The sample included nine 4-year-old Spanish children (6 girls and 3 boys), along with their teacher. Pseudonyms are used for all names in this study. These children came from similar cultural, linguistic, and socio-economic backgrounds, all from lower-middle-class families in the locality. Children displayed varying levels of language proficiency, with one child presenting more limited communication skills. However, the LE greatly benefited this child, as it required interaction and communication with peers.

All children participated in the same activities, although the teacher provided individualized support where needed, including modeling language, prompting explanations, and facilitating peer interactions. This approach ensured that each child could engage meaningfully according to their abilities and developmental level. The limited sample size facilitated close individual follow-up and in-depth observation of children's developmental patterns within the knowledge application domain, enabling detailed documentation of their participation, verbal contributions, reasoning processes, and role enactment across activities.

The teacher (second author) had 12 years of experience and training in science education. The design and evaluation of the LE were developed collaboratively by all the researchers, with the second author responsible for its implementation and for supporting children's active engagement in each activity.

We obtained ethical approval for this study from the first author's institution, Universidad de Malaga (Spain), reference number 31-2022-H.

3.3. Design of the Doctors Learning Enviroment

The Doctors' Learning Environment (hereinafter, DLE) is a trimester-based project, focusing on a daily life problem addressing the human body and diseases, doctors, and medical tools.

Children engaged in the DLE in groups of 2 or 3 children, for 45 min each day, at least three days a week. Group composition was heterogeneous in terms of language abilities and levels of participation. The DLE comprises a wide range of activities, which are introduced progressively. On a daily basis, the teacher assigns the children to different activities to ensure their participation in all of them. Roles were systematically rotated during the role-play and inquiry activities, ensuring that all children had the opportunity to experience each role.

Each activity begins with an assembly to explain its content and to identify the children's prior ideas. These assemblies take place daily to reflect on knowledge and evaluate learning. As an example, an excerpt from the initial assembly dialogue is presented:

— Teacher: *What happens when we get sick?*
— Children: *I feel sad and tired.*
— Teacher: *What should we do?*
— Blanca: *We should go to the doctor so they can examine us and find out what's wrong.*
— Teacher: *What's in the doctor's office, and what examination tools are used?*
— Children: *Something the doctor puts in their ears and on your heart to listen* [stethoscope], *a flashlight, bandages, a stick* [tongue depressor], *an examination table, prescriptions, they wear a gown, ointments, syrups, pills.*

Specifically, DLE encompasses activities involving role-play, as well as inquiry. Tables 1 and 2 describe these activities, including objectives, the assessment criteria, and the relevant Bloom's taxonomy category. These activities are carried out using resources designed for this purpose, including posters, and are complemented by worksheets from the reference book (Segarra et al., 2018).

Table 1. Role-play activities in the DLE.

Activity	Description	Objective	Assessment Criteria	Bloom's Taxonomy
01. Presentation of the DLE	Assignment of roles for each child (doctor, nurse, and patients) and creation of patient lists.	Know medical roles and consultation elements.	List the elements of a medical consultation.	Remember + Factual (Listing)
02. Waiting room and body parts	Card game to match names and illustrations of human body parts and learn about specialists.	Know human body parts and their locations. Know doctors' specialties and medical equipment.	List medical specialists and tools. Relate body parts to their corresponding drawings.	Remember + Factual (Listing) Understanding + Conceptual (Relating)
03. What's happening, doctor?	Children use a human body diagram and cards to match the patient's illness with an organ or body part.	Identify organs and body systems in a human body diagram.	Relate organs and body systems to their corresponding drawings.	Understanding + Conceptual (Relating)
04. Examination	A child plays doctor to examine the patient for diagnosis.	Identify symptoms of diseases in a patient and make a diagnosis. Measure a child's heigh. Weigh a child on a scale.	Relate organs and body systems to diseases.	Understanding + Conceptual (Relating)
05. The pharmacy	A child acting as a pharmacist administers the medicine to the patient.	Administer medication.	List some medications.	Remember + Factual (Listing)

Table 1. *Cont.*

Activity	Description	Objective	Assessment Criteria	Bloom's Taxonomy
06. The ophthalmologist	A child acting as an ophthalmologist determines if the patient needs glasses.	Learn about different medical specialists. Recognize vision as a sense and recall the others.	Relate organs and body systems to specialists.	Understanding + Conceptual (Relating)
07. The dentist	A child acting as a dentist identifies the aching tooth in the patient and instructs them on how to brush properly.	Learn about different medical specialists. Learn about oral hygiene. Learn about the teeth, molars, tongue and tastes.	Relate organs and body systems to specialists.	Understanding + Conceptual (Relating)
08. Bones and skeleton	Game where children identify different bones in a skeleton and in their body. Children create a skeleton using pasta and sticks.	Understand the skeleton's function, major bone names, and their body locations.	List the names of some bones. Identify some bones in your body. Explain what the skeleton is and its function.	Remember + Factual (Listing) Remember + Factual (Identifying) Understanding + Conceptual (Explaining)
09. Muscles	Game in which children locate the names of some muscles in their body.	Learn muscle names and their body locations.	List the names of some muscles. Identify some muscles in your body.	Remember + Factual (Listing) Remember + Factual (Identifying)
10. Digestive system	Game representing the path of food through the digestive system. Children build a traffic light with healthy and unhealthy foods. Children place images of different organs on a silhouette.	Learn the digestive system parts and explain food's path. Know healthy foods.	List healthy and unhealthy foods. Relate digestion to the digestive system. Explain the path that food follows in the body.	Remember + Factual (Listing) Understanding + Conceptual (Relating) Understanding + Conceptual (Explaining)
11. Heart and circulatory system	Children observe a simulation of the blood's circulation through arteries and veins. Game in which children listen to their heart beating during various activities. Children perform a cardiac resuscitation.	Learn the circulatory system's components and explain blood's circulation. Connect the heartbeat pattern to everyday activities.	Relate blood circulation to the circulatory system. Explain how blood circulation takes place.	Understanding + Conceptual (Relating) Understanding + Conceptual (Explaining)

Table 2. Inquiry activities in the DLE.

Activity	Description	Objective	Assessment Criteria	Bloom's Taxonomy
12. Human body bust	Children associate organs with their system and place them in the bust.	*Engaging* the child in *exploring* the organs in the bust.	Identify organs and systems in the bust.	Remember + Factual (Identifying)
13. Operating room	Using real pig organs, children identify, describe, and explain their function.	*Engaging* the child in *exploring* real organs, *explaining* their function, and *evaluating* their location.	Identify real organs.	Remember + Factual (Identifying)

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Table 2. *Cont.*

Activity	Description	Objective	Assessment Criteria	Bloom's Taxonomy
14. The X-ray	Children identify bones in X-rays and determine possible fractures.	*Engaging* the child in *exploring* bone images in X-rays and *explaining* if any bone is broken and the measures for its healing.	Relate the skeleton and X-ray.	Understanding + Conceptual (Relating)
15. Lungs and respiratory system	Children identify the parts of the respiratory system on a worksheet, perform a breathing exercise, build mock lungs using plastic bags and drinking straws, and explain how they work.	*Engaging* by identifying the parts of the respiratory system, *exploring* through inhalation and exhalation, *explaining* the process, and *elaborating* lungs using bags and drinking straws to understand their functioning.	Relate respiration with its system. Explain how the lungs function.	Understanding + Conceptual (Relating) Understanding + Conceptual (Explaining)
16. The ultrasound	Children bring their ultrasound scans to compare them with those of their classmates.	*Exploring* an ultrasound image and *explaining* the growth of the baby.	Explain what an ultrasound is.	Understanding + Conceptual (Explaining)
17. Searching for information about organs and systems	Guided by their parents, children research information about an organ and system, craft a mural, and deliver a presentation in class.	*Exploring* knowledge about an organ/system through information search. *Elaborating* a mural about an organ/system and *explaining* it to classmates. *Evaluating* the learning outcomes.	Explain an organ and system to your classmates.	Understanding + Conceptual (Explaining)

Note: The text in italics indicates the stages of the 5E inquiry model (Bybee et al., 2006) developed in this task.

For the role-play, after the assembly and the organization of different learning areas in the classroom, the teacher assigns the roles, recording the children's names and functions. The roles rotated throughout the learning experience. Inquiry includes all stages of the 5E model (Engage, Explore, Explain, Elaborate, or Evaluate) (Bybee et al., 2006), as well as others focusing on specific stages.

The teacher provided individualized scaffolding when necessary, particularly for children who required additional linguistic or cognitive support. This support included prompting questions, reformulating children's ideas, encouraging peer dialogue, and guiding observations without directing their responses.

3.4. Data Collection Procedure and Data Analysis

Data was collected over a quarter using various instruments: classroom observations, teacher–child dialogues, observational field notes, and all written productions created during activities. Data collection followed the ethical guidelines of the committee overseeing human experimentation, with permission obtained from all parents for their children's participation.

The assessment was holistic, continuous, and formative, aligning well with the characteristics of early childhood education. The teacher conducted this assessment by daily monitoring each child's progress and challenges, with the aim of customizing interventions to individual needs and implementing the most effective strategies. In cases of uncertainty during the assessment process, the teacher consulted with the other researchers, and final decisions were reached collaboratively through consensus. A wide range of learning experiences was offered to help every child to reach their maximum potential based on their abilities.

In order to assess progression in the knowledge application domain of critical thinking within the ENCIC-CT model (Franco-Mariscal et al., 2024), the teacher used the assessment criteria presented in Tables 1 and 2. These criteria are aligned with the cognitive and knowledge dimensions of Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Specifically, they correspond to the levels 'Remember + Factual' and 'Understanding + Conceptual,' which are appropriate for 4-year-old children. 'Remember + Factual' tasks assessed abilities related to Listing and Identifying, while 'Understanding + Conceptual' tasks evaluated skills like Relating and Explaining.

Each criterion was rated at one of three achievement levels: achieved (for mostly appropriate responses), in progress (for partially correct responses), and not achieved (for inappropriate responses). This three-level system was selected to provide a clear and manageable framework for capturing variations in children's performance. It allows for differentiation between fully competent responses, those in development, and responses that do not meet expectations, while maintaining simplicity and reliability in scoring, particularly given the young age of the participants and the qualitative, context-specific nature of the tasks.

Scoring decisions were made collaboratively by all researchers, who discussed any discrepancies to ensure consistency and shared understanding in the evaluation process. Mean percentages were then calculated for each dimension and level. In addition, the use of appropriate scientific terminology was explicitly considered for explanation tasks, providing further guidance for interpreting the quality of children's responses.

4. Results

This section describes the outcomes of role-play, followed by inquiry.

4.1. Role-Play Activities

4.1.1. Activity 1: DLE Presentation

The DLE began with the introductory assembly, as previously depicted. Afterward, three areas are established (waiting room, medical examination, and pharmacy), decorated with displays of the human body, diagrams of bodily systems, organ images, anatomical busts, medical tools, etc.

Next, characters (doctor, nurse, and patients) are assigned, and they are dressed in medical attire. They recorded their names and roles in the DLE agenda, and during each session, they rotate roles. The doctor managed the examination room, the nurse the pharmacy, and the patients gathered in the waiting room. The nurse listed patients and called them by order of arrival for examinations.

4.1.2. Activity 2: Waiting Room and Body Parts

The library's LE functions as the waiting room, offering body-related books and games for children. Here, the children played with cards featuring drawings of specific body parts, which they must match with their names (Figure 1A, left). These cards are also incorporated into literacy activities.

This game showed doctor specializations (cardiologists, dentists, etc.), which will be explored in subsequent activities. Participants are encouraged to associate each specialist with the corresponding body part.

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They also had cards to match body parts or to learn about medical tools they should cut out, paste, and label in a first-aid kit (Figure 1A, right) (Segarra et al., 2018).

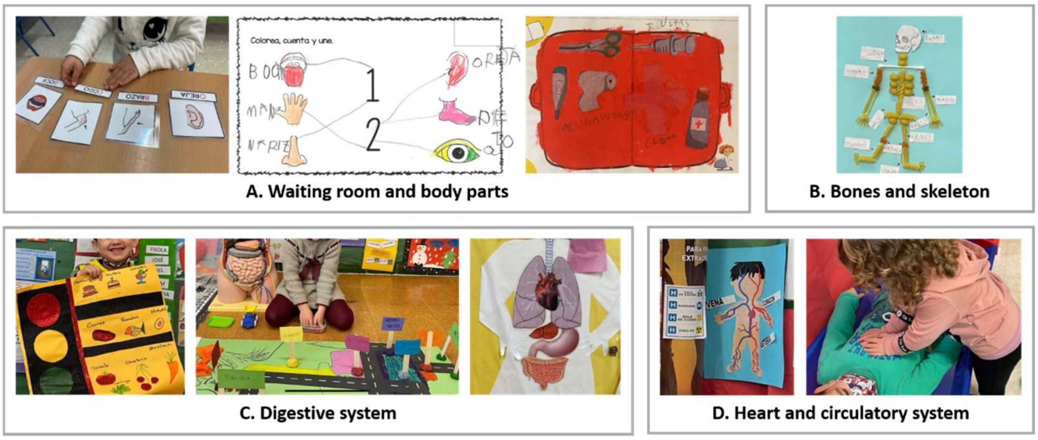

Figure 1. Role-play activities related to human body parts.

4.1.3. Activity 3: What's Happening, Doctor?

The doctor welcomed the patient and requested that they describe their symptoms. To illustrate, the following dialogue between two children is provided:

— Doctor Valeria: *Blanca, please, tell me, what's bothering you? How long have you been feeling unwell?*
— Patient Blanca: *My tummy hurts, and I have a cough.*
— Doctor Valeria: *Since when?*
— Patient Blanca: *Two days ago.*

The doctor used the cards from activity 2 to match the patient's symptoms with specific body parts (Figure 2A), aided by a human body diagram to connect to organs and systems. In this instance, she needed to pinpoint the location of the abdomen, throat, and mouth. This activity was repeated in an assembly, letting children observe peers' trial and error.

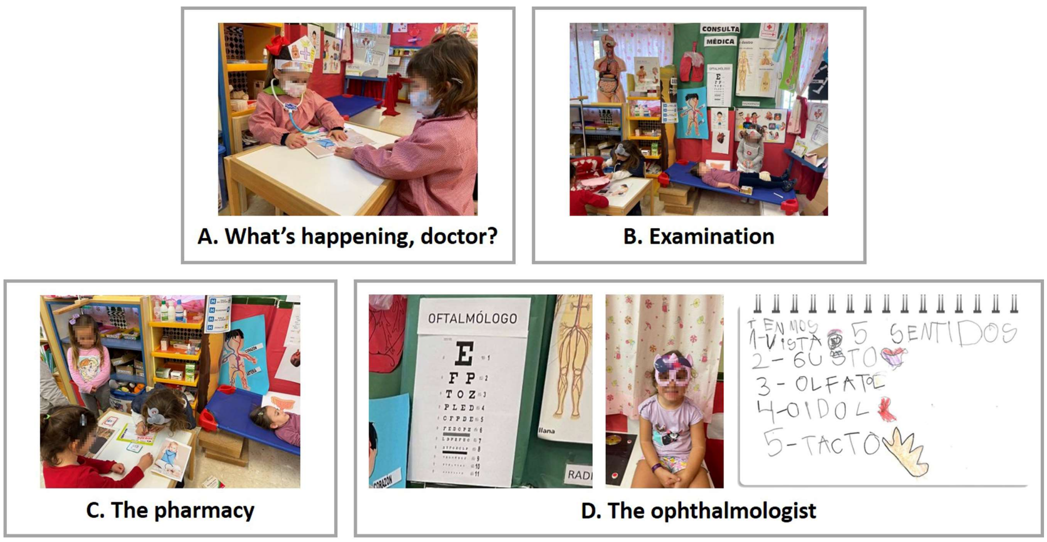

Figure 2. Role-play activities involving visits to a medical specialist.

4.1.4. Activity 4: Examination

The patient's examination began with standard inquiries and height and weight measurements. The patient reclined for the doctor's examination (Figure 2B) and diagnosis. The following lines illustrate a role-play:

— Doctor Valeria: *Please, lie down on the examination table. Does it hurt here? And here?* [The doctor touches the patient's abdomen and listens to her heartbeat with a stethoscope. Then, she asks the patient to open her mouth.]
— Doctor Valeria: *You have a slight fever [After checking her forehead]. I'll send you a yummy medicine to make you feel better. I'll also give you a paper to purchase this medicine at the pharmacy. Take it for five days.*
— Patient Blanca: *Alright, doctor.*

After the valoration, the doctor can decide to prescribe medication (activity 5) (syrup, pills, suppositories, or ointment), refer the patient to a specialist (ophthalmologist, dentist, etc.) (activities 6 and 7), or recommend a treatment (X-ray, ultrasound, etc.) (activities 14 and 16).

4.1.5. Activity 5: The Pharmacy

If the doctor prescribed medication, the patient visits the pharmacy, where the nurse reads the prescription and dispenses the medication (Figure 2C).

4.1.6. Activity 6: The Ophthalmologist

In activity 4, the doctor asked the patient about their vision, and if it is negative, they referred the patient to the ophthalmologist. There, the patient, wearing toy glasses, must identify the letter or number pointed out by the ophthalmologist on a chart (Figure 2D). This activity is also used to recall names and functions of the senses.

4.1.7. Activity 7: The Dentist

The children used a mouth model (Figure 2B, bottom left) to match each part with its name (mouth, tooth, molar, tongue, palate, uvula). Then, they counted the dental pieces, and differentiate between teeth and molars. They read the flavors written on the tongue and identify which area corresponds to each taste.

In the role-play, a child played dentist to diagnose the patient's toothache. The dentist emphasized the importance of oral hygiene and taught the patient how to brush their teeth using the model.

4.1.8. Activity 8: Bones and Skeleton

First, the teacher presented a skeleton image on the digital whiteboard and explained its role in supporting the body. The teacher highlighted some bones, and the musculoskeletal system to which they belong. One girl remarked that without a skeleton, we would be like clothes, simply falling.

Next, they located certain bones on the whiteboard skeleton and counted each type. Afterward, they crafted a skeleton using pasta and sticks (Figure 1B) and labelled each bone.

Finally, the children played by touching the bones on their own bodies as the teacher named them, gradually increasing the speed.

4.1.9. Activity 9: Muscles

The teacher explained that muscles are part of the musculoskeletal system, they wrap around bones, and they enable movement. She pointed out the location of biceps, calf muscles, and quadriceps. Then, a game similar to the one with bones in the previous activity was played.

4.1.10. Activity 10: Digestive System

The activity starts with a food analysis, categorizing them on a mural with a healthy food traffic light (red for unhealthy, amber for partially healthy, and green for very healthy;

Figure 1C, left). It was explained that foods contain nutrients absorbed by the small intestine. Then, the children are tasked with recognizing healthy breakfast options.

The activity proceeded with a game simulating the digestive system (Figure 1C, center), using plasticine balls as food, a toy truck to represent the food's journey through the body, and parking spots to depict various organs. Children load the truck with plasticine and, starting from the mouth, follow the path through the digestive system to the anus. At each organ, they make alterations to the plasticine while explaining the process.

This activity also incorporated a silhouette (Figure 1C, right) for placing images of different organs.

4.1.11. Activity 11: Heart and Circulatory System

Through a simulation, children learn about the circulatory system's parts, observe blood flow in arteries and veins, and listen to the heartbeat. Then, they label parts of the circulatory system on a poster (Figure 1D, left).

Subsequently, they listen to their hearts and count beats after various activities (sitting, running, jumping) to understand the heart rate's relation to activities. Finally, they learn that the heart can stop, but there are life-saving first aid techniques. The teacher demonstrates cardiopulmonary resuscitation on a mannequin, and the children engage in simulations (Figure 1D).

4.2. Inquiry

4.2.1. Activity 12: Human Body Bust

This activity used an anatomical model of the human body to guide the inquiry:

- Engage: Children remove organs from the bust and label them.
- Explore: They touch organs to become familiar with their shape and size.
- Evaluate: They place each organ in the bust and link it to its corresponding system.

After positioning the organs, one child points to them while another child names them. In the following task, cards with organ names are handed out to the children to read and locate them in the bust. Finally, they are asked to count organs between two body areas, such as between the neck and waist.

4.2.2. Activity 13: Operating Room

This activity aims to identify real organs, working as follows:

- Engage: Initially, the children noticed that the heart shapes on the posters and the bust did not match their drawings, making comments like the following:
    - — Paola: *That's not a heart.*
    - — Juan: *Why isn't it like a real heart?*
    - — Teacher: *Drawing the heart in our body is challenging, so a simplified representation was created.*

In response to these comments, the teacher purchased several pig organs from a butcher shop.

- Explore: The next day, the following dialogue occurred:
    - — Teacher: *We are going to transform the DLE into an operating room, where doctors perform surgeries to heal our organs. We will see real organs.*

The children expressed doubts (*What's an operating room? Real organs? Aren't they inside our bodies?*).

When they saw what the teacher had in her hands [a heart], they said:

— Julia: *That's so strange, what is it?*
— Ana: *Do we have that inside us like that?* [Anticipation grew.]

The teacher proceeded to show other organs (lungs, liver, kidneys, and brain) (Figure 3), and the children explored their shapes, colors, sizes, texture, fragility, and smell. Their comments varied:

— Juan: *They're so soft!*
— Daniela: *Are the lungs like this?*
— Omar: *That's gross!*

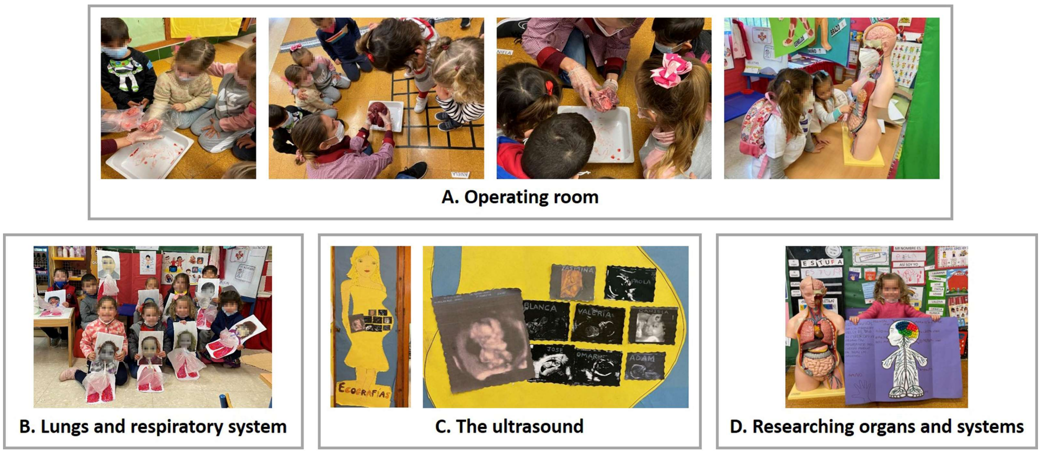

Figure 3. Activities involving inquiry.

Some children hesitated to touch the brain, with one girl thinking each hemisphere was a different brain.

— Adam and Paola: *Teacher, I'm scared to touch them.* [Despite the comment, they still touched them.]
— Blanca: *Look, two brains!*

As they passed the brain around, it got slightly damaged.

— Paola: *It's broken!* [With amazement and sadness.]

The teacher emphasized that our organs are delicate and therefore protected by bones. She urged the children to be cautious and not push or hit each other to prevent injuries.

Exploring the organs triggered different emotions in the children, including confusion, interest, amusement, surprise, amazement, doubt, nausea, happiness, and, in some cases, a touch of fear. This can be observed in Figure 3A, where one girl embraces another as a sign of protection. The rest of the process is defined below:

- Explain: After experimenting with each real organ, the children described and explained their functions. For instance: The heart is soft and carries blood everywhere.
- Evaluate: The children write organ names and place them on the bust (Figure 3).

4.2.3. Activity 14: X-Rays

This activity involves reviewing human body bones and understanding how they appear in X-rays:

- Engage: Children are asked to bring X-rays for bone identification and write and read their names. The teacher also provides some X-rays from the web.
- Explore: Children observe the bones in each X-ray and check their sizes.
- Explain: They analyze the X-rays to identify any fractures, determine the specialist, and suggest treatment.

4.2.4. Activity 15: Lungs and Respiratory System

This activity covers the following:

- Engage: Children color and label a respiratory system worksheet.
- Explore: Children practice breathing (inhaling and exhaling) with teacher guidance and observe the process.
- Explain: They describe lung function during breathing.
- Elaborate: Each child has a cardboard cutout with a picture of their face and another representing the lungs, which they color. Then, they place straws on the drawing alongside two plastic bags and blow to observe how the bags inflate as air enters (Figure 3B).

4.2.5. Activity 16: The Ultrasound

This activity explores the development of a baby in the mother's womb.

- Engage: Each child brings their own prenatal ultrasound to class, and a mural is created (Figure 3C).
- Explore: Children observe the ultrasounds and identify baby parts.
- Explain: They describe differences between the ultrasounds and relate them to baby growth. Some comments refer to baby size:
  - — Valeria: *How tiny!*
  - — Blanca: *Daniela is the biggest.*

  Or in their state:
  - — Juan: *They're sleeping.*
  - — Omar: *They all have their eyes closed.*

4.2.6. Activity 17: Researching Organs and Systems

This activity covers all stages of inquiry and runs concurrently with other activities:

- Engage: Children are encouraged to explore a specific organ or system at home.
- Explore: Each child researches the chosen topic with parental assistance, using drawings, age-appropriate readings, or educational videos.
- Explain: The teacher tracks their progress, and each child explains what they have learned.
- Elaborate: Their work is displayed on a mural with illustrations and hands-on elements.
- Evaluate: The mural helps each child present their findings to their peers, and they use the bust to point out the organ or system. Figure 3D show a girl explaining the brain.

4.3. Learning Outcomes

Figure 4 illustrate the findings, displaying the achievement levels reached for Listing, Identifying, and Relating tasks.

The Listing task (Remember + Factual) yielded the highest overall achievement levels, with an average of 76.18% of responses classified as achieved. Full achievement (100%) was observed in categories such as Healthy and Unhealthy Foods, Muscles, Organs, and Elements of a Medical Consultation and Equipment, a level not reached in any other task. Lower achievement levels were noted in Bones, Systems, and Specialists, reflecting greater variability in children's recall of more specific anatomical terms and professional terminology.

In the Identifying task (Remember + Factual), achievement levels were more evenly distributed, with an average of 58.33% of responses classified as achieved. Higher performance was observed in identifying Organs and Systems in the bust (77.7%), whereas tasks involving identification of Real Organs and Muscles in their own body elicited more partially correct or developing responses.

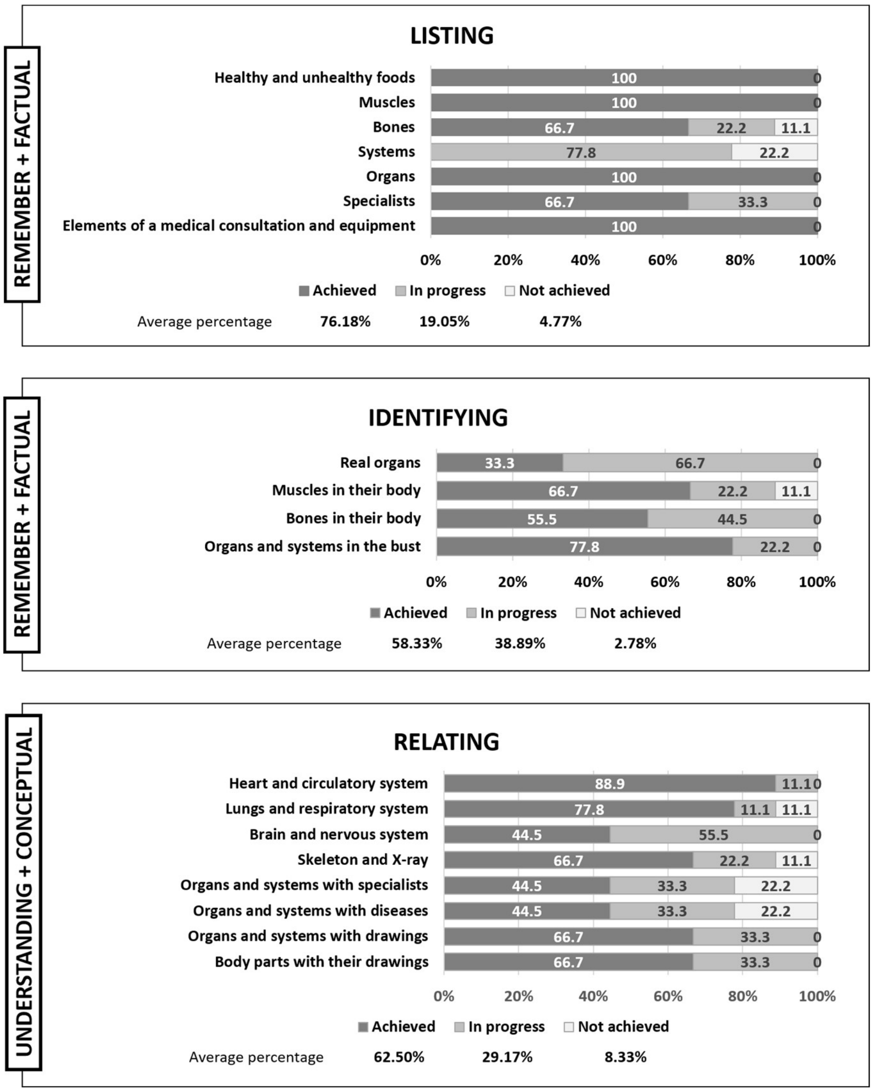

Figure 4. Achievement levels for Listing, Identifying, and Relating tasks.

In the Relating task (Understanding + Conceptual), the average proportion of responses classified as achieved was 62.50%. Higher levels of performance were observed in relations such as Heart and Circulatory System (88.9%) and Lungs and Respiratory System (77.8%). Greater difficulty was evident in Brain and Nerves and Skeleton and X-ray, suggesting that establishing certain conceptual connections posed more complexity for the children.

Figure 5 presents the outcomes for the Explaining task, providing example responses. In the Explaining task (Understanding + Conceptual), the average proportion of responses classified as achieved was 72.21% The examples illustrate qualitative differences across performance levels. In the achieved category, children provided more elaborated explanations that included functional relationships (e.g., linking the brain with nerves or describing digestion as a process). In the in-progress category, responses were shorter and often partially descriptive (e.g., pointing to body parts or offering single-function explanations). In the not achieved category, responses reflected misconceptions, confusion (e.g., confusing ultrasound with X-ray), or the absence of explanation.

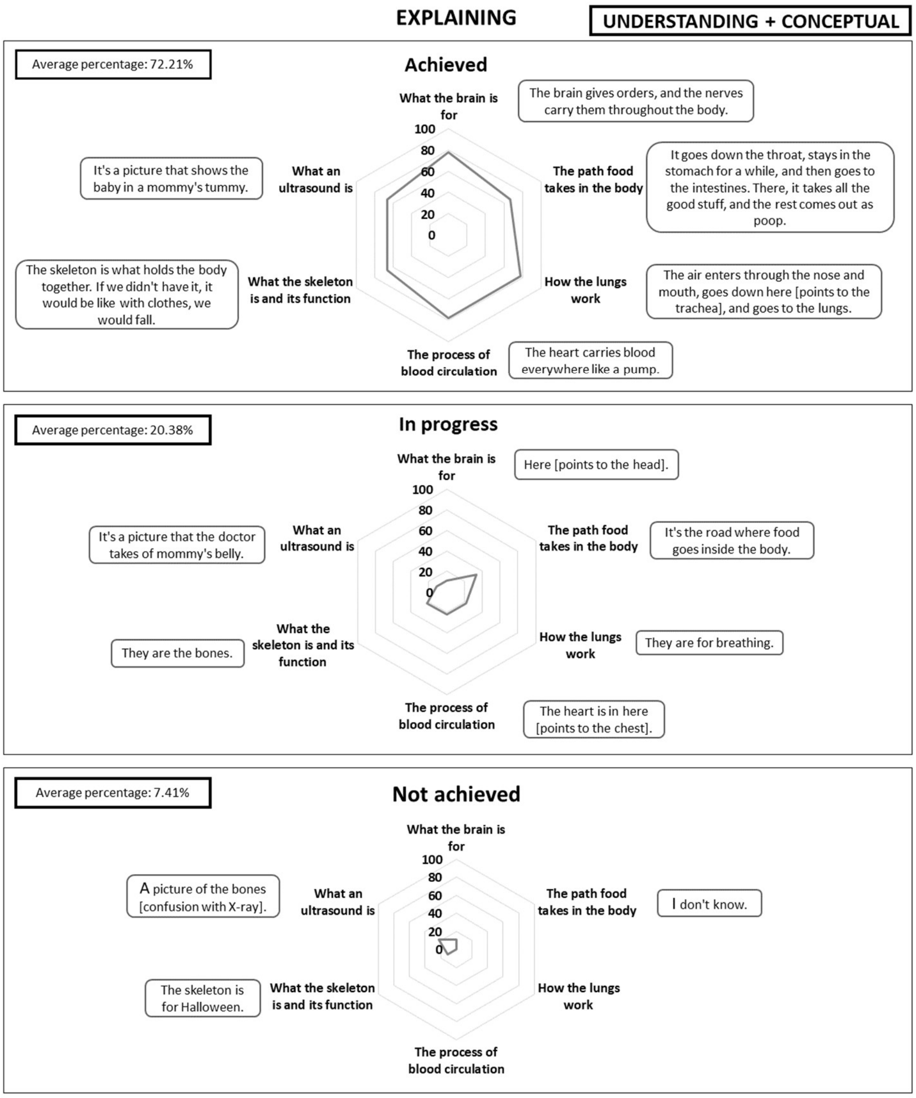

Figure 5. Achievement levels for explaining task and response examples.

5. Discussion

As an exploratory and descriptive case study, DLE appears to help achieve relevant outcomes for this age in the knowledge application domain, including 'Remember + Factual' and 'Understanding + Conceptual' (Anderson & Krathwohl, 2001). At least 58% of the children achieved successful outcomes in all tasks, with Listing and Explaining showing higher average learning percentages (76.18% and 72.21%, respectively). The highest percentages of unsuccessful objectives were obtained in Understanding + Conceptual. These results should be interpreted within the specific context of this small sample and do not warrant generalizable developmental conclusions.

The main difficulties were observed in listing names of systems, bones, or specialists; identifying real organs and the location of certain bones or muscles in their bodies; relating the brain to the nervous system or some organs and systems to diseases or specialists; and explaining digestion, an ultrasound, or the skeleton.

The findings suggest that science learning experiences, particularly opportunities to engage with the knowledge application domain of critical thinking in science education, can begin to develop from an early age within the context of the LE's topic, design, and game-based activities (Elkind, 2007; O'Reilly et al., 2022); role play (Åkerblom et al., 2019); and inquiries (Bybee et al., 2006), all of which have been evidenced effective in the literature.

In this sense, the observed behaviours can be interpreted as emerging or developing forms of critical thinking, rather than as fully established skills.

The daily life problem about the human body and illness appeared to support the development of knowledge application domain of critical thinking, since it interested the children (Wurtele & Kenny, 2011). Some key aspects of the design included the integration in the DLE of a high number of well-defined and organized areas (Sáez-Bondía et al., 2024), with daily transformations (Greenman, 2005), where the child could express their interest (Dejonckheere et al., 2016). However, due to the qualitative and context-specific nature of the data, these interpretations should be considered descriptive and exploratory.

The variety of spaces provided opportunities for inquiry: Engaging, Exploring, Explaining, Elaborating, and Evaluating (Cabrera & Colosi, 2010). In essence, DLE activities involving role play or inquiry appeared to support the integration of scientific content with the early development of fundamental scientific skills, including observing, comparing, identifying, classifying, measuring, and communicating (Jirout & Zimmerman, 2015).

6. Implications and Limitations

The knowledge application domain in daily life problems, such as the human body, addressed through a DLE, may inform early childhood health education (Lewallen et al., 2015). Although DLE covers some health-related activities like oral hygiene (activity 7) and healthy eating (activity 10), there are other important health topics to address, such as personal well-being, physical activity, personal hygiene, mental health, and obesity.

This study should be understood as an exploratory and descriptive case study, involving a small sample of nine children to allow for personalized daily monitoring for research purposes. This sample size is suitable for illustrative purposes and enabled in-depth observation of children's developmental patterns; however, it also limits the generalizability of the findings beyond this particular educational setting.

Given the participants' age and the predominantly qualitative, context-bound nature of the data, the results should be interpreted as indications of emerging manifestations of critical thinking within the knowledge application domain, rather than as evidence of stable or fully developed skills. The observed behaviours reflect developmental processes in progress and should not be assumed to represent consolidated abilities transferable to other contexts without further investigation.

Future research could expand the sample size, adopt longitudinal designs, and triangulate data sources to further explore developmental patterns across different educational contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

LE	Learning Environments
DLE	Doctors' Learning Environment

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