ESCOLA DE DOUTORAMENTO
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Inés
Mosquera Bargiela

Tese de doutoramento

PENSAMENTO CRÍTICO E PRÁCTICAS CIENTÍFICAS NA FORMACIÓN DO PROFESORADO E A SÚA IMPLICACIÓN NA AULA DE INFANTIL: INDAGANDO SOBRE A CAÍDA DE OBXECTOS

Santiago de Compostela, 2021

Programa de Doutoramento en Educación

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DECLARACIÓN DO AUTOR/A DA TESE

D./Dna. **Inés Mosquera Bargiela**

Título da tese: **Pensamento crítico e prácticas científicas na formación do profesorado e a súa implicación na aula de infantil: indagando sobre a caída de obxectos**

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En condición de: **Director/a**

Título da tese: **Pensamento crítico e prácticas científicas na formación do profesorado e a súa implicación na aula de infantil: indagando sobre a caída de obxectos**

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ÍNDICE

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SUMMARY

This doctoral thesis aims to analyse scientific practices as well as critical thinking (from now on CT) performed by early year education students when learning science in the context of an inquiry-based task. Taking into account that CT has not been previously explored from an empirical perspective at this level of education, to address this general goal, a study that entails three levels of analysis was carried out: 1) scientific practices in the curriculum and teachers' training programs in our region as well as the pre-service teachers' educators views on CT notion and learning environments to promote it; 2) the role of an early childhood teacher, particularly the use of questioning as a teaching strategy that can enhance children's inquiry and argumentation skills when they are involved in an inquiry-based task, and 3) the performance of CT skills and dispositions by the children.

International reform documents have called for an emphasis on students' engagement in core scientific practices, such as scientific inquiry and argumentation, from an early age (National Academies of Sciences, Engineering, and Medicine, NASEM, 2018). Moreover, in the recent years, scientific practices have gained more presence in international and national curricular documents and have a large body of research. However, there is a scarcity of studies on scientific practices and CT in early childhood education. A search on the literature revealed that most of the research on inquiry have focused on students' acquisition of inquiry skills (e.g., Burtscher, 2011; Hsin & Wu, 2011; Kambouri & Michaelides, 2014), whereas teachers' guidance and how inquiry activities are

implemented have not been deeply explored, what is necessary to shed some light on how students better perform inquiry and argumentation skills. This thesis attempts to investigate these aspects paying attention to teacher and students' interactions. Argumentation and CT are very much interrelated; however they have not been deeply explored in early years. Most argumentation studies attend to argumentative dialogic movements prompted by drawings of stories (Dovigo, 2016) and the Philosophy for Children (P4C) program (Daniel et al., 2017) pays an emphasis on the importance of promoting CT at this stage. Drwaing from this gap on the literature this thesis investigates how scientific practices and CT were performed by early childhood students when learning science in the context of understanding scientific notions as gravity and air friction using an inquiry-based approach.

The general goal of the thesis is specified in three research objectives and their respective research questions:

O1. *To characterize the state of art of scientific practices and critical thinking.*

RQ1) How are scientific practices integrated into the early childhood education curriculum?

RQ2) How are these practices presented on initial and continuous training plans for pre-service and in-service early childhood teachers?

RQ3) How critical thinking interventions studies in higher education are characterised?

RQ4) What notion of critical thinking do pre-service teacher educators have?

RQ5) What type of learning environments do pre-service teacher educators declare to implement in their instruction to promote critical thinking?

O2. *To identify didactic strategies, particularly teacher's questions that favour the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions.*

RQ6) What is the nature of a teacher's guidance in an inquiry-based learning activity? Specifically, what kinds of driving questions do teachers use to engage children in inquiry?

RQ7) How does teachers' driving questions affect students' enactment of inquiry and argumentation skills?

O3. *To identify critical thinking skills and dispositions in students' discourse in a science context.*

RQ8) How are the questions posed by the teacher that activate certain critical thinking skills and dispositions by early childhood students?

RQ9) What is the relationship between the teacher's questions and the practice of critical thinking by the students?

Theoretical framework

The theoretical framework can be situated within the studies in science education that focus on learning and teaching science and CT through scientific practices in early years. For that, the study is framed within three bodies of knowledge: 1) scientific practices in early years, 2) critical thinking in science education, 3) Teachers' guidance in inquiry-based teaching, particularly the role of questioning in the activation of critical thinking and scientific practices.

Scientific practices in early years

Reports from the Organisation for Economic Cooperation and Development (OECD) disclosed that engaging in science since early years has affordances in later students' achievement (OECD, 2012, 2017). This brings light to the importance of promoting science in early childhood education. In line with this situation is the growing concern in science instruction about how to promote it in conjunction with scientific practices. It is our understanding learning science implies participating in scientific practices. According to Reiser, Berland and Kenyon (2012) these practices imply the construction of scientific knowledge and the understanding of why it is constructed, examined, evaluated, and improved in a certain way. This view seeks to promote the participation of students in scientific practices, abandoning the idea of a mere acquisition of theoretical knowledge. In this study we focus on inquiry and argumentation, two of the three core practices that the term scientific practices encompass.

Inquiry-based science has been introduced in most science education plans (OECD, 2007; Ramnarain, 2018; Rocard et al., 2007; Zhang, 2016), which derivate in multiple meanings. In this thesis, we follow the inquiry definition proposed by Bevins and Price (2016), who regarded inquiry as a question-driven, open-ended process of supporting students' knowledge and investigating skills to find, and internalize, new concepts and solutions to the questions that have been formulated. This definition, inspired on Dewey's roots and Kelly's (2014) work emphasize the dialectical process that emerge in a situation where students try to reach a solution. Moreover, we concur with Evagorou et al. (2020), stating that other skills such as argumentation might be also developed when children engaged in an inquiry-based learning activity as both practices overlap in their territories of engagement.

Research have addressed the acquisition of children's inquiry skills when dealing with diverse scientific notions and and physical phenomena as: water cycle (Hsin & Wu, 2011; Kambouri & Michaelides, 2014), the changes of state of different substances and compounds (Cruz-Guzmán et al., 2017), meteorological phenomena and astronomical events (Burtscher, 2011) and the concept of shadow (Bayir, 2019). Nonetheless, attention to teacher's guidance and how inquiry activities are implemented is necessary to shed some lights on how students better perform inquiry skills, which is what thesis aims to investigate.

Argumentation is one of the scientific practices necessary to understand how knowledge, it is built, assessed, and communicated, as scientists provide arguments to link evidence with the conclusions through justifications (Brown et al., 2010; McNeill & Krajcik, 2011). Two skills students need to develop for the participation in the culture of science are constructing explanations and basing their arguments on evidence. As inquiry, it has been conceptualized in different ways depending which the focus is on. For the purposes of this study, we define it as a socio-dialogical process that involves an interaction between children constructing claims and evidence and the establishment of a valid conclusion, explanation or other claims about the natural world (Berland & Reiser, 2011; Driver et al., 2000). Research findings suggest that by incorporating argumentation in science teaching, children might develop a stronger understanding of content knowledge and improve their ability to justify their own claims (McNeill, 2011). In argumentative classrooms, that is precisely what students do, they tentatively construct their claims supported by reasonable evidence either as individuals or as a group to present it later to their peers to seek critique or come up with alternatives. In this sense, the goal of argumentation is not only to interact through ideas but also to reach an agreement where teachers and students work together as a community to improve their arguments through cognitive conflict (Ford & Wargo, 2012; Walton, 1998).

Research on argumentation in science education is relatively recent, focusing these early studies on exploring whether argumentation took place on the classroom (Jiménez-Aleixandre & Erduran, 2015). Often, findings pointed out children were not able to formulate sound arguments. In the last decade, scarce studies on argumentation skills were carried out in early years (e.g., Kultti & Pramling, 2020), usually focusing on children's reasoning skills (Mercier, 2011) or in arguments posed by children in a mathematical activity (Breive, 2017) or contexts of play (Migdalek et al., 2015). As far as we know, Dovigo (2016) it is the only study that addresses how argumentation starts to get shaped in early years through the dialogical movements between the children and their teacher.

Critical thinking in science education

Critical thinking is considered as a seminal goal in education, and there is some consensus among educators about the need to establish it as a core skill at a curricular and teaching level (Binkley et al., 2012). Nonetheless, the multifaceted (Barnaby, 2016), and dynamic (Kuhn, 2019) character of this notion, makes difficult to achieve a unique definition, and discussions persist about the way CT can be achieved through education (Abrami et al., 2008; Niu, et al., 2013). Critical thinking has been conceptualized in various ways from philosophy, psychology, and education. Nonetheless, they present a common characteristic: CT requires a domain of context-specific knowledge to evaluate specific beliefs or statements (Greene & Yu, 2016; Puig et al., 2020). This thesis adopts this perspective, although it also considers important, especially at an early age, to attend to other factors that are part of the affective and social domain.

In this study, CT definition is drawn from Facione's (1990) and Facione and Facione et al.'s (1995) framework, agreed on an Erasmus+ European Project (Critical Thinking Across Higher Education Curricula, CRITHINKEDU) and refined in RODA, our research group (Jiménez-Aleixandre & Puig, in press). It is our understanding that CT is a set of skills and dispositions that enable students and people to guide conscious actions based on reasons and values, but also on independent thinking. Following these authors, we consider that CT involves considering empirical evidence, thus it can be developed through the practice of argumentation (Kuhn, 2019), but it contains also other components, some cognitive or metacognitive, as self-regulation, some dispositional, as willingness to reconsider and revise views, and affective. The notion of skills it is drawn from Facione (1990), understanding that they allow students development at a cognitive and personal level. Furthermore, we undertake the idea that dispositions consist of the internal motivation to act or respond in a certain way (Facione, 2000). To operationalize the definition of CT, researchers have identified a set of specific CT skills and dispositions, whose development must be exercised from an early age and in varied contexts that allow activating them (Facione, 1990; Facione et al., 1995). In science teaching, according to Jiménez-Aleixandre and Puig (in press), one way to achieve this objective is to involve students in processes of knowledge construction through scientific practices where teacher-student dialogic interaction takes place.

Pre-service teachers' educators, being responsible of the teaching of future teachers, have a key role on the CT development on pre-service teachers, which ultimately would have an impact on the children they will teach on the future. Despite literature points the crucial role of the educators in this process (Janssen et al., 2019; Pithers & Soden, 2000), scarce investigations have been carried out about educators' CT skills and dispositions.

The teaching-learning environment or the social climate of the classroom concerns the relationship between the characteristics of the group of students and the teaching methods used so that, ultimately, they can deepen their learning beyond the levels of reproduction (Fraser et al., 1982; Struyven et al., 2006). According to these authors, the interactions between teachers and students or the structural characteristics of the classroom, among others, could consequently determine their CT skills. At the core of learning environments, teaching methods and activities are central themes in empirical CT studies. There are several investigations focused on the teaching of CT, however, there are no conclusive results on what the best conditions for an instruction are to be successful in terms of its development (Tiruneh et al., 2014). In this study, Ennis' (1989, 2016) framework for researchers and educators as well as Abrami et al. (2015) intervention approaches play a key role since they are also adopted as analytical frameworks.

This thesis engages students in the practice of CT during an inquiry-based activity that aims to promote argumentation and inquiry skills. Critical thinking is usually associated with the other scientific practice addressed in this study, argumentation, since it largely involves the evaluation of statements or knowledge through the analysis of evidence (Giri & Paily, 2020). One of the most recent characterizations of CT in science contributed by Jiménez-Aleixandre and Puig (in press) includes a series of components related, on the one hand, to reasoned judgment, and, on the other hand, with the orientation to action. Although we agree with this vision, we understand that, in the early childhood education stage, CT should be promoted from a dialogic interaction in contexts that promote curiosity, the formulation of questions and the search for answers through experiments, as well as the construction of valid justifications refuting alternatives (Kuhn, 1993; Nussbaum & Sinatra, 2003).

The integration of CT in science instruction at early years can be achieved in diverse manners. We believe that CT can be embedded in inquiry-based learning as a dialogic practice in a way that help students to mobilize diverse CT skills as analyse, explanation evaluation, etc., all along with diverse inquiry and argumentation skills. Nonetheless, scarce research has been carried out on CT in early years science and the existing studies, as far as we have been able to know, tend to focus on the development of certain skills by the students (Corral-Verdugo et al., 1996; Harbi, 2016; León, 2015, among others).

Teachers' guidance in inquiry-based teaching. The role of questioning in the activation of critical thinking and scientific practices.

The actions of teachers are crucial in driving the thinking process during the enactment of an inquiry-based activity, bringing out meaningful learning. For this, the role of the teacher needs to shift from an information accumulator to an "active designer" (Gormally et al., 2009, p. 16). Nonetheless, teachers still face difficulties to implement inquiry-based activities and opt for more traditional approaches. Bevins and Price (2016) and Constantinou et al. (2018) point out as constraints the content-laden curricula, inappropriate assessment procedures for inquiry approaches as well as lack of resources and lack of knowledge about the amount of guidance. In recent years, scholars and educators have started to name **inquiry-based teaching (IBT)** as a way to bring key features of authentic scientific inquiry into the science classroom, offering the students experiences to develop the understanding of scientific concepts and connect them with everyday life (Constantinou et al., 2018). For the purpose of this study IBT is regarded as a motivational approach of learning science as it focuses on children's interests and prompts active learning by enabling students to conduct their own investigations (Vorholzer &

von Aufschnaiter, 2019). We concur with Furtak et al. (2012) in understanding IBT as part of a continuum of guidance from less to more guidance. Despite the importance of teachers' guidance in inquiry-based teaching, very few studies have focused on teacher strategies to promote inquiry skills in early childhood education.

Questions play a fundamental role in inquiry as it starts with a question (Herranen & Aksela, 2019) and are considered the backbone of classroom investigations (Kawalkar & Vijapurkar, 2013). **Questioning** have even been used to define inquiry as 'question-driven learning', since questions drive the lessons as students gather and interpret data to answer that question, construct an explanation, and communicate the results. Teacher questions play a critical importance in initiating various cognitive functions (Aschner, 1961; Carner, 1963) that teachers need to be professional questioners (Gall, 1984). Nonetheless, a set of studies has shown that questioning is a skill that is lacking in classrooms in early childhood (Asay & Orgill, 2010), Furthermore, teachers' questioning empirical studies in early childhood are scarce and emphasise children's conceptual understanding (Eshach, 2011) and conceptual change (Smith et al., 1993; Yip, 1998) not stressing the importance of the teacher's role. It is also our understanding that the type of questions posed by the teacher anchor the investigation the children will be undertaking in a lesson, leading them to gather and use data to develop explanations of scientific phenomena. These questions are known as investigation questions and are sometimes referred in the literature as 'driving questions' (Krajcik et al., 1998).

Methods, participants, and educational context

The methodological approach is qualitative, appropriated to study educational process (Creswell & Creswell, 2014). It seeks to understand the participants' meanings, and how they make sense about the experiences lived (Merriam, 2009). The design of the investigation followed an embedded case study as it considers multiples units of analysis that focus on different aspects of the case (Scholz & Tieje, 2002) enabling a mixture of qualitative research techniques to be incorporated into the overall research designs. It comprises several levels of analysis (units) that allow us to explore the context regarding scientific practices and critical thinking in early education and analyses these dimensions in an early childhood classroom. These units of analysis are: (1) the curriculum, (2) teacher training plans, (3) systematic literature review, (4) interviews with the pre-service teachers' educators, and in the early childhood education classroom, (5) scientific practices, and (6) CT skills and dispositions promoted by the teacher and enacted by children.

The *first unit of analysis* refers to the early childhood education curriculum of Galicia (Xunta de Galicia, 2009) focusing on the inquiry, modelling and argumentation practices present in the prescriptive elements. A content analysis was carried out, understanding this analysis strategy as a process of identification, codification, and categorization of the primary patterns on the data (Patton, 2002). A rubric was built based on the descriptors identified in the literature and in interaction with the data.

The *second unit of analysis* deals with the identification of the scientific practices on the initial and continuous teacher training plans, carrying a content analysis and comprised three phases: 1) identification and counting of the number of training actions, 2) identification of the recipients and how many of these actions were aimed at in-service teachers of early childhood education and 3) identification of the competences included in the actions and whether or not there were explicit references to scientific practices.

The *third unit of analysis* refers to the characterization of CT intervention studies in higher education. A systematic literature review was carried out within the CRITHINKEDU project scope; therefore, other CT experts were involved. For the analysis, a 7-dimension rubric was was built jointly on the literature on CT interventions: (a) type of study; (b) CT aims (Facione, 1990; Facione et al, 1995); (c) CT approach (Ennis, 1989; Sternberg, 1986); (d) type of intervention (Abrami et al., 2015); (e) teaching strategies (Ennis, 2016); (f) teaching materials; (g) reported difficulties.

The *fourth unit of analysis* aims to explore the CT notions and learning environment pre-service teachers' education declare to implement to promote CT. For this purpose, semi-structured interviews were carried out to five educators from a Galician public university. For the data analysis process, the rubric developed for the systematic literature review was applied as it comprises the same dimensions, except the CT conceptualization which was analysed according to Facione (1990) and Facione et al. (1995) framework.

The *fifth and sixth unit of analysis* aims to explore the teachers' questions thar favour the enactment of inquiry and argumentation skills (fifth unit of analysis) and CT skills and dispositions (sixth unit of analysis) when 25 students early childhood students and their teacher engage in an inquiry-based activity about air friction and gravity. Data collection included audio recordings, field notes, and pictures. The main analytical strategy followed was discourse analysis, focusing on how children engage in the scientific practice of inquiry and argumentation as well as CT through a dialogic interaction as them and their teacher co-constructed content knowledge about air friction and gravity in and through talk.

The analytical process was carried out through open-coding techniques allowing to emerge categories (Mills et al., 2010). An iterative process begun working back and forth between the raw data, existing literature, codes, themes, and visual data display. The categories in this thesis were elaborated by the researcher from existing literature, adapted to data, and refined. Drawing together the inductive-deductive and thematic data is the first step for the reflection and writing cycle.

Results

An integration of scientific practices in the early childhood curriculum and teacher training plans

The three scientific practices (inquiry, modelling and argumentation) were present on the early childhood curriculum, however, not with the same frequency. Inquiry is the most common practice, prevailing the skills of observation and experimentation/manipulation. Observation appears most frequently within the evaluation criteria and was closely linked to the content of living beings (characteristics, behaviours and vital functions) and the phenomena or elements of the physical environment corresponding to the second content area of the curriculum, knowledge of the environment. The skill of experiment/manipulate was also remarkably present in the evaluation criteria, with examples such as: "Experiment with objects and materials to obtain information and observe reactions" (Xunta de Galicia, 2009, p. 129). This operation relates to curriculum content linked to object properties.

Modelling is the second most frequent practice in the curriculum, with a higher presence the skills of explain (natural) phenomena and represent entities or phenomena through paintings, models, etc. Once again, it was on the evaluation criteria where a greater number of modelling skills were mentioned. It is worth mentioning the use of models it is not present at a curricular level in early childhood education.

Argumentation is the least common scientific practice, emphasizing the skill of using and identifying evidence. This was included in all the prescriptive elements, with a greater presence in the contents and evaluation criteria. It is included, for example, in one of the evaluation criteria: "Identify and name some of its components [of the natural environment], establishing simple relationships of interdependence" (Xunta de Galicia, 2009, p. 135).

Two subjects related to science education were identified on the initial training plans in the three public universities of our province, Galicia. The scientific practices on these training plans were explicitly mentioned on two out of the compulsory subjects through a specific competence (E.36) as well as in the evaluation criteria. Regarding the optative subject, no explicit mention of scientific practices was found.

The annual teacher training plan 2015-2016 for professional development (Xunta de Galicia, 2015) comprises 226 formative actions. Thirteen of them addressed a science or a science education topic, and 2 out of these were related to the information and technologies. Regarding the target of the activities, it should be noted that only 1 out of the 226 activities, named "Management and treatment of urban waste in the Sogama model", was aimed at the in-service early childhood teachers. The other activities were aimed at secondary school science teachers, as well as professors. In no case there were explicit references to scientific practices within the competencies to be worked on.

Critical thinking: from the literature to the classrooms

The analysis of the literature revealed that almost half of the analysed studies (N=5) used quantitative methods; 4 qualitative; and 3 mixed methods. In addition, also 6 studies aimed to analyse CT skills and 4 opted for focusing on both, skills, and dispositions. No studies were carried out to only develop dispositions. The immersive approach was the most common adopted (N=9), not making the CT teaching principles explicit. Concerning the types of intervention, self-study was the most frequent (N=8), followed by dialogue (N=6). Some examples can be found on Silva et al. (2015, 2016) students needed to analyse a scientific paper and write an output that lately would be submitted to peer-review. In general, it can be said that dialogue is related with argumentative practices in different forms. Mentoring was not reported in any study. In line with the type of intervention are the findings related to the teaching strategies as they pointed out that Lecture-Discussion Teaching (LDT) was present in 4 studies, whereas a combination of LDT and PBL was only present in 3 studies. Most of these studies promoted an argumentative context through the use online platforms, texts, or the delivery of lectures. It should be noted that other teaching strategies were proposed on the research, namely: peer-observation and self-assessment (Janulevičien e & Kavaliauskiene, 2012), and cooperative learning (Klimoviene et al., 2006). The reviewed papers provided diverse contexts and teaching materials for the promotion of CT, with most of them implementing writing activities and debates. Despite 7 studies did not mention which learning materials were used, 5 of them (e.g., Torres Merchán & Solbes, 2012; Silva et al., 2016) mentioned articles, texts, and essays as teaching materials.

The analysis of interviews pointed out that participants (T) considered CT as a set of skills and dispositions. Two of the CT definitions given by the participating educators were coherent with Facione's definition (1990), making explicit that CT is comprised of several sub-skills, or that it implicitly integrates skills. They favour the skills of inference and evaluation, as well as the disposition of open-mindedness. However, no mentioned to cognitive maturity was made. Regarding the learning environment they declared to implement, in general terms, CT was promoted in their own classrooms through individual study and dialogue, LDT, and the use of articles, texts as well as books that show students a different perspective or prompt questions. Last, they declared CT was not implemented formally in their own instruction and that they did not have specific assessment rubrics for this purpose.

Inquiry-based teaching: teacher role in children's engagement in inquiry and argumentation practices

The teacher, Anne, followed an inquiry teaching cycle that emerged from her own practice and students' answers, that allowed her to help them in the construction of scientific knowledge about gravity and air friction. Her teaching cycle can be characterised by a 'closed guidance' that included ten types of driving questions: (a) hypothesis; (b) express scientific ideas; (c) design part of the experiment; (d) collect data; (e) analyse and interpret data; (f) construct claims justifying their answers; (g) revise claims; (h) assess claims; (i) draw conclusions; (j) rebut others' claims.

Most of the questions formulated by Anne were related to *posing hypothesis* (N=25), which were present at the beginning of almost every episode and used as a strategy to engage children in the inquiry activity. The questions that aimed at the *assessment of claims* (N=2) or the *rebuttal of others' claims* (N=3) were the least formulated. It is worth mentioned that as children dived into the activity testing more objects, the questions became more frequent, diverse and complex, emerging the ones related to the design of the experiment, the expression of scientific ideas, or the rebuttal of others' claims.

The inquiry and argumentation skills that students enacted the most were the *formulation of hypothesis* (N=26) and the *construction of claims to justify their answers* (N=25). On the other hand, the least frequent skill was *revise claims* (N=4). It appeared when students reflected on their previous answers. There is a higher number of skills enacted by students than teachers' questions. Anne guided the students through questions the most during the development of these episodes; however, they were also the longest ones in terms of duration. In these episodes, she prompted students to engage in diverse skills, such as express their scientific ideas, analyse, and interpret data, construct claims to justify their answers, revise their claims, and draw conclusions.

Critical thinking practice by early childhood students. The role of the questions on the skills and dispositions activation

To contextualize the analysis, we remind the reader that the research activity in which the students participate was the one described in the previous subsection. It aimed to contribute to students' understanding of the scientific aspects of the world around them through the enactment of scientific practices and CT.

The skills that the teacher promoted the most were the explanation (N=29), followed by the inference (N=24), and analysis (N=23). The inference skill was presented at the beginning of each cycle throughout all episodes except the last one when the children draw conclusions. It was associated with the request for the formulation or revision of hypotheses if a student proposes an alternative explanation. Questions associated with the skills of explanation were also presented throughout the episodes, with a greater presence from the moment the teacher demanded that they compare the fall of two objects, which was more complex and encouraged the generation of more explanations. This skill was associated with the request of explanations in which students present arguments related to the previously formulated hypotheses. The guidance provided by the teacher regarding the analysis skill was most evident at the time of the inquiry cycle when analyzing the results of their experiments, especially in those episodes in which they have some complexity for the children and require them to repeat them. Moreover, this help usually appears when there were object comparisons or a new variable was introduced (e.g., dropping the object from a higher height). Regarding the questions that promoted the dispositions, it was the systematicity the one with a greater presence. These questions helped children to perceive and reflect on possible variables that might influence the development of the experiments, in particular, in regards of the experimental design.

The comparison between the skills promoted by the teacher and those perceived in the students showed a concordance between both. In general, we can affirm that the questions guide student participation. Most of the skills developed by the students show a slight increase in their frequency with respect to the questions posed by the teacher. Nonetheless, this cannot be said in terms of dispositions, given that children's enactment is lower.

Conclusions

The analysis of the first research objective, *to characterize the state of art of scientific practices and critical thinking*, regarding the scientific practices allowed us to stablish three conclusions:

1. Inquiry is the scientific practice that receives the most attention in Galicia's early childhood education curriculum.
2. The least present scientific practice at the curricular level is argumentation.
3. Initial and continuous teacher training plans do not offer training in science practices.

The analysis of the first research objective, *to characterize the state of art of scientific practices and critical thinking*, regarding the CT practices allowed us to stablish eight conclusions:

4. The literature reveals that most CT interventions are short-term and focus on skills rather than dispositions.
5. Most interventions do not make the CT teaching principles explicit, as opposed to a minority that combines implicit and explicit teaching.
6. The LDT (lecture-discussion teaching) strategy based on dialogue and supported by individual activities is the most common in the CT interventions analysed.

7. Educators agree in understanding CT as a notion that encompasses diverse skills and dispositions, however, the definitions they hold are varied.
8. The most valued CT skills by educators are inference and evaluation, while the dispositions receive less attention, which is in line with the results found in previous analysed studies.
9. Critical thinking is implicitly integrated into teacher training, which implies it is developed through practice.
10. Dialogue and discussions are considered of great importance by educators as a means of promoting the CT, which highlights the connection between CT and argumentation.
11. CT assessment is not explicitly integrated in educators' instruction nor in the programs of their subjects, but it is regarded as another element of the summative assessment process.

The analysis of the second research objective, *to identify didactic strategies, particularly teacher's questions that favour the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions,* allowed us to stablish six conclusions:

12. The type of questions posed by the teacher are repeated thorough the activity, creating a guiding inquiry cycle emerged from the teacher's experience and her interactions with students.
13. The most frequently asked questions show that the teacher stress the key processes for understanding the activity and the concepts for drawing conclusions.
14. There is a positive relationship between the type of questions asked by the teacher and the skills mobilized by the students.
15. The way questions are asked encourages certain inquiry skills.
16. The questions asked by the teacher promote to a greater extent inquiry than argumentation skills.
17. Scientific practices of inquiry and argumentation overlaps in their cognitive and procedural fields.
18. Questioning helps students to mobilize previously acquired scientific knowledge during the development of the activity

The analysis of the third research objective, *to identify critical thinking skills and dispositions in students' discourse in a science context*, allowed us to stablish four conclusions:

19. There is no pattern between the teachers' questions and CT skills and dispositions articulated by the students. Teacher questions do not seem to give rise to a significant variation in the skills and dispositions of the students either in number or in variety.
20. The skill of explanation, linked to the scientific practice of argumentation, has been promoted and enacted frequently.
21. The skill of evaluation, of vital importance for the critical analysis of the information, is not promoted by the teacher and is not present in the discourse of the students.
22. Dispositions are promoted to a lesser extent than CT skills and questions have little impact on these in students' discourse.

Educational implications

An educational implication related to the *first research objective* refers to the presence of scientific practices are present at a curricular level. Although they are present, being the inquiry that receives the most attention in our curriculum, the initial and continuous teacher training plans analysed do not include activities that allow their development. Given the importance of training teachers in scientific practices in order to achieve the effective transfer of these in the classroom, we suggest, in line with the proposal of Nordine et al. (2021) articulate teacher training plans that prioritize the development of a small and robust body of ideas through the enactment of scientific practices. Extending this approach to the entire education system at the curricular and training level requires the participation of various educational agents and institutions and greater research at this stage of education.

Another educational implication regarding the *first objective* and CT practices deals with the fact that the most learning environments to promote CT according to educators involve processes of argumentation and debates, which reveals the connection between the CT and the argumentation. In this sense, we agree with Giry and Paily (2020) and Kuhn (2019) that argumentation must be integrated into a science learning environment to promote CT. Since both encompass higher order thinking skills, their teaching involves students exercising them through classroom practice. In addition, following the line of the previous implication, we believe that an active, with a specific purpose initial and continuous teacher training, that targets CT is of vital importance to activate their development by early childhood students. Finally, the review of the interventions and the interviews revealed that CT evaluation should be further investigated specially in the qualitative evaluation by means of instruments/rubrics that allow it. One implication is the need to develop studies that allow the development of useful tools for teachers that can be integrated into formal planning.

An educational implication related to the *second research objective* derives from the findings that certain types of questions promote certain skills among children, which makes it easier to design activities and carry out strategies by teachers. Thus, questions such as "what do you think will happen?" or "how will it fall?" promote the ability to formulate hypotheses. When the teacher asked, "What do you think happened?", after engaging on the experiment, this question served the students as a prompt to analyse and interpret the data. However, it should be noted that not all teachers have sufficient didactic knowledge about effective ways to promote CT and scientific practices. Sustained teacher training over time - in addition to experience - would play a crucial role in not only adopting this role, but also adapting it to the activity as students demand it.

It is also worth noting the justification of answers, the most common skill, which is linked to argumentation. This could suggest that early childhood students are able to begin to justify the answers supported by the use of evidence, so adaptations of the CER model (Krajick & McNeill, 2015) in which the connection between these central elements of the argument are made explicit could be of great help at an early age. In particular, when students are not used to providing justifications and teachers' guidance through questioning it is not enough.

Related to the third research object an educational implication is related to the complexity of the CT practice, which prompts students to perform dispositions to a lesser extent than skills. One of these skills is the explanation, linked to the justification of answers and, therefore, to the scientific practice of argumentation. This reveals a gap with the curriculum, where this skill did not appear collected and with the literature where no research is known to address these aspects in early childhood education. Furthermore, the evaluation skill was not promoted by the teacher or performed by the students. We believe that since children are consumers of information from an early age, they should begin to develop this skill, linking it to the practice of argumentation and within the limits of their experience, as Delamain and Spring (2021) have shown in their study with students of this stage.

Last, the analysis of the teacher's and students' discourse showed that the design and context of the task must be taken into account when promoting CT skills and dispositions, since their development depends largely on them. An inquiry-based and physics-related activity has its own characteristics and, as a result, students develop certain skills and dispositions that would surely vary if the task were different. That is, CT development is dependent on the context in which students are involved (Greene & Yu, 2016). This is of great importance because the unit and, therefore, the activities and concepts that are intended for children to learn, are not "simple" activities, but their design focus around phenomena, and may have integrated different scientific ideas using them as a central motivating and guiding element. Lowell and McNeill (2019) indicate that this type of design can help to encourage CT in elementary students and the role of teachers in this context is to ask questions about the phenomenon to guide students towards the draw of conclusions.

THEORETICAL GROUNDING

1. INTRODUCTION

1.1. Justification of the research

This doctoral thesis focuses on analysing scientific practices as well as critical thinking (from now on CT, in Galician PC) performed by early year education students when learning science in the context of an inquiry-based task. To address this main goal, it is necessary to carry out a study that entails three levels of analysis, since CT is a notion that has not been previously explored in early childhood education, as far as the literature shows, from an empirical perspective. Thus, exploring how this notion is contemplated in the curriculum and by teachers' educators at this educational level was necessary to address this general aim. The thesis encompasses the analysis of: 1) CT and scientific practices in the curriculum and teachers' training programs in our context as well as pre-service teacher's educators views on CT notion and how to promote it; 2) the role of an early childhood teacher, particularly the use of questioning as a teaching strategy and how this strategy can enhance the inquiry and argumentation practices by students can and 3) the enactment of CT by a group of early childhood students in an inquiry-based activity guided by a teacher with previous experience in inquiry-based teaching and CT development through scientific practices.

International reform documents have called for an emphasis on students' engagement in core scientific practices, such as scientific inquiry and argumentation, from an early age (National Academies of Sciences, Engineering, and Medicine, NASEM, 2018). A key component of science learning is to engage students in scientific practices. Research shows that involving learners in scientific practices leads to a more sophisticated understanding of key ideas and scientific models and of the nature of science (Lehrer & Schauble, 2015). For the purpose of this study, we draw from Reiser, Berland and Kenyon's (2012) view of scientific practices that not only involves building the knowledge and understanding the reason of it, but also the social interactions that accompany this process. We define the operational definitions of inquiry from Eshach and Fried (2005) consisting of observing, asking questions, hypothesizing, representing data (tables, diagrams, etc.), interpreting data and formulating models. Modelling operational definitions involves students' participations on the development, use and assessment of models (Schwarz *et al*., 2009) and, regarding the scientific practice of argumentation, we concur with Berland and Reiser (2011) that it implies learners' engagement in a dialogic process in which they socially construct, critique and revise claims about the natural world.

In the recent years, scientific practices have gained more presence in international and national curricular documents and there is a large part of the scientific community that accepts the metaphor of children as little scientists (Legare, 2012). Furthermore, these practices have a large body of research; however, few studies focus on early childhood education and the majority are quite descriptive. Currently, studies are being carried out about why early childhood and primary education fail to meet this new approach and authors as Early et al., (2010), Pell and Jarvis (2003) and Kallery and Psillos (2002) point out several factors related to in-service teachers such as lack of materials, low self-confidence, or lack of content knowledge to engage students in science practices. As the findings of this thesis will show, these difficulties become more prominent in our context since, on the one hand, pre-service teachers have scarce science-related subjects during the degree and, on the other hand, early childhood teachers have few choices to continuous training about science education these options do not contain any subject-matter knowledge.

There is an agreement that CT can be developed through the enactment of scientific practices, nonetheless, research had focused more on the latter. Critical thinking research has been mostly addressed from a theoretical standpoint and carried out in higher educational levels (Davies & Barnett, 2015). In addition, the notion of what CT entails for the teachers remains unclear, as each holds their own definition with a tendency to favour the skills (Bargiela et al., 2021). This leads to a situation in which there is not an agreement between researchers as well as educators to which teaching strategy would promote greater CT outcomes (Tiruneh et al., 2014). In a similar line, authors such as Smith and Holmes (2020) and Willingham (2007) have agreed that CT is better taught in the context of rich subject matter knowledge, nonetheless, there is not much investigation about which contexts are more favourable to promote it. Furthermore, Tiruneh (2016) affirmed the students' level of knowledge on the activity they are engaged in would influence the development of CT skills and dispositions. Therefore, we affirm that in this thesis the context of an inquiry-based activity shapes the research as well as children's skill and dispositions development.

We argue that learning both, scientific practices, and CT from a young age through science learning is important as it supports children's development in science and other developmental domains. The idea that children are innate scientists with a wide curiosity is accepted by most of the teachers and researchers, stating that this curiosity is not only satisfied when they engage in science learning, but also it helps them to make sense of the world they live in (Eshach & Fried, 2005; Greenfield, 2009, 2017; Katz, 2010). In addition, we believe children develop a positive attitude towards science (Gomes & Fleer, 2020; Mantzicopoulos et al. 2013), gains on the practices needed for doing science (Fusaro & Smith, 2018; Samarapungavan et al., 2015) and on specific scientific concepts (Hadzigeorgiou, 2015; Sackes, 2015). Science teaching in early years should be taught focusing on content knowledge relevant to children's world (Adams, 2012), which they can experience and carry out investigations on. Therefore, we concur with Larimore (2020) that identifying a range of appropriate content, fostering children's sensemaking while building a broader cognitive and non-cognitive foundation for them to connect with on the future would be appropriate. In this thesis, the in-service teacher addresses different physical phenomena to answer the question 'why the submarines float?', relating these phenomena with their daily lives.

There is a scarcity of studies on scientific practices and CT in early childhood education, finding that most of the research on inquiry have focused on students' acquisition of inquiry skills (e.g., Burtscher, 2011; Hsin & Wu, 2011; Kambouri & Michaelides, 2014) and attention to teachers' guidance and how inquiry activities are implemented is necessary to shed some light on how students better perform inquiry and argumentation skills, which is what this thesis attempts to investigate. Argumentation and CT has been less addressed on early years, being mostly promoted through argumentative dialogic movements prompted by drawings of stories (Dovigo, 2016) as well as the Philosophy for Children (P4C) program (Daniel et al., 2017). This gap on the literature led us to investigate how scientific as well as CT practices were performed by early childhood students when learning science in the context of an inquiry-based task about gravity and air friction.

This investigation was developed under a European research project, Critical Thinking Across the European Higher Education Curricula (CRITHINKEDU), which aimed to deliver a set of guidelines and instructional approaches to teach and assess CT across different courses, which prompted us to carry out a curricular and training plans analysis. The first research objective presents the state of the question through this analysis in relation to the scientific practices on the early childhood education curriculum (RQ1) and on the teacher training plans (RQ2). The first research objective also features the characterization of CT interventions on the literature (RQ3) as well as the notion pre-service teachers' educators have about CT (RQ4) and the CT learning environments in diverse areas of education they declared to implement to promote it (RQ5). To answer the second research objective, we analysed which kinds of driving questions the in-service teacher used to engage the children in inquiry and how they affect students' development of inquiry skills. The third research objective address which questions the in-service teacher posed and how these influence on the children's development of CT skills and dispositions.

Research question 1 and 2 (first research objective) were carried out under the project "Scientific Practices in Science Teaching and Learning, Dimensions in Transference and Performance" (SCI-PRAC), code EDU2015-66643-C2-2-P. They were related to the project's research objective concerned with the characterization of levels of progress in scientific practices in a way that promotes the mastery of scientific content associated with them. Research question 3, 4 and 5 (first research objective) was closely related to CRITHINKEDU project, previously mentioned. The second and third research were developed under the project "Promoting the development of CT and the social and metacognitive dimension of epistemic performances in science classrooms in the post-truth era" (ESPIGA), code PGC2018-096581-B-C22. The connection with this third project is with the objectives 1) to identify and characterize learning environments for early childhood education school students engage in epistemic practices and CT for learning science and 2) to explore how early childhood education school students engage in epistemic performances from a cognitive perspective.

This thesis draws from previous research developed within the research group RODA (Reasoning, Discourse and Argumentation) about the development of scientific practices, specifically, the use of evidence (Fernández Monteira, 2017). This study revealed children's use of evidence increased during the three school years, playing purposeful observation an important role in the generation of first-hand data. According to this study, students' reflection about their own experiences should be promoted in early years, what is closely related to the notion of purposeful observation. We believe that purposeful observation, although it is not explicitly addressed on the present thesis, it is inherently part the teaching process used to guide the activity. The second objective attends to the teacher's guidance and how this guidance impacts the development of inquiry and argumentation practices by students in the context of an inquiry-based activity. Moreover, an analysis of the literature of inquiry teaching at this educational level had been carried out.

The objectives of the thesis are closely linked since 1) they present the state of the art for scientific practices (RQ1 and RQ2) and CT (RQ3, RQ4, and RQ5); 2) they focus on the scientific practices, inquiry and argumentation (RQ6 and RQ7), as well as CT (RQ8 and RQ9) through the dialogic movements between the in-service teacher and the children. In the case of the RQ1 and RQ2, attention is on the analysis of the scientific practices on the early childhood curriculum, whereas in RQ3, a systematic review was carried out to haracterize the best learning environments to promote CT. In the second and third research objectives, the analysis focuses on teacher's questioning and how they affect students' development of inquiry and argumentation practices (RQ6 and RQ7) as well as CT skills and dispositions (RQ8 and RQ9).

The first research objective, specifically RQ1 and RQ2, addresses the integration of scientific practices in the early childhood curriculum and on initial and annual training plans for pre-service and in-service teachers respectively. This aims to set the ground for future papers and justifying the need of further research on this topic as it was found argumentation was the least common practice in the curriculum and in-service teachers did not have opportunities to attend science related formative actions.

Furthermore, first research objective, particularly RQ3, RQ4, and RQ5, compiles a systematic review that characterises CT intervention studies in the field of education at the stage of higher education. The analysis was carried out applying content analysis and a rubric that was co-design with European experts on CT. The findings presented in this thesis were partly published on Dominguez (2018). Besides, an analysis about the CT notion and the learning environment that a group of five pre-service teacher educators declared to implement in their classrooms was analysed.

The second research objective (RQ6 and RQ7) focuses on the analysis of the teacher's guidance, specifically the kind of questions she posed during an inquiry-based activity and how the questions influence students' performance of inquiry and argumentation. It is a guided inquiry-based task about gravity and air friction that involves the progressive testing of diverse objects to reach a conclusion based on evidence. Findings show, on the one hand, that the most frequent questions were related to the posing of hypothesis and the justification of claims, which was in line with students' inquiry and argumentation skills. On the other hand, results revealed there was a relationship between teachers' driving questions and students' performance in inquiry and argumentation skills as they displayed a higher complexity as the activity developed. The findings also suggest the importance of questioning as an integral part of inquiry-based learning and for creating opportunities for early childhood educators to engage in training activities related to questioning.

It is worth noting that the analysis was initiated during a three-month pre-doctoral research stay at the Institute for Science Education and Communication (ISEC) at the University of Groningen, partially funded by an ESERA Travel Award 2019 and the scholarship of the Xunta de Galicia 2018. This gave rise to the co-authorship with Professor Lucy Avraamidou, who contributed to the analysis framework of the scientific practices in research.

The third research objective (RQ8 and RQ9) share the same of focus of analysis than objective 2 and the task under analysis is the same. CT is added to this analysis. Particularly, attention is on the CT skills and dispositions mobilized by children during the dialogic interactions m and the teacher. Findings show that teacher's questions activated the skills of explanation and inference, related to hypothesis formulation, and analysis. These results suggested that the role of the teacher promotes CT through an inquiry-based activity at three key moments. The first takes place in the posed of hypotheses, what contributed to students' performance on the skill of inference, just as the teacher gives rise to dispositions such as open-mindedness. The second moment occurred when analysing the results and looking for explanations for them, in which analysis and explanation skills predominate; although, others such as systematicity were also perceived to assess the adequacy in the design of the experiment. The third moment occurred when establishing the conclusions that led the teacher to promote the skill of interpretation, favouring the co-construction of scientific knowledge such as the presence of air, the role of weight and gravity in the fall of the objects.

1.2. Objectives

The main goal of this thesis is to analyse scientific as well as CT practices performed by early childhood education students when learning science in the context of an inquiry-based task about gravity and air friction. This main goal requires to address three interrelated levels of analysis, from more general to more specific dimensions linked with this goal: 1) scientific practices and CT in early childhood curriculum, teachers' initial and continuous training plans as well as teacher educators' implemented learning environment for the CT promotion; 2) teachers' guidance and questions for the fostering of inquiry and argumentation skills; 3) CT enactment in early childhood students' discourse.

O1. *To characterize the state of art of scientific practices and critical thinking,* presented in two chapters.

RQ1) How are scientific practices integrated into the early childhood education curriculum?

RQ2) How are these practices presented on initial and continuous training plans for pre-service and in-service early childhood teachers?

RQ3) How critical thinking interventions studies in higher education are characterised?

RQ4) What notion of critical thinking do pre-service teacher educators have?

RQ5) What type of learning environments do pre-service teacher educators declare to implement in their instruction to promote critical thinking?

It is noteworthy that RQ1 and RQ2, which findings are presented in chapter 4, were part of the study published in Bargiela, I., Puig, B., & Blanco-Anaya, P. (2018). Una aproximación al análisis del currículum y planes de formación del profesorado de Galicia. *Enseñanza de las Ciencias, 36*(1), 7-23. DOI:10.5565/rev/ensciencias.2311. Universitat Autònoma de Barcelona, ISSN: 0212-4521. Furthermore, the RQ3 findings addressed on chapter 5 were partially published on Dominguez (coord.) (2018). *A European review on Critical Thinking educational practices* *in Higher Education Institutions*. Vila Real: UTAD. ISBN: 978-989-704-258-4. Available at: http://crithinkedu.utad.pt/en/intellectual-outputs. More details about the implications of the researcher and authorizations are available on annex 1.

O2. *To identify didactic strategies, particularly teacher's questions that favors the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions.*

RQ6) What is the nature of a teacher's guidance in an inquiry-based learning activity? Specifically, what kinds of driving questions do teacher use to engage children in inquiry?

RQ7) How does teachers' driving questions affect students' enactment of inquiry and argumentation skills?

O3. *To identify critical thinking skills and dispositions in students' discourse in a science context*.

RQ8) How are the questions posed by the teacher that activate certain critical thinking skills and dispositions by early childhood students?

RQ9) What is the relationship between the teacher's questions and the practice of critical thinking by the students?

1.3. Organization of the thesis

This study is organised in three parts: the theoretical grounding, which comprises chapters 1 and 2; the methods, developed in chapter 3; the findings that are divided from chapter 4 to 7; and the conclusions as well as final considerations that compose a sole final chapter.

In this first one, *Introduction*, it is indicated the justification of the research as well as the objectives and research questions.

In the second, *Theoretical framework*, it is discussed the three bodies of knowledge necessary for this study: (a) scientific practices in early years, with an emphasis on inquiry and argumentation; (b) critical thinking in science education; and (c) teachers' guidance in inquiry-based teaching.

In the third, *Methods*, it is described the type of investigation that was carried out, meaning, a qualitative embedded single-case study design. Afterwards, the context, participants, data collection and data analysis process are addressed for each unit of analysis to answer the research questions.

The following chapter, from fourth to seventh, corresponds to the findings.

In the fourth, *Integration of the scientific practices on the early childhood curriculum and the teacher training plans*, includes the findings after applying content analysis to the early childhood curriculum of our province (Xunta de Galicia, 2009) as well as teacher training initial and continuous plans to know if and how scientific practices are presented on them.

In the fifth, *Critical thinking: from the literature to the classrooms*, a systematic literature review was carried out to characterise CT educational studies in higher education. Furthermore, five pre-service teachers' educators were interviewed to know their CT notion as well as the learning environment they implement on their own classrooms to promote it.

In the sixth, *Inquiry-based teaching: teacher role in children's engagement in inquiry and argumentation practices*, the questions posed by the teacher were analysed to consider also how they influenced to the children's enactment of inquiry and argumentation skills.

In the seventh, *Critical thinking performance in a science activity*, the questions posed by the teacher were analysed to explore how they influenced on children's performance on CT skills and dispositions.

Finally, in the eighth, *Conclusions, educational implications and final considerations*, the conclusions that derive from this study are indicated and discussed along with the educational implications, both for research and for educational practice. The last section of the thesis has been intended to comment on the limitations of the study and the future lines of research that emerge from the present study.

2. THEORETICAL FRAMEWORK

The theoretical framework of this thesis can be situated within the studies in science education that focus on learning and teaching science and CT through scientific practices in early years. Aligned with this approach, CT is considered a situated practice that involves a set of skills and dispositions enacted through dialogue in the science classrooms. Scientific practices and CT are considered interrelated activities that can be activated by the teacher through questioning. This section addresses the most relevant theoretical underpinnings that are used in this research.

2.1. Scientific practices in early years

Reports from the Organisation for Economic Cooperation and Development (OECD) disclosed that engaging in science since early years has affordances in later students' achievement (OECD, 2012, 2017). This brings light to the importance of promoting science in early childhood education. In line with this situation is the growing concern in science instruction about how to promote it in conjunction with scientific practices. Diverse European projects (e.g., S-TEAM; KidsINNScience) have focused on generating resources and teaching materials to work on scientific practices and analyse teaching strategies for their effective implementation. From these projects, and from recent research on teacher training, they derive reflections about the need to pay greater attention to the performance and transfer of scientific practices from an early age (Krajcik & McNeill, 2015).

Learning science implies participating in scientific practices, which authors such as Kelly (2008, p. 99) define as “the specific ways in which members of a community propose, justify, evaluate and legitimize knowledge statements in a disciplinary framework.” Reiser, Berland and Kenyon (2012) point out that these practices imply the construction of scientific knowledge and the understanding of why it is constructed, examined, evaluated, and improved in a certain way. The notion of practice, according to the National Research Council (NRC, 2012), emphasizes the need to use not only skills, but also specific knowledge for each practice. This view seeks to promote the participation of students in scientific practices, abandoning the idea of a mere acquisition of theoretical knowledge. In this study we focus on inquiry and argumentation, two of the three core practices that the term scientific practices encompass. There is a need in science education to shift the focus on classrooms from memorizing facts to engaging students in an authentic scientific practice in which they use the data to shape evidence for the support of scientific claims (Chen et al., 2017; Sampson et al., 2011).

There is a consensus in the scientific community that science learning should be promoted by students participating in scientific practices from an early age (e.g., Eshach & Fried, 2005; Trundle, 2015). Authors such as Larimore (2020) and Davis et al. (2020) support a change in science education to a more comprehensive approach that allow students to develop an understanding on how knowledge is built and acquired through the sustained participation in scientific practices and discourse. One of the proposals which has been presented with the aim of achieving this objective, is the idea of situating the use of knowledge in meaningful context for children. This helps them to make sense of real-world phenomena as they use evidence to construct and critique multiple explanations (McNeill, 2020) by engaging the children in a process skill and the science -epistemic- practice to understand what, how, and why it occurs the phenomena (Lehrer & Schauble, 2015). Nevertheless, despite the importance of introducing these practices and the existence of teaching resources designed to promote them, translating it into practice remains to be a challenge for teachers at different levels (Kelly, 2008; Reiser, Berland and Kenyon, 2012, among others).

This thesis focuses on examining scientific and CT practices performed by early childhood education students when learning science in the context of an inquiry-based task about gravity and air friction. Inquiry and argumentation have presented diverse definitions in the literature. In the following paragraphs we frame out study in the notions of inquiry and argumentation as separated practices, nonetheless, we concur with Bell et al. (2012) that they are interrelated.

Inquiry has its roots at the beginning of the twentieth century in the studies of Piaget (1929) and the insights of Dewey (1933), and Vygotsky (1978), which put the focus on the importance of the children's curiosity, imagination, and their yearning to interact during the learning process. Nonetheless, it was not until Joseph J. Schwab's work (1962) that inquiry began to take significance in science teaching in the United States of America (Bybee, 2011). In Spain, a reform on science education was carried out during that time, considering that scientific knowledge should be taught carrying investigations that reflect the ways scientists work (Crujeiras-Pérez, 2015). In this sense, inquiry would be the model that science education should follow.

Years later, in the international context, there was a shift on the focus to processes of science, emphasizing students learnt specific processes such as observing, measuring, or inferring at the same time they acquire concepts (Bybee, 2011). However, this attempt led to favour the processes, thus, inquiry was introduced as a teaching strategy to stress the importance of learning science by practicing skills. Since then, inquiry-based science has been introduced in most science education plans (OECD, 2007; Ramnarain, 2018; Rocard et al., 2007; Zhang, 2016), which derivate in multiple meanings.

In the 1990s, the National Science Education Standards defined the term in the following terms:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (NRC, 1996, p. 23)

The National Science Education Standards (NSES) were published as a new set of standards for K-12 Science Inquiry (NRC, 2000) to promote students' development of (a) necessary abilities to do inquiry and (b) understanding scientific inquiry. In other words, students should learn how scientists do their work and how scientific knowledge is developed, critiqued, and eventually accepted by the community. This process, as Lederman et al. (2019) pointed out, it is in its essence inquiry.

The skills mentioned on the NRC's (1996) definition were established as desirable for students to develop in the NRC (2012). It is in these standards and in Next Generation Science Standards (NGSS, 2013) where it is emphasized the "doing" of scientific inquiry, naming them practices. This approach based on scientific practices is starting to make some impact on different countries such as Canada (e.g., Öberg & Campbell, 2019), Taiwan (e.g., Cheng et al., 2021), Mexico (Bahamonde & Gómez-Galindo, 2016), the Netherlands (e.g., Prins et al., 2018), and Spain (e.g., Crujeiras-Pérez & Jiménez-Aleixandre, 2019). In some countries such as ours, the term scientific practices it is not explicitly used on the curricula. Nonetheless, in the official elementary education curriculum (Boletín Oficial del Estado [BOE], 2008) is possible to find some of the inquiry skills: "*experimentation with objects and materials will basically allow the inquiry into and knowledge of the elements of reality from both a physical and logico-mathematical perspective, the two being inseparable at this age*" (p. 1033).

Inquiry has been characterized in several ways, sometimes oversimplifying it as hands-on activities. Furthermore, its features ranged from simple descriptions of students actively guiding their own learning with the teacher acting as a facilitator, to more elaborated lists of actions for the teacher, students, and curriculum (Curran & Kitchin, 2019; González-Rodríguez & Crujeiras-Pérez, 2016). The term inquiry is often used to refer to the scientific methodology, the learning process, or the teaching strategy (Minner et al., 2010). In this thesis, we follow the inquiry definition proposed by Bevins and Price (2016), who regarded inquiry as a question-driven, open-ended process of supporting students' knowledge and investigating skills to find, and internalize, new concepts and solutions to the questions that have been formulated. This definition, inspired on Dewey's roots and Kelly's (2014) work emphasize the dialectical process that emerge in a situation where students try to reach a solution. In this way, more attention is on students' as active learners, engaging cognitively to develop evidence-based explanations and not on an oversimplified hands-on activity (Hmelo et al., 2007). In addition, our view concurs with Evagorou et al. (2020), stating that other skills such as argumentation might be also developed when children engaged in an inquiry-based learning activity as both practices overlap in their territories of engagement. Biggers (2018) situated both teachers and learners at the core of inquiry's definition, emphasising their participatory relationship and their enacted scientific practice.

Lederman et al. (2014, 2019) elaborated a description of inquiry aspects K-12 students should develop an understanding about. Table 1 provides a brief overview of them.

Table 1. Description of inquiry aspects K-12 students should develop in the classroom

Feature	Description
Classroom investigations began with a question but might not test any hypothesis	The NRC (2000) stated that for an investigation to be carried out a question about the natural world should be posed.
No pre-defined sequence of steps is followed in investigations	To get a better understanding of scientists' work, a variety of methodologies employed should be employed in order to answer the question at hand.
The inquiry process is guided by the question asked	Students should understand the alignment between the question and methodologies to answer it.
The same procedures carried out by different people might not get the same results	Students need to understand data does not stand by itself; the scientist who explore the same data may come to different conclusions.

Feature	Description
Scientific data and evidence are not the same	Data are observations gathered during the investigation, however, evidence, is the product of data analysis and interpretation in relation to a specific question.
Explanations are developed from the data collected and students' previous knowledge	As investigations are guided by current knowledge, it is interesting to understand conclusions take into account the new set of data analysed as well as the already accepted knowledge.

We acknowledge the impossibility to compare the scientific inquiry to the school inquiry as the latter might suffer for some constraints such as time (Grandy & Duschl, 2007). Other difficulties when it comes to be implemented on early childhood education classes might be related to the amount of time spent on science lessons at this educational stage (Piasta et al., 2014; Tu, 2006). The reasons for this lack of time could be find because of the emphasis on language, mathematics, and literacy instruction in the early years (French & Woodring, 2012; Greenfield et al., 2009; Guo et al., 2016); teachers' limited knowledge about science content (Kallery & Psillos, 2001; Tu, 2006) or self-efficacy (Gerde et al., 2018; Oppermann et al., 2019).

Many studies have addressed the acquisition of scientific knowledge or skills (e.g., Cruz-Guzmán et al., 2018; Valls-Bautista et al., 2021) or the expressed perceptions of pre-service teachers (e.g., van Katwijk et al., 2021). Furthermore, inquiry has been researched at a high school level through the lens of diverse teaching approaches and activities such as cooperative (e.g., Crujeiras-Pérez & Cambeiro, 2018) or mobile learning (e.g., Liu et al., 2020) as well as laboratory activities (e.g., Wardani et al., 2017; Sesen & Tarhan, 2013). Diverse studies have addressed the examination of children's inquiry skills when dealing with diverse scientific notions and physical phenomena as: water cycle (Hsin & Wu, 2011; Kambouri & Michaelides, 2014), the changes of state of different substances and compounds (Cruz-Guzmán et al., 2017), meteorological phenomena and astronomical events (Burtscher, 2011) and the concept of shadow (Bayir, 2019). These studies reported on similar results: students' insights into the scientific notions increased along with their inquiry skills such as predicting, manipulating materials, collecting, and interpreting data as well as drawing conclusions. Monteira and Jiménez-Aleixandre's (2016) study reported that children were able to use observation and evidence in sophisticated ways as to revise their initial ideas, to decide between alternative ideas or to propose explanations, when studying the behaviour of snails. We agree with Cantó et al., (2016) that the acquisition of scientific skills (e.g., hypotheses formulation, carrying out experiments) is of great importance at this educational stage and we believe that implementing inquiry-based activities could promote children's inquiry skills, as previous studies have shown. Nonetheless, attention to teacher's guidance and how inquiry activities are implemented is necessary to shed some lights on how students better perform inquiry skills, which is what thesis aims to investigate.

Argumentation roots can be found in Greece under the name of rhetoric. The philosopher, Aristoteles, was recognised as the father of the argumentation theory (Walton, 1996). He defined it as a mode of logical reasoning that start from a premise. This reasoning is produced through the rhetoric understood as the art of "good talking". For this philosopher a good argumentation consists of convincing of something true and verifiable by logical procedures, therefore, emotions do not have room on it (Plantin, 2005). Trying to advance beyond the traditional initiate-respond-evaluate (IRE) practices of the early twentieth century, the framework proposed by the NCR (2012) made some recommendations. Argumentation is one of the scientific practices necessary to understand how knowledge, it is built, assessed, and communicated, as scientists provide arguments to link evidence with the conclusions through justifications (Brown et al., 2010; McNeill & Krajcik, 2011). Two skills students need to develop for the participation in the culture of science are constructing explanations and basing their arguments on evidence. In the European context, the OECD also includes argumentation as one of the competencies, linking it with the analysis and evaluation of "data, claims and arguments […] to draw appropriate scientific conclusions" (OECD, 2017, p. 15, 21-24). These approaches emphasize analytical and reflective skills; thus, it is interrelated with CT (Hand et al., 2018).

Scholars differ widely on its definition (van Eemeren et al., 2014; Wagemans, 2019; Allchin & Zemplén, 2020). For instance, argumentation can be characterized as a scientific practice that is used to "*solve problems and advance knowledge*" (Duschl & Osborne, 2002, p. 41). For the purpose of this study, we define it as a socio-dialogical process that involves an interaction between children constructing claims and evidence and the establishment of a valid conclusion, explanation or other claims about the natural world (Berland & Reiser, 2011; Driver et al., 2000). The ability to use scientific evidence to support claims is considered a core skill to participate in scientific argumentation (Henderson *et al.*, 2018) and is a key practice to identify the argument's weaknesses and strengths in order to look for the best explanation of a phenomena (NRC, 2012). As Crujeiras-Pérez et al. (2020) stated, to achieve this goal, it is necessary to introduce this practice continuously in the classroom.

Several researchers have proposed dialogic teaching strategies to foster argumentation in the classroom. Osborne (2012) suggests the creation of learning opportunities that favours students' social interactions among themselves and with their teacher. On a similar line, Duschl (2008) recommends the use of conversations to deepen students' understanding of the relationship between the evidence and explanation, taking on a wide range of applications. Gilles and Buck's (2020) work revealed the need to analyse students' argumentative discourse practice as it was demonstrated that are highly dependent on those of their teacher. Despite all these benefits, argumentation have not been incorporated as a usual practice in the classrooms. Some difficulties teachers might face are related with the creation of an authentic inquiry environment through questions and guidance (Hundal et al., 2014) as well as the re-framing of the classroom to a more dialogic and student-centred interaction (Berland & Hammer, 2012). On a more personal level, teachers might not feel confident enough regarding the (a) understanding and application or argumentation (Braund et al., 2013; Christolodou & Osborne, 2014) and (b) how to frame an argumentative question (McNeill & Knight, 2013). Students, specially from upper educational stages, also face challenges such as a low level of interacting with evidence (Berland & Reiser, 2009; Hundal et al., 2014; Yun & Kim, 2014) or lack of CT skills as well as low conceptual understanding (Choi et al., 2015; Herrenkohl & Cornelius, 2013).

Research findings suggest that by incorporating argumentation in science teaching, children might develop a stronger understanding of content knowledge and improve their ability to justify their own claims (McNeill, 2011). In argumentative classrooms, that is precisely what students do, they tentatively construct their claims supported by reasonable evidence either as individuals or as a group to present it later on to their peers to seek critique or come up with alternatives. In this sense, the goal of argumentation is not only to interact through ideas but also to reach an agreement where teachers and students work together as a community to improve their arguments through cognitive conflict (Ford & Wargo, 2012; Wallon, 1998).

There is a big body of research on argumentation science education. Most studies focus on the analysis of students' arguments, particularly the quality of students' oral or written argumentation (e.g.,Ageitos & Puig, 2021; Evagorou & Osborne, 2013). Evagorou and Osborne (2013) aimed to identify how middle schoolers co-construct written arguments when working in pairs when presented with an instructional approach within an SSI. Chin and Osborne (2010) investigated the written and oral students' questions as a probe for initiating collaborative argumentation. Cooper and Oliver-Hoyo (2016) investigated the use of written and oral arguments construction as a technique to foster higher education students' understanding of noncovalent interactions based on McNeill et al.'s (2006) and Sandoval's (2003) framework.

Research on argumentation in science education is relatively recent, focusing these early studies on exploring whether argumentation took place on the classroom (Jiménez-Aleixandre & Erduran, 2015). Often, findings pointed out children were not able to formulate sound arguments. In the last decade, scarce studies on argumentation skills were carried out in early years (e.g., Kultti & Pramling, 2020), usually focusing on children's reasoning skills (Mercier, 2011) or in arguments posed by children in a mathematical activity (Breive, 2017) or contexts of play (Migdalek et al., 2015).

Kuhn and Moore (2015) propose a thinking curriculum in which argumentation is a stand-alone competency for middle schoolers, which should offer them the opportunity to pose claims, justify them evaluating evidence and reflect about its relevance according to the topic at hand. Most of the previous studies have focused on upper elementary (e.g., Chen et al., 2017), middle school (e.g., Kawalkar & Vijapurkar, 2013), high school (e.g., McNeill & Pimentel, 2010; Osborne et al., 2013) and college students (e.g., Kelly & Takao, 2002). Hence, little information currently exists on argumentation in early childhood education, even though research suggest that early science practices are fundamental for developing scientific reasoning, the ability to comprehend concepts as well as to develop inquiry skills (Chen et al., 2017; Eshach et al., 2011). As far as we know, Dovigo (2016) it is the only study that addresses how argumentation starts to get shaped in early years through the dialogical movements between the children and their teacher. In what follows, an overview is presented of literature in the context of elementary education, if given the age proximity, specific insights would be still relevant for this study.

Kim and Roth (2018) investigated children's argumentation through social interactions, focusing on the concrete ways in which children and teacher relate using language in formulating claims and evidence and develop argumentation by taking the responsibility for justification (e.g., burden of proof, Walton, 1988, 2006). The study was conducted over the course of an entire school year on a multi-age classroom (7-8 years-old) in the context of an urban school in western Canada. The task, in which children encountered a mystery object entails two lessons which both were recorded and transcribed. The findings showed students' capacity for connecting claim and evidence responding to the burden of proof. In addition, the results revealed that teachers played a significant role to emphasize the importance of evidence but also experienced difficulties removing children's favoured ideas during the turn taking of argumentative dialogue. Another study developed by Larrain et al. (2018) pays attention to the effect of an argumentative dialogue task in knowledge construction by 4th graders. There were no differences in the immediate post-test scores between the control and experimental groups (after controlling for pre-test), however, the intervention group showed significantly higher scores in delayed post-tests. Çınar and Bayraktar, (2014) worked with 5th grade Students to examine the effect of argumentation-based teaching on conceptual understanding related to the topic of "Matter and Change". Results pointed out that the argumentation-based science teaching approach had a positive impact in students' conceptual understanding. Ryu and Sandoval (2015) worked with three groups of 7th grade students as they collaborated to explain a complex scientific question. The findings indicated that the clear goal of task completion allowed a single member to dominate group discussions, which prevented substantive argumentation.

Argumentation has also the potential to enhance students' scientific and CT (Erduran et al., 2004; Kim & Roth, 2014; Sampson & Clark, 2008) given that both entails the evaluation of claims and knowledge through the analysis of evidence (Giry & Paily, 2020). Hence, in the section that follows, we address the notion of CT in science education with a focus on its development in early years.

2.2. Critical thinking in science education

Critical thinking is a concept that has been used in education and educational research for more than 20 years (Avraamidou, in press), but as Jiménez-Aleixandre and Puig point out (in press) the crisis we live nowadays, as the COVID-19 pandemic, give this notion character of urgency in all levels of education. This puts CT on spot as an essential axis in science education (Puig et al., 2021), entailing the training of students in skills to build knowledge and solve problems related to science.

Critical thinking is considered as a seminal goal in education, and there is some consensus among educators about the need to establish it as a core skill at a curricular and teaching level (Binkley et al., 2012). Nonetheless, the multifaceted (Barnaby, 2016), and dynamic (Kuhn, 2019) character of this notion, makes difficult to achieve a unique definition, and discussions persist about the way CT can be achieved through education (Abrami et al., 2008; Niu, et al., 2013). Critical thinking has been conceptualized in various ways from philosophy, psychology, and education. Nonetheless, they present a common characteristic: CT requires a domain of context-specific knowledge to evaluate specific beliefs or statements (Greene & Yu, 2016; Puig et al., 2020). This thesis adopts this perspective, although it also considers important, especially at an early age, to attend to other factors that are part of the affective and social domain.

We draw the notion of skills Facione (1990) (table 2), understanding that they allow students development at a cognitive and personal level. These skills were proposed by the American Philosophical Association (APA), which convened an authoritative panel of 46 international experts on CT in order to produce a definitive account of the concept as included in the Delphi Report (Facione, 1990). In addition, we undertake the idea that dispositions consist of the internal motivation to act or respond in a certain way (Facione, 2000) (see table 3). To operationalize the definition of CT, researchers have identified a set of specific CT skills and dispositions, whose development must be exercised from an early age and in varied contexts that allow activating them (Facione, 1990; Facione et al., 1995). In science teaching, according to Jiménez-Aleixandre and Puig (in press), one way to achieve this objective is to involve students in processes of knowledge construction through scientific practices where teacher-student dialogic interaction takes place.

Table 2. Critical thinking skills draw from Facione (1990)

Skills	Definition
Interpretation	"To comprehend and express the meaning or significance of a wide variety of experiences, situations, data […]." (p. 16)
Analysis	To identify the presumed relationship among claims questions, concepts or descriptions.
Evaluation	To assess the soundness of claims which are descriptions of a person's perception, judgement or opinion.
Inference	To identify elements to draw reasonable conclusions; to pose hypothesis; to contemplate pertinent information and to infer consequences from data.
Explanation	To state the results based on evidential, conceptual and criteriological reasoning presenting them in form of convincing arguments.
Self-regulation	To monitor self-consciously one's own judgments with a view toward questioning, confirming, validating, or correcting either one's reasoning or one's results.

Table 3. Critical thinking dispositions draw from Facione et al. (1995)

Dispositions	Definition
Truth-seeking	Being audacious about asking questions and honest about following inquiry even if the findings do not support our own interests or opinions.
Open-mindedness	"Tolerant of divergent views and sensitive to the possibility of one's own bias." (p. 6)
Analyticity	Value the application of reasoning and use of evidence to solve problems as well as conceptual or practical difficulties.
Systematicity	"Being organized, orderly, focused and diligent in inquiry." (p. 7)
Self-confidence	Trust the integrity of one's own reasoned judgements and predisposition to reach with others a rational solution of problems.
Inquisitiveness	Curiosity and desire for learning even when the application of the knowledge is not promptly evident.
Cognitive maturity	Approach to problems and decision making admitting that some ill-structured situations might have more than one plausible option and some judgements must be made based on context and evidence.

In this thesis, our CT definition is drawn from Facione's (1990) and Facione and Facione et al.'s (1995) framework, agreed on an Erasmus+ European Project (CRITHINKEDU) and refined in our research group (Jiménez-Aleixandre & Puig, in press). It is our understanding that **CT is a set of skills and dispositions** that enable students and people to guide conscious actions based on reasons and values, but also on independent thinking. Following these authors, we consider that CT involves taking into account empirical evidence, thus it can be developed through the practice of argumentation (Kuhn, 2019), but it contains also other components, some cognitive or metacognitive, as self-regulation, some dispositional, as willingness to reconsider and revise views, and affective. Davies and Barnett (2015) propose a model of CT that includes six integrated dimensions: 1) core skills in critical argumentation (reasoning and inference making); 2) critical judgements; 3) CT dispositions and attitudes; 4) critical being and critical actions; 5) societal and ideology critique, and 6) critical creativity or critical openness" (p. 8). According to the authors, this model is aligned with a view of CT that considers both an individual dimension and a sociocultural dimension. We concur with this view, since we see CT as a multidimensional and complex activity that involves the mobilization of skills to make individual actions and/or decisions. As Winch (2006) suggests, CT skills are connected to the ability to form opinions and negotiate a way in the world and are, therefore, closely associated with the idea of autonomy as a central organizing feature of life in contemporary societies. Our view of CT is framed in these two perspectives: considering CT as a dialogic practice and as criticality, comprising attention to identities and to critical action. Critical action presents two facets: 1) critical consciousness, the capacity to analyse and criticize inequalities and discourses that justify them (Fairclough, 1995) and 2) critical participation, which is related to engaging in action. The perspective of CT oriented to action is rising attention nowadays in research on CT in science education, however because this research takes place in early childhood education, we believe some distinctions need to be made.

Children, as well as adults, are exposed to a world full of questionable information and inconsistencies. As early as the age of four and, specially, when children are competent enough to read, they are submerged in a world of advertising, misleading reporting, and social media, which can have a negative impact on their emotions. The sooner they are helped to develop a set of skills and dispositions that help them to approach some of this material with a critical eye the better they will be able to make self-reliant judgements. It is true that CT is a high-level skill, but children have been shown to be competent in it within the limits of their experience (Delamain & Spring, 2021). In this context, education plays a key role and early childhood teachers should bear in mind that children are able to think deeply and critically about problems related with their lived experiences and this degree of thinking does not halt when children walk through the classroom (Davis-Seaver, 2000). It is their mission as educators not to only believe in the children's capabilities but also to adapt the educational experiences and learning environment so children can start to develop these skills. In this thesis, we pay attention to the pre-service teacher's educators given in a medium term, the former will be on the classrooms promoting -or not- CT; an early childhood in-service teacher as well as 25 children since we believe both are highly involved in the learning process and their practices overlap. Specifically, we focus on 1) which learning environment the educators declare to implement in order to promote CT; 2) which questions the in-service teacher pose to foster CT, and 3) how children articulate CT through the engagement in an inquiry-based activity.

Pre-service teachers' educators, being responsible of the teaching of future teachers, have a key role on the CT development on pre-service teachers, which ultimately would have an impact on the children they will teach on the future. Despite literature points the crucial role of the educators in this process (Janssen et al., 2019; Pithers & Soden, 2000), scarce investigations have been carried out about educators' CT skills and dispositions. The limited research available suggests that among higher education teachers there seems to be no consensus on what CT implies (Choy & Cheah, 2009), tending to promote it through an implicit approach, for example, activities based on dialogue (Balleara et al., 2021; Puig et al., 2019). This may be associated with the complex and multifaceted nature of the CT, which leads to different conceptualizations. We agree with Klassen and Tze (2014) that a prerequisite for effective CT teaching should be that teachers should be good critical thinkers and perceive it as relevant to contribute to its development in the classroom. Previous learning experiences as well as professional development opportunities that explicitly focus on teaching CT can influence a teacher's decision on whether or not to incorporate CT into their own classrooms (Howe, 2004).

Educational research trends seem to indicate a growing interest in how CT can be promoted by the specific characteristics of learning environments (Dökmecioğlu et al., 2020; Ennis, 2016). The teaching-learning environment or the social climate of the classroom concerns the relationship between the characteristics of the group of students and the teaching methods used so that, ultimately, they can deepen their learning beyond the levels of reproduction (Fraser et al., 1982; Struyven et al., 2006). According to these authors, the interactions between teachers and students or the structural characteristics of the classroom, among others, could consequently determine their CT skills. We agree with Saçli et al. (2017) that the characteristics of these environments play a relevant role in ensuring effective CT instruction. At the core of learning environments, teaching methods and activities are central themes in empirical CT studies. Diverse investigations have focused on the effects of certain didactic strategies. Torres Merchán and Solbes (2016) or Santika et al.'s (2018) work showed the positive impact of didactic interventions using socio-scientific issues with university students. Yuliati et al. (2018) focused on the use of authentic problems of daily life in higher education students. A common characteristic of these studies is that they focus on students' CT development, leaving aside the figure of the teacher and his/her impact on this process. The investigation of Tenreiro-Vieira and Vieira (2006) address the training of teachers in CT and the impact of the teaching intervention on the students' CT performance. The authors developed a training project in which they involved elementary science teachers to promote the development of CT skills on the students. In a similar vein, Vieira and Tenreiro-Vieira (2014), through an action research methodology, implemented a model (Vieira et al., 2010) for the formulation of questions which is based on the interrelation of components such as scientific knowledge, skills, dispositions, as well as criteria such as rigor, precision or validity. This model showed a positive impact on CT skills development and scientific literacy in primary school students. On a similar venue, Semilarski et al. (2019) as well as Eren and Akinoglu (2013) examined the effect of a problem based (PBL) approach intervention; Fitriani et al. (2020) a combination of PBL with the predict-observe-explain (POE) model; and Hasnunidah et al. (2020) implemented an argument-driven inquiry (ADI) learning model. Ruiz et al. (2013) recommended the use of discussions, and Sinaga and Feranie (2017) reported a development on skills through the use of writing tasks. These works provide data of great interest in the matter; however, argumentation does not constitute a dimension to be analysed. In addition, teachers' need to develop CT in the classroom were identified in the literature. The needs found are: (a) specific teacher training on how to effectively promote and implement CT in the classroom (Dominguez, 2018; Petek & Bedir, 2018), and (b) a framework for its teaching, since it is understood that this would help teachers foster it (Fahim & Eslamdoost, 2014). This thesis aims to contribute by analysing the educators' conceptualization of CT and the learning environments they declare to promote it. Furthermore, we aim to show the role of a kindergarten teacher with a long tradition on teaching science through scientific practices, help students to develop CT.

There are several investigations focused on the teaching of CT, however, there are no conclusive results on what the best conditions for an instruction are to be successful in terms of its development (Tiruneh et al., 2014). Ennis (1989) tried to provide a framework for researchers and educators by presenting four instructional approaches. The *general approach* occurs when skills and dispositions are taught separately from content knowledge, while in the *infusion approach* instruction occurs within the subject combined with explicit teaching of general principles. The *immersion approach* integrates the CT into the subject instruction, but with the assumption that students will acquire the skills once they engage in subject instruction. Finally, the *mixed approach*, proposed by Sternberg (1986), consists of a combination of the general approach with the infusion or immersion approach. Abrami et al. (2008) investigated the effects of different CT instruction methods using the approaches proposed by Ennis (1989) and, in a later work, Abrami et al. (2015), provided a more detailed approach by developing a set of four instructional strategies, which are described in Table 4.

Table 4. Description of critical thinking intervention

Category	Description
Individual Study	This includes instructional techniques and learning activities that are based on students' individual work. Among the activities are reading, active listening, reflecting, and solving problems on the learners' own.
Dialogue	This instructional intervention has its roots in the Socratic method, hence why the didactic strategy used to integrate the dialogue is the discussion. This discussion can adopt multiple forms, such as whole-class debates, within-groups discussions and/or online discussion forums.
Authentic instruction	In this category, students are presented with authentic problems that may or may not be related to daily-life issues that engage them and stimulate them to inquiry. Simulations, role-playing and dilemmas are included as possible methods.

Category	Description
Mentoring	Mentoring is one-on-one interaction between someone with more expertise and someone with less expertise. Tutoring, coaching, apprenticeship, or modelling are examples of mentoring.

Source: Adapted from Abrami *et al.* (2015)

The study by Abrami et al. (2015) revealed that the most effective type of intervention to promote CT skills was a combination of authentic instruction, dialogue, and mentoring. Likewise, these authors, in a previous study (Abrami et al., 2008), affirmed that training actions focused specifically on the teaching of CT helped teachers to achieve more effective pedagogical results. In a similar line, Ennis (2016) proposes two basic teaching methods to promote it: discussion-based teaching (LDT) and problem-based learning (PBL). LDT consists of a talk -usually accompanied by a reading from a textbook- followed by a discussion. Nonetheless, the PBL method requires addressing an issue that generally requires researching, developing, testing and discussing hypotheses or solutions and possible alternatives.

This thesis engages students in the practice of CT during an inquiry-based activity that aims to promote argumentation and inquiry skills. Drawing from Kuhn (2019) CT is considered as a dynamic activity that can be developed through the practice, however as Puig et al. (2021) suggest, its exercise might vary in complexity depending on the topic and the context. For instance, assessing the arguments produced by classmate in peer negotiation may pose less difficulties than assessing information presented by the teacher. Furthermore, CT is usually associated with the other scientific practice addressed in this study, argumentation, since it largely involves the evaluation of statements or knowledge through the analysis of evidence (Giri & Paily, 2020). One of the most recent characterizations of CT in science contributed by Jiménez-Aleixandre and Puig (in press) includes a series of components related, on the one hand, to reasoned judgment, and, on the other hand, with the orientation to action. Although we agree with this vision, we understand that, in the early childhood education stage, CT should be promoted from a dialogic interaction in contexts that promote curiosity, the formulation of questions and the search for answers through experiments, as well as the construction of valid justifications refuting alternatives (Kuhn, 1993; Nussbaum & Sinatra, 2003), as this is the case of the present study. We concur with Giri and Paily (2020) that argumentation should be integrated into the science learning environment to promote CT. Since both, CT and argumentation, require higher order thinking skills, their teaching involve strategies to be practiced by students (Mason, 1996). Nonetheless, early childhood education presents challenges since the belief that students at this stage are not capable of developing abstract thinking or to pose sound arguments, despite the existence of studies that contradict this idea with data (Jiménez-Aleixandre & Erduran, 2015; Zembal-Saul, 2008).

The integration of CT in science instruction at early years can be achieved in diverse manners. We believe that CT can be embedded in inquiry-based learning as a dialogic practice in a way that help students to mobilize diverse CT skills as analyse, explanation evaluation, etc., all along with diverse inquiry and argumentation skills. However, teachers might face some difficulties as the number of students, the number of hours of teaching, the curriculum and their own training and knowledge on CT instruction, among other elements (Puig & Jiménez Aleixandre, in press). According to Vincent-Lacrin (2019), the consideration of CT as a practice that requires time to developed and the acknowledgment that CT can be taught from early years to higher education, might motivate educational institutions and teachers to dedicate more time for their students to cultivate CT.

Research on CT in science instruction in early years is scarce. The existing studies, as far as we have been able to know, tend to focus on the development of certain skills by the students (Corral-Verdugo et al., 1996; Harbi, 2016; León, 2015, among others). Corral-Verdugo et al.'s (1996) work involved 64 5-year-old children in a task that requires discerning between facts and opinions about the crisis caused by the generation of waste. Harbi (2016) incorporated some of the principles of Edgar Morin's educational philosophy in a comic that was used as reading material in a discussion group of children. The results suggested that the use of comics may be a suitable means of developing CT and introducing complex and abstract concepts to children. León (2015) identified the different aspects of CT in five kindergarten classrooms and the strategies used by teachers in the development of this type of thinking in children. The data revealed that the students developed CT skills by promoting curiosity, questioning, discussion and reflection during class time. Other studies such as that of Kuhn (1999) proposed a model for the development of CT addressing metacognition and epistemic knowledge. Finally, other research focuses on examining the impact of programs such as Philosophy for Children (P4C), where CT plays a central role. Daniel et al. (2017) implemented P4C-based activities in 28 classrooms aged 5 to 12 in four different countries. The results showed that these activities promoted the cognitive development of the students, in addition to providing indications of the modes of thought and epistemological perspectives that are involved in the development of the dialogic CT. A common characteristic of these studies is that they focus on the role of the student, not paying attention to the teacher's role and how it influences the learning process. It is the study by Dovigo (2016) the only one, as far as we know, that links argumentation and CT, analysing how argumentation begins to take shape in children through dialogic movements between teachers and children as well as between peers. In this context, we agree with Evagorou et al. (2020) that attention to dialogue and argumentation can also be promoted through inquiry contexts, since both practices share characteristics and overlap in their procedures when implementing them. We concur with the perspective of Dovigo (2016) understanding that to develop CT at an early age it is necessary to analyse the dialogic practice between teachers and students.

2.3. Teachers' guidance in inquiry-based teaching. The role of questioning in the activation of critical thinking and scientific practices

There is a wealth body of research about teachers' guidance in different contexts and approaches such as inquiry-based teaching. Nonetheless, examining the literature, it is not clear under what circumstances the teacher activates more effectively inquiry skills on children. Kirschner et al. (2006) stated inquiry-based learning is less effective than direct instruction as the teacher provides minimal supervisor, whereas Chinn (2007) considered it to be more effective if sufficient and appropriate scaffolding is given. Furtak et al. (2012) conclude from their meta-analysis that teacher-led activities had a greater effect on students' outcomes. Lazonder and Harmsen (2016) investigated the role of guidance in inquiry-based contexts. The findings revealed positive effects of guidance on learning activities, as well as students' performance and learning outcomes. Two conclusions can be draw from the literature: (a) it still remains unclear which teaching strategies might have greater learning outcomes; (b) in many studies the terms "guidance" and "scaffolding" are used indifferently. It is our believe that both notions need some clarification. Scaffolding refers to provide tailored support to students' needs, implying a fading in the responsibility from the teacher to the learner (Fernández-Monteira et al., 2020). Guidance stressed the degree of autonomy given to the students, establishing four levels of inquiry -verification, structured, guided, and open- depending on if the teacher allow them to come up with the research question, collect the data as well as interpret the results by themselves. This work is situated on a guided inquiry given that the teacher presents a structured activity that, on the one hand, allows her to generate her own inquiry cycle and, on the other hand, allows the students to come up with their own ideas and interpretations during its development.

To enact inquiry-based learning successfully, the actions of teachers are crucial in driving the thinking process that, in turn, will bring out meaningful learning. For this, the role of the teacher needs to shift from an information accumulator to an "active designer" (Gormally et al., 2009, p. 16). Crawford (2000) identified how different tasks required the teacher to assume different roles, some of them with a high level of expertise. Among roles can be find motivator, diagnostician, guide, innovator, experimenter, researcher, modeller, mentor, collaborator, learner. However, the implementation of the inquiry-based context does not come without challenges. Schwab (1958) identified four reasons teachers opted for a more traditional approach: (a) it is time-consuming, and content would have to be left uncovered; (b) presenting the students with a wide array of options could potentially create more doubts; (c) pressure from industry for the acquisition of certain skills; (d) they believed it would be too costly. Bevins and Price (2016) and Constantinou et al. (2018) point out as constraints the content-laden curricula, inappropriate assessment procedures for inquiry approaches, lack of resources, lack of knowledge about the amount of guidance, and the tendency to opt for recipe-type activities due to a lack of confidence in their skills or pedagogical content knowledge.

In recent years, scholars and educators have started to name **inquiry-based teaching (IBT)** as a way to bring key features of authentic scientific inquiry into the science classroom, offering the students experiences to develop the understanding of scientific concepts and connect them with everyday life (Constantinou et al., 2018). For the purpose of this study IBT is regarded as a motivational approach of learning science as it focuses on children's interests and prompts active learning by enabling students to conduct their own investigations (Vorholzer & von Aufschnaiter, 2019). This term encompasses the teaching of specific science process skills (teaching *of* inquiry) and the scientific concepts of using inquiry process skills (teaching *through* inquiry). We concur with Furtak et al. (2012) in understanding IBT as part of a continuum of guidance from less to more guidance. Despite the importance of teachers' guidance in inquiry-based teaching, very few studies have focused on teacher strategies to promote inquiry skills in early childhood education. Given this scarcity of literature in what follows, we provide an overview of some studies carried out in the context of elementary education, assuming that given the age proximity, specific insights would be still relevant for this study.

Curran and Kitchin (2019) and Zimmerman (2007) have stated that children at early ages have well developed abilities to engage in scientific reasoning when the activity is adapted to them, and the teacher provide appropriate learning support or scaffolding. Particularly relevant for the purposes of this thesis is the study developed by Jenns and Mills (2009), who followed a single cohort of students from kindergarten to fifth grade with the aim to investigate how teachers and children co-constructed a discourse of inquiry. The authors point to the critical role of the teacher answering students' questions and comments in ways that allowed them to deepen their inquiries as collaborative learners, a key aspect for our study. Another study aligned with the focus of our research, the relationships between teacher talk and children's practices, carried out by Studhalter et al. (2021), points to the importance of language in inquiry-based instruction in early science instruction. The authors conceptualized the role of teacher talk within both a scaffolding and guidance framework, what this study supports. Regarding the type of scaffolding provided by the teachers, Herrenkohl et al. (2011) illustrated teachers' pedagogical practices around the teaching scientific inquiry through a web-based system called Web of Inquiry (WOI). This website scaffolded students as they worked together developing hypothesis, designing experiments, collecting, and analysing data about physical, earth, and life science content. Results pointed out to instructional explanations, dialogues, scaffolding, the used of WOI and peer-dialogue as key practised. In addition, teachers guided students in developing more sophisticated connections between theory, formulating alternative hypothesis, experimental design, and data analysis.

A relevant study was developed by Eshach's (2011), who proposed a range of didactic strategies that early childhood education teachers can consider when implementing an inquiry-based approach, such as using similarities, repeating children's answers, voicing the beginning of terms, providing gesture hints, and questioning.

Questions play a fundamental role in inquiry as it starts with a question (Herranen & Aksela, 2019) and are considered the backbone of classroom investigations (Kawalkar & Vijapurkar, 2013). **Questioning** have even been used to define inquiry as 'question-driven learning', since questions drive the lessons as students gather and interpret data to answer that question, construct an explanation, and communicate the results. Teacher questions should help students to develop different cognitive functions in a classroom discourse. In addition, questioning should help students to solve experimental problems and scaffold the knowledge acquired (Wells, 1993), structuring discursive and analytic attitudes (Crawford, 2000). The role of the teacher in increasing student talk (e.g., Günel et al., 2012; Martin & Hand, 2009), guiding the negotiations (Kawalkar & Vijapurkar, 2013), implementing argumentation (Martin & Hand, 2009) and improving the reasoning skills (Benus et al., 2010) resonates in their pedagogical development (McNeill & Pimentel, 2010; Oliveira, 2010; Pimentel & McNeill, 2013). Teacher questions play a critical importance in initiating various cognitive functions (Aschner, 1961; Carner, 1963) that teachers need to be professional questioners (Gall, 1984). Nonetheless, a set of studies has shown that questioning is a skill that is lacking in classrooms in early childhood (Asay & Orgill, 2010), in favour of collecting data (Forbes et al., 2013). Furthermore, teachers' questioning empirical studies in early childhood are scarce and emphasise children's conceptual understanding (Eshach, 2011) and conceptual change (Smith et al., 1993; Yip, 1998) not stressing the importance of the teacher's role. It is also our understanding that the type of questions posed by the teacher anchor the investigation the children will be undertaking in a lesson, leading them to gather and use data to develop explanations of scientific phenomena. These questions are known as investigation questions and are sometimes referred in the literature as 'driving questions' (Krajcik et al., 1998).

The role of the teacher in early years at these contexts would be based on providing guidance to students and formulating questions that stimulate their thinking (Eshach & Fried, 2005). As mentioned before, we consider questioning to be a powerful tool that helps educators learn about students' ideas, formulate hypotheses, elaborate explanations, evaluate evidence, justify statements, and help children build scientific knowledge (Chin & Osborne, 2008). These are inquiry skills collected in educational documents (NGSS, 2013; NRC, 2012) and noted in the literature (Eshach & Fried, 2005; Metz, 2008), since inquiry involves students in research on natural phenomena through experimental and conceptual explorations, as well as in collaborative discussions to communicate scientific ideas to develop a consensus on the topic under discussion. Therefore, exploring what the teacher does, says, and thinks alongside children's interactions is critical to determining how their participation changes over time, but also to understanding student thinking and participation in scientific practices (Fleer & Robbins, 2003), as well as the strategies that the teacher uses to promote these practices and the development of other skills such as CT.

METHODS

3. METHODOLOGY

This chapter approaches the methodological aspects that guide this study, which are framed within the qualitative research. In this section, different strategies of analysis are described to characterize the state of art in relation to scientific practices and CT in teachers' training plans as well as to explore how both dimensions are integrated in the early childhood classroom.

Firstly, it will be presented the philosophical grounding of the research, specifically looking at the epistemological, ontological, and axiological positions of the researcher, as well as the description of the chosen methodological approach. Secondly, the research context is presented for each unit of analysis. Details for each one will be provided about the (a) context and participants and (b) data collection and analysis. Furthermore, considerations will be given to the research methods and the rationale for the chosen methods, their strengths, and limitations, and how the methods support the trustworthiness of the study. This chapter will end by exploring the ethical considerations that guided the researcher throughout the study.

3.1. Methodological approach

Research has become an integral part of early childhood education as seen through the adopted policies and practices at an international, national, and local level. Research in early science years look to produce new knowledge built from teachers' and children's perceptions, experiences, and practices in order to help both to promote a more effective learning and students to make sense of their learning experience, respectively. This thesis focuses on the analysis of scientific practices as well as CT in the early childhood curriculum, teacher training plans and classroom enactment through a dialogic interaction between the teacher and her students. Thus, the study relies on qualitative research, as we try to establish a complex picture of the phenomenon under study through the collection of multiple sources of data (curricular and official documents, literature, interviews, and non-participatory observation) at the different sites where participants develop their teaching and learning activities with the objective to learn about the meaning that the participants ascribe to their words at the activity at hand (Creswell & Creswell, 2014). Specifically, in the context of this study, this methodology is applied in order to (a) characterize the state of art of scientific practices and CT through the analysis of the curriculum, initial and annual teacher training plans as well as the literature review and the interviews of pre-service teachers' educators; (b) identify teacher's questions that favour the students' enactment in inquiry and argumentation as well as CT practices through the analysis of teacher-students' interactions and (c) students' engagement in scientific practices and CT skills and dispositions. As Merriam (2009) stated, qualitative research deals with the "[…] understanding of meaning that people have constructed, that is, how people make sense of their world and the experiences they have in the world" (p. 13). Qualitative studies, as the one it is being presenting, focus on context, interpretation, subjectivity, representation, and the non-neutrality of the researcher (Denzin & Lincoln, 2005; Schwandt, 2015).

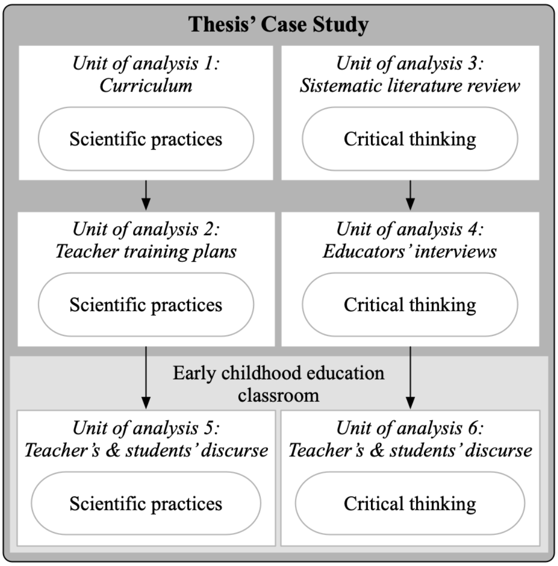
Guba and Lincoln (1994) suggest that the research paradigm should be explored prior to the consideration of research methods as the researcher positioning might define how they view the world and, consequently, shape the nature of the study. The chosen research methodology will be also guided by the research paradigm and philosophical considerations; therefore, it is important for the researcher to make their philosophical position clear (Denscombe, 2010). As a researcher, I position myself in an ***interpretivist paradigm*** as our objective is to understand a specific phenomenon from subjective experiences of individuals. We concur with Denzin and Lincoln (2005, p. 5) that "objective reality can never be captured […] only know through representations" and acknowledge the social and educational reality is not objective but shaped by human experiences and social contexts, being an interaction between the known and the knower (Willis, 2007). In line with the research paradigm and in terms of ***ontological considerations***, we consider necessary to clarify how the researcher views, thinks and feels the world. Her beliefs are grounded within sociocultural theoretical perspectives and the assumption that science learning is a cultural enactment, embedded in our everyday interactions through different agents that help children to develop tools for thinking (Rogoff, 1990; Vygotsky, 1978). These beliefs are also in line with the main objective of the thesis as the researcher is involved in issues that concerns children's science learning in the context of a public primary school. In addition, it is my believe that the ***axiology*** plays an important part in the development of the research. The researcher acknowledges that her own value base has influenced the research topic and how the research is approached. A guiding principle, which influenced the researcher's thinking throughout the study, was the assumption that science learning is embedded in our everyday interactions through different agents that help children to develop skills for future learning. Moreover, as a woman, and an early childhood schoolteacher, the researcher brings to this study her own experiences as well as her own beliefs about education, teaching methods and children's skills, which are mostly aligned with the schoolteacher of this study. Even though the researcher did not teach in a school, thus her practical knowledge is limited, as someone who has experienced the same educational system, did her teacher training and master's Practicum in early childhood classrooms, and is currently researching in this educational stage, she had several opportunities to gain insights about the culture and practices of different classrooms, being able to relate with the participants. To avoid and minimize the bias or the tendency to influence the results, the researcher was constantly aware of her own feelings, opinions and kept open to data and evidence that arose during the analysis process. In addition, the researcher tried to minimize the effect triangulating the data with other researchers as well as meeting biweekly with a group of international PhD students.

Another feature of qualitative research that we would like to reflect about is the ***researcher positionality*** in the study. When undertaking qualitative research, the researcher needs to be mindful of the impact they bring to the context they are investigating as (s)he is directly involved in the process, attempting to access the participants' thoughts, feelings, and reasoning (Sutton & Austin, 2015). Over the past decades, an extensive debate about objectivity and positionality when conducting qualitative research has emerged. Across several disciplines, researchers have reflected on the impact of research-participants relationships on the research process and its outcomes. A debate is still ongoing about whether *insiders* -researchers with similar background and beliefs as the participants- have an advantage in collective qualitative data over *outsiders* (Flores, 2018). Over the years, there has been a shift in how this is viewed and nowadays it is addressed from a more constructivist perspective that recognizes the research-participants relationship moves within a continuum influenced by fluid identities of both, researcher, and participants themselves. Within this thesis the researcher will be seen as an insider when she was in the early childhood classroom and interviewing the teacher educators, and as an outsider when the focus group took place. This dual role has potential benefits and limitations that should be considered. For instance, adopting the role of an insider could make the participants feel more at ease and willing to share their views and experiences. Nonetheless, due to the social desirability, they also might or fail to expand on certain aspects of the topic or feel the need to express opinions that are seen more favourable with the researcher (Corbin-Dwyer & Buckle, 2009). In this regard, as the researcher and her supervisors collected the data gathering views from other colleagues, the researcher has not just an ethical but also a professional responsibility to ensure the data and findings are treated confidentially and represented sensitively. The awareness of such implications enabled the researcher to reflect upon these factors and ensure that she was responsive and reflective about research decisions and her actions, explained in the 3.3 section.

Following on from the consideration of a variety of methodological approaches for this research, a **case study design** was adopted, as it allows us to attain an in-depth knowledge covering contextual conditions that to our understanding might influence the phenomenon under study (Yin, 2009). According to Merriam (1998, p. 13), a case study is "an intensive, holistic description and analysis of a bounded phenomenon such as a program, an institution, a person, a process, or a social unit". Case studies usually imply a detailed and intensive analysis of a particular context-bounded event, situation, or social unit within a real-life context and a defined time frame (Miles et al., 2014). In addition, case studies enable us to collect different kinds of data (e.g., interviews, documents, observations, among others) to provide us an in-depth look at the interactions or that organization or individual. Therefore, it is important to "fence in" (Merriam, 1998, p. 27) what we are going to study, defining the case, as the research questions will reflect its boundaries and definition.

This thesis adopts an embedded single-case design as it considers multiples units of analysis that focus on different aspects of the case (Scholz & Tieje, 2002) enabling a mixture of qualitative research techniques to be incorporated into the overall research designs. It comprises several levels of analysis (units) that allow us to explore the context regarding scientific practices and critical thinking in early education and analyses these dimensions in an early childhood classroom. These units of analysis are: (1) the curriculum, (2) teacher training plans, (3) systematic literature review, (4) interviews with the pre-service teachers' educators, and in the early childhood education classroom, (5) scientific practices and (6) CT skills and dispositions promoted by the teacher and enacted by children, as it is displayed on figure 1. These units of analysis included, as *first-hand data,* non-participatory observation, audio recordings, six individual interviews and one group semi-structured interviews and as *second-hand data,* field notes and pictures. It was felt that gathering data via a mixture of methods helped the collection of a more holistic and richer data set.

Figure 1. Units of analysis in the embedded single-case study



A main strength of the case study research lies within the possibility to experience real-life situations directly in relation with the phenomena as they unfold in practice, providing a detailed description (Flyvbjerg, 2006). In addition, the ability to triangulate data by using a mixture of methods is seen as an advantage (Johnson & Onwuegbuzie, 2004) and can also add to the credibility of a study (Robson, 2011). Nonetheless, some limitations of the methodology need to be addressed. Cohen et al. (2007) and Yin (2009) have questioned that case designs lack rigour and findings cannot be generalised. Stake (1976) have argued that there are two kinds of generalizations, one related to a rationalistic approach and other more intuitive, empirical, based on personal direct and vicarious experience. The author asserts that case studies may not add much to the former but to the latter are considered a powerful means for building them. We concur with this perspective as well as Guenter and Falk's (2019) viewpoint, who concluded that the knowledge derived from small qualitative investigations is as valid and useful as the others since the creation of new knowledge is an iterative process, in which claims of truth are disputed and confirmed based on evidence and theories.

3.2. Research context: contexts, participants, data collection and analysis

In this section we present the context, participants, data collection and analysis process regarding each unit of analysis. Below, in table 5 we present a relationship of the units of analysis and each research objective and research question.

Table 5. Research objective, questions, object of analysis and its unit of analysis

Research objective	Research question	Object of analysis	Unit of analysis
O1. To characterize the state of art of scientific practices and critical thinking	RQ1) How are scientific practices integrated into the early childhood education curriculum? RQ2) How are these practices presented on initial and continuous training plans for pre-service and in-service early childhood teachers?	Early childhood education curriculum; pre-service teacher training and in-service teacher formative plans.	1 and 2
	RQ3) How critical thinking interventions studies in higher education are characterised?	Characterization of critical thinking intervention studies on the literature	3
	RQ4) What notion of critical thinking do pre-service teacher educators have? RQ5) What type of learning environments do pre-service teacher educators declare to implement in their instruction to promote critical thinking?	Identification of CT notion and learning environments declared by pre-service teacher's educators	4

Research objective	Research question	Object of analysis	Unit of analysis
O2. To identify didactic strategies, particularly teacher's questions that favour the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions	RQ6) What is the nature of a teacher's guidance in an inquiry-based learning activity? Specifically, what kinds of driving questions do teachers use to engage children in inquiry? RQ7) How does teachers' driving questions affect students' enactment of inquiry-based skills?	Teacher's questions and their influence on students' engagement on inquiry and argumentation skills	5
O3. To identify critical thinking skills and dispositions in students' discourse in a science context	RQ8) How are the questions posed by the teacher that activate certain critical thinking skills and dispositions by early childhood students? RQ9) What is the relationship between the teacher's questions and the practice of critical thinking by the students?	Teacher's questions and their influence on students' critical thinking skills and dispositions	6

3.2.1. Unit of analysis 1: Early childhood curriculum

The first unit of the analysis refers to the early childhood education curriculum of Galicia (Xunta de Galicia, 2009) in order to *characterize the state of art of scientific practices and critical thinking* and specifically, to answer the first research question:

> RQ1) *How are scientific practices integrated into the early childhood education curriculum?*

The Spanish curriculum set the basic competences, contents, and dimensions that all children should develop, and the provinces have autonomy to add or modify some aspects. In the case of Galicia, both documents are very similar having the same content areas, among other dimensions. The analysed curriculum was downloaded from the official website of Xunta de Galicia, the local government, to be more specific, from the education department. The research familiarized herself with the official document through different cycles of reading. After that, a search on the literature about the scientific practices of inquiry, modelling, and argumentation was conducted to identify the descriptors of said practices. A set of descriptors were identified in the NRC (2012) document as well as on Gilbert and Justi (2016) and Erduran and Jiménez-Aleixandre (2007) studies.

A content analysis was carried out, understanding this analysis strategy as a process of identification, codification, and categorization of the primary patterns on the data (Patton, 2002). We analysed the content of the curriculum of our province (Xunta de Galicia, 2009), focusing on the inquiry, modelling and argumentation practices present in the prescriptive elements. A rubric was built based on the descriptors identified in the literature and in interaction with the data (table 6). The analysis was carried out by two of the authors and contrasted by a third.

Table 6. Inquiry, modelling, and argumentation operations

Scientific practices	Operations
Inquiry	Observe
	Ask questions
	Formulate hypotheses
	Design experiments
	Experiment - Manipulate
	Investigate
	Explore
	Collect data
	Interpret information
Modelling	Explain (natural) phenomena
	Represent entities or phenomena through drawings, models, etc.
	Use of models
Argumentation	Use and identify evidence
	Justify answers
	Draw conclusions

In the analysis of the curriculum, the scientific practices and operations that were part of these were identified in the first place in the prescriptive elements (objectives, contents, and evaluation criteria). This was done for each of the three content areas of the curriculum, which are: 1) self-knowledge and personal autonomy, 2) knowledge of the environment, and 3) languages: communication and representation. The first two areas were subdivided into four blocks, and the last one into three. The second area is linked to all those aspects related to science, namely: i) physical environment: elements, relations, and measurement, ii) approximation to nature, and iii) culture and life in society. Afterwards, the data were classified according to the indicators previously presented, counting the total number, and classifying the operations according to scientific practice and the prescriptive element in which it was found.

3.2.2. Unit of analysis 2: Initial and annual teacher training plans

The second unit of analysis deals with the identification of the scientific practices on the initial and continuous teacher training plans, corresponding to the 1st research objective, to *characterize the state of art of scientific practices and critical thinking,* specifically the second research question:

> *RQ2) How are these practices presented on initial and continuous training plans for pre-service and in-service early childhood teachers?*

Our province, Galicia, has three universities and all of them offer the Early Childhood Teacher Education degree. We analysed the pre-service teacher training plans of the three universities to identify the number of subjects related to science education. Nonetheless, there is not an actual curriculum for the degree, therefore, the researcher explored on the degree website of each university the published syllabus of each subject. Two subjects from each university were identified as related to science education, and content analysis was applied focusing the analysis on three dimensions: 1) number of subjects related to science education, 2) components of the curriculum and 3) explicit mention of scientific practices in the subject program.

The professional development for early childhood in-service teachers is offered through the education department of the Xunta de Galicia.

Specifically, there are several centres such as the Autonomic Centre of Training and Innovation (CAFI in Spanish) and the net of Centres for the Teacher Training (CFR in Spanish) are scattered through the province and offer online as well as face-to-face training activities. In the past, the Xunta de Galicia used to publish a compilation document in which these activities for teachers of all educational levels were specified. The analysis was carried at the end of 2016; however, the annual in-service teacher plan of that year has not been published yet by that time. Therefore, we opted to analyse the document of 2015 (Xunta de Galicia, 2015) in order to identify which science training activities in-service early childhood teachers, have access to.

The was carried out through content analysis and comprised three phases: 1) identification and counting of the number of training actions, 2) identification of the recipients and how many of these actions were aimed at in-service teachers of early childhood education and 3) identification of the competences included in the actions and whether or not there were explicit references to scientific practices.

3.2.3. Unit of analysis 3: Systematic literature review

The third unit of analysis aims to answer the 1st research objective, to *characterize the state of art of scientific practices and critical thinking,* more precisely the third research question:

> *RQ3) How critical thinking interventions studies in higher education are characterised?*

A broader systematic literature review was carried out within the CRITHINKEDU project scope; therefore, the researcher and her supervisors met with other CT experts to discuss and agree on the steps they should be taken in order to stablish a systematic process regarding the search, selection, as well as data extraction. These steps are discussed below, nonetheless, as it is noted on step (c), our study only focus on the articles that belong to the education field.

a) *Database and Keywords identification*: the papers were searched in national and international databases, with content published both in English or in Spanish. The databases used were: Web of Science, SCOPUS, EBSCO, ProQuest, ERIC, JSTOR, RCAAP, ESCI, SCIELO, Index Copernicus, RACO, Dialnet, and Google Scholar. The keywords selected for the search were: critical thinking, higher education, and interventions. Other terms related to these keywords were included and connected with Boolean operators (or, and) to extend, define, and refine the quality of the search. A total of 276 studies were found.
b) *Selection of papers as well as inclusion and exclusion criteria:* the selected papers had to be peer-reviewed articles regarding CT interventions in HE and empirically based research. Book chapters, proceedings and theses were excluded from the initial corpus. Moreover, the studies must present some kind of instructional intervention, which involves either teacher-led classroom instruction or computer-based instruction, or any other some sort of instruction by the teacher or researcher (Tiruneh et al., 2014). This resulted in 27 papers.
c) *Sample refinement*: the 27 papers were carefully read and classified according to their area of knowledge. Given this study deals with pre-service teachers, only studies in the scope of the education field were selected. This resulted in a total of 12 articles, which will be indicated with an asterisk (*) on the bibliographic references section.
d) *Data extraction and analysis*: for the characterization of CT interventions, a rubric was built jointly on the literature on CT interventions (e.g., Abrami et al., 2015; Ennis, 1989, 2016; Facione, 1990) and the data, in discussion with international CT experts. The rubric comprises 7 dimensions described below:

1. *Type of study*. It comprises three methods used for research design and draws by Creswell and Creswell (2014): quantitative, when the study aims to test CT by examining the relationship among variables that can be measured on instruments, allowing

for numeric data to be analysed; qualitative, if the study explores the meaning that participants (individuals or groups) ascribe to CT; and mixed methods, when the study combines elements of qualitative and quantitative approaches for the purposes of breadth and depth of understanding.

2. *Critical thinking aims*. The categories have been drawn from the APA Delphi Report (Facione, 1990) as well as Facione et al. (1995), including skills, dispositions, and a combination of both elements.
3. *Critical thinking approach*. We draw from Ennis' (1989) and Sternberg's (1986) categories of CT instruction that include: the general approach, in which CT is taught separately from the content of an existing subject-matter. The infusion approach attempts to integrate CT instruction into standard subject-matter instruction and makes the general principles of CT explicit to the students. The immersion approach tries to incorporate CT within standard subject-matter instruction, although the general CT principles and procedures are not made explicit to students. Last, the mixed approach, consists of a combination of the general approach with either the infusion or the immersion approach.
4. *Type of interventions*. The categories have been taken from Abrami et al.'s (2015) categorisation of instruction interventions. Self-study includes instructional techniques and learning activities that are based on the students' individual work. Dialogue encompasses learning through discussion. Authentic instruction consists of presenting students with real problems, or problems that engaging and stimulate them to enquire. The category other includes any interventions that do not fit in the previous categories as described by Abrami et al. (2015).
5. *Teaching strategies*. This dimension includes the two teaching methods for fostering CT as described by Ennis (2016): Lecture-discussion teaching (LDT) and Problem-Based Learning (PBL). It should be noted that a combination of both or other strategies could be included in this dimension. Lecture-discussion

teaching consists of a lecture (usually accompanied by some textbook reading) presenting one or various aspects of the subject matter, followed by a discussion section. Problem-Based Learning deals with a subject-matter issue, which usually requires researching, developing, testing, and discussing hypotheses or solutions and possible alternatives.

6. *Teaching materials*. This corresponds to items or activities used in CT interventions and includes four emerging categories from the data analysis.
7. *Reported difficulties*. It includes emerging categories in the intervention studies from the data analysis.

3.2.4. Unit of analysis 4: Pre-service teachers' educators

The fourth unit of analysis refers to the first research objective, to *characterize the state of art of scientific practices and critical thinking,* specifically, the fourth and fifth research question:

RQ4) What notion of critical thinking do pre-service teacher educators have?

RQ5) What type of learning environments do pre-service teacher educators declare to implement in their instruction to promote critical thinking?

The researcher and her supervisors contacted potential participants working in the Faculties of Education (Santiago de Compostela) and Teacher Training (Lugo) from a Galician public university as it is our understanding their importance lies within; they are the ones that are transferring their knowledge to pre-service teachers who in a future will teach children. They were informed about the purpose and the procedure follow for the development of interviews and ask their availability to participate in the study. Five pre-service teachers' educators were selected on the following basis: (a) that they were educators in graduate or postgraduate teacher training courses, (b) that they come from different domains, and (c) that the promotion of CT is explicitly mentioned in the syllabus of their courses. All the teachers who are presented below, boast extensive experience implementing active pedagogies in their own classrooms, and while their research interests differ, they all include CT. Below, we present a more detailed description of the participants:

- *T1* is interested in CT in relation with the Didactics of Social Sciences through a place-based learning approach. He also works closely with other teachers who implement innovative activities in their own classrooms, and as such, he is able to present examples of their activities in the faculty. His research interests include the way in which CT can be linked with the social representations and identities of students as well as with heritage in education.
- *T2* is from the industry, which means that she is able to bring a new perspective to teaching Pedagogy and Training Processes. In the classroom, she implements CT through the concept of democratic classrooms; a system in which everyone has the right to have and express their own voice. Her research interests include tutoring and teaching E-learning, and she is also interested in the ways in which bridges can be created between the university and the workforce.
- *T3* teaches developmental and educational psychology. In the classroom, she uses the Socratic Method to make the ideas and reasoning of students explicit through questioning and discussion. Her research interests include creativity and CT using the SEM model.
- *T4* implements CT in his Sociology lessons from a gender and activism perspective, and his classroom activities encompass a wide range of topics: co-education, gender violence, social change, social and ethnical problems, to name just a few, and the relationship that these topics have with education.
- *T5* also uses place-based learning to teach the Didactics of Social Sciences, specifically history, by visiting places to elicit emotions in his students. He also incorporates CT in the classroom from an activism perspective. His areas of interest include the social and

professional competencies of pre-service teachers, the processes for the identification and appropriation of assets in diverse educational contexts and landscape and heritage.

The data collection sessions took place during 2017 and lasted an average of 40 minutes. The interviewer began by explaining the European project, CRITHINKEDU, before outlining the aims of the interview and the data collection procedure. The questions included aim to explore the learning environment implemented in the educators' classroom to promote CT. Particularly, open-ended questions (see appendix) were included covering these CT dimensions: CT conceptualisation, intent CT aims, overall approach, type of intervention, teaching strategies, learning materials, and assessment. The interviewer was free to decide on the question order and how to verbally express the questions.

For the data analysis process, the rubric developed for the systematic literature review was applied as it comprises the same dimensions, except the CT conceptualization which was analysed according to Facione (1990) and Facione et al. (1995) framework.

3.2.5. Units of analysis 5 & 6: Early childhood education classroom

The fifth and sixth unit of analysis are related to the early childhood classroom and comprises the 2nd research objective, *to identify didactic strategies, particularly teacher's questions that favour the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions*, and 3rd research objective, *to identify critical thinking skills and dispositions in students' discourse in a science context*, respectively. To be more specific, the fifth unit of analysis aims to answer the sixth and seventh research question that deal with teacher's inquiry driving questions and their influence on children's inquiry and argumentation skills enactment.

RQ6) What is the nature of a teacher's guidance in an inquiry-based learning activity? Specifically, what kinds of driving questions do teachers use to engage children in inquiry?

RQ7) How does teachers' driving questions affect students' enactment of inquiry and argumentation skills?

The sixth unit of analysis also deals with teacher's questions and how they influence students' development of CT skills and dispositions. This unit of analysis corresponds with the eighth and ninth research question.

RQ8) How are the questions posed by the teacher that activate certain critical thinking skills and dispositions by early childhood students?

RQ9) What is the relationship between the teacher's questions and the practice of critical thinking by the students?

Given that both unit of analysis share the same context, participants, teaching sequence, and main analytical strategy, all will be presented and discussed in this section.

The context in which the study has been conducted is a primary school in inner Galicia (Spain). The school is considered an urban school, although students from neighbouring villages attend it. Families have a medium socio-cultural level and have known each other and the teacher since they started the schooling at the age of three.

The participants were one class of 25 students aged 5 and 6 years old in the last year of early childhood education and their schoolteacher, Anne (pseudonym). She was purposefully selected based on her long-term experience in teaching and designing science activities, along with her previous collaboration with our research group. Anne had over 30 years of professional experience in teaching science in early years. Nonetheless, her teaching practices evolved over the years. Noticing a lack of engagement in children and how she was always repeating the same materials each year, she decided to shift her practice to be more student-centred, finding in inquiry-based teaching the perfect ally. This change was gradual; by attending diverse professional development courses, participating in pedagogical renewal movements, and talking with other teachers, among other actions, she started to build her teaching practice. At a moment in time, she met other five early childhood teachers and decided to constitute a professional group named Torque. They started to look for more innovative approaches in early childhood and found in science inquiry-based projects a really good way to engage children. They hold biweekly meetings during each school year to decide the topic of their yearly science project as well as to discuss how it progress on their respective classrooms. The themes they approach were diverse, ranging from animals (e.g., chickens) to physical phenomena (clouds, lights, and shadows). This professional group has been awarded for their innovative work in diverse schools in our region.

The teacher and her colleagues were in charge of the *design of the teaching sequence*. During the first trimester, they looked up information, resources, activities, and resources to implement it on their classrooms as well as looked for collaboration with experts on the subject. Among these experts a physicist that is also part of the research group can be found. The researcher met previously with the group to discuss the implementation of the teaching sequence as well as the role the researcher would adopt. The activity analysed in this thesis was the first one "an approximation of gravity and air friction" in a larger inquiry-based learning unit comprised by 10 sessions of 30 - 45 minutes in which students were engaged in various activities for the purpose of examining the forces (see table 7). As displayed on the table 7, the activity deals with an approximation to the concept of gravity and air friction.

Table 7. Inquiry-based unit about forces

Inquiry-based activity	Topic
1	An approximation of gravity and air friction
2	An introduction to forces
3	Vectors as a way to represent the forces
4	Floatation
5	Archimedes' principle
6	Review on Archimedes' principle with an emphasis on form
7	Review on floatation with an emphasis on weight
8	How salinity affects floatation
9	Cartesian diver task (Archimedes' and Pascal's principle)
10	Submarines

The children were seated in a circle and Anne was in the middle with the objects that were going to be tested: paper sheet, book, leaf, balloon, stone, feather, rubber, and cotton (see figure 2). Anne introduced them briefly to the students and asked them if they knew what the activity might be about. Subsequently, the driving question was introduced: 'What would happen if each object was dropped?' Every object was introduced again and prompted by teacher's questioning; children hypothesised and provided justifications while trying to answer it. One or two children, in representation of the classroom, went to the centre to test their hypothesis, and collect data during this process. Anne highlighted children's participation in practices as inquiry and argumentation and guided them. At the end, children drew conclusions about the phenomena they were exploring.

Figure 2. Some of the objects used for the experiments and children testing them

The data collection took place during the regular 2016 – 2017 course between April and June. The researcher, who attended all the sessions on a weekly basis, played the role of a non-participating observer in order to ensure she did not influence the children's behaviour during the development of the activity. Nonetheless, it should be highlighted this bias was minimized since they already know her from the previous year. Three instruments were chosen for data collection and triangulation: 1) audio recordings, 2) researcher's field notes and 3) pictures.

1. *Audio recordings*: Their purpose was to capture the participants' discourse and their interaction between themselves while engaging in the task. A total of ten sessions were recorded. Before the beginning of each session, the researcher set up two hidden audio recorders in different places to assure that everything they say would be recorded. We concur that video images would add to the investigation, however, due to privacy issues, we were only allowed to record the audio. The literal transcription of the interactions is produced for subsequent analysis.
2. *Field notes*. The researcher was in charge of collecting field notes for each session. These notes included the distribution of the material as well as the children, comments on the progress made by

them in different tasks, identification of some of the children in certain moments of the activity (who said what), notes written by the teacher on the blackboard, as well as difficulties observed during the implementation of the activity.

3. *Pictures*: They were taken during the development of the activity as well as of some children's productions after the activity.

Data analysis in qualitative studies means to bring meaning to a set of data from different materials (Anfara et al., 2002). As a researcher, it was expected to deal with multiple units for which *discourse analysis* was applied to answer the second and third research objective. As a strategy, it has a long history in educational research. Different authors have proposed diverse approaches such as Gee and Handford (2012), who suggested that discourse analysis can be approached based on a linguistic analysis or through a critical approach. This thesis draws from Gee's (1999) work, the definition of discourse analysis as a strategy that not only allowed us to understand and analyse the language, but also how it "is integrated in other elements that go into social practices" (p. 9-10). We focus on how children engage in the scientific practice of inquiry and argumentation as well as CT through a dialogic interaction as them and their teacher co-constructed content knowledge about air friction and gravity in and through talk. It is our understanding that in the analysed classroom the focus is on true dialogue as the teacher's questions constitutes a prominent feature of classroom talk (Lemke, 1990).

In this context, the analytical process was carried out through open-coding techniques allowing to emerge categories (Mills et al., 2010). An iterative process begun working back and forth between the raw data, existing literature, codes, themes, and visual data display. The categories in this thesis were elaborated by the researcher from existing literature, adapted to data, and refined. Drawing together the inductive-deductive and thematic data is the first step for the reflection and writing cycle. Data were analysed by the author of the thesis and further refined through group discussions with the supervisors until an agreement was reached. As the findings were written up, analysis continues with reflection on the results, coming back to the analysis, writing up some of the findings, reflecting back to the results, and so on. This process was executed multiple times to deepen the analysis. Nonetheless, as the second and third objective have particularities, they will be presented and discussed on the next subsections.

3.2.5.1. Teachers' questions and inquiry and argumentation skills enacted by early childhood students

The analytical process that the fifth unit of analysis had followed, to explore the students' and teacher interventions through their discourse, consisted of a set of steps summarised on the next paragraph.

First, the researcher organised the data corpus and familiarised herself with it. After that, it was decided the audio was going to be transcribed to answer the research objectives. The researcher came back to the listening-transcription process time and time again, given that qualitative research advances and questions changed (Moore & Llompart, 2017). The data was transcript as literally as possible, respecting the participants' first language (Galician, Spanish) and expressions used.

For analytical purposes, the unit of analysis defined was the utterances. This comprised each intervention of the participants in which different statements, questions or skills were reflected in it. After several readings and getting a comprehensive idea, turns can be compiled into episodes. Some episodes might be made up of several turns related to the same discussed issue or the same skill developed (Gee, 2015). In this unit of analysis, the episodes were defined by the object students tested. A total of 13 episodes were identified.

Two different coding frameworks were developed to code the utterances to address the two research questions, respectively: teacher's questions posed to engage children (RQ6) and how teacher's questioning influence children's engagement in the practices of inquiry and argumentation (RQ7).

For the RQ6, 100 utterances were identified in Anne's discourse, distributed unevenly in the episodes. The analysis focussed on the type of questions posed by the teacher during the activity. It needs to be highlighted that in the same utterance, more than one question can show;

therefore, different categories and a greater number of questions than utterances can appear. The analysis on teacher's questions followed an inductive and iterative process, in which categories emerged in interaction with data and literature review (Mills et al., 2010). The coding scheme comprised the inquiry and argumentation questions that emerged from teacher's discourse. After interpreting individually, the type of questions formulated by the teacher, results were further refined and finalised through group discussions among the authors and in collaboration with Prof. Lucy Avraamidou.

Regarding the RQ7, 104 utterances were identified in children's discourse, distributed unevenly in 13 episodes. To identify the different kinds and patterns of interaction in classroom talk, we traced the question asked by Anne, the responses they prompted on the children, and how she followed-up on them. For the analysis, we first identified the inquiry and argumentation skills enacted by students, in correspondence to the same categories defined for teacher's questions; and then, we compared in each episode the number and type of questions posed by the teacher with the number and variety of skills enacted by the students.

3.2.5.2. Teachers' questions and critical thinking skills and dispositions developed by children

The analytical process that the sixth unit of analysis also comprised the students' and teacher interventions through their discourse, therefore, the transcription process followed was the same as the described in the 3.2.5.1. subsection. Furthermore, both units of analysis share the utterances as analytical unit as well as the same criteria and number for the definition of episodes.

An analytical framework for the coding of the utterances was developed based on the CT skills (Facione, 1990) and dispositions (Facione et al., 1995) theoretical framework (see section 2 of the chapter 2) to address the two research questions, respectively: the teacher's questions posed to the students (RQ8) and the relationship between said questions and the CT skills and dispositions developed by the children (RQ9).

For the RQ8, 99 utterances were identified in the teacher's discourse, unevenly distributed in the 13 episodes. The analysis focused on the questions posed by the teacher during the activity. It should be noted that more than one question can be shown in the same utterance; thus, different CT skills and dispositions may appear. The analysis of the teacher's questions followed an inductive and iterative process, in which the categories emerged in interaction with the data and the literature review (Mills et al., 2010). After individually interpreting the type of questions asked, the results were refined and finalized through group discussions among the authors.

Regarding the RQ9, 101 utterances were identified in the children's discourse, unevenly distributed in the episodes. For the analysis, we first identified the skills and dispositions expressed by the students, and then we examined the relationship between the number and type of questions posed by the teacher and the number and variety of skills and dispositions enacted by the students.

3.3. Ethical considerations

Empirical research involves interfering in educational settings that otherwise would be engaging in teaching or learning. Therefore, the researcher should ask herself whether it is or not culturally and ethically acceptable to meddle in the everyday lives of educators and their students. Educational research entails finding out what we do not know and is dependent on a clear question, purpose, and methodology. Ethical rigor, then, demands that it seeks the trust and integrity on the researched and the education community (Clarke, 2006; Limes-Taylor Henderson & Esposito, 2017). This thesis involves analysing data obtained from official documents, interviews with higher education teachers, and an early childhood classroom's recording, therefore it follows three main ethical principles: 1) research should be for the benefit of the society, and no risk should be done to the individuals participating; 2) participants should be treated with respect; and 3) procedures should not exploit participants and should be just (Mertens, 2014). The researchers involved are obligated to consider the beliefs, values, and ethical principles that guide their research. In addition, a number of ethical considerations were taken into account to ensure the integrity of the participants:

- *Written consent*. The in-service teacher was informed of the objectives of this study and was asked to participate so to safeguard the voluntary participation. Afterwards, the families were given a written consent form, providing information about the purpose of the research and the use of data, and their authorization was requested for the participation of the students, as all were minors. This consent allowed for the participants to be recorded on audio and got taken pictures. These materials will be used guaranteeing anonymity; therefore, the images will always be edited to prevent the identification of the children. The pre-service teachers' educators were also informed through a written authorization about the purpose of the study, the use of data, as well as their authorization.
- *Anonymity and confidentiality*. In this study, the in-service teacher as well as the children were identified with pseudonyms, respecting the sex of the student. Pre-service teachers' educators were identified as "teachers (T)". No references to the school centre or universities were made in order to ensure the privacy.

FINDINGS

RESULTADOS

Os resultados da tese abórdanse en 4 capítulos. Nos capítulos cuarto e quinto discútense os resultados referentes ao primeiro obxectivo de investigación relacionado coas prácticas científicas e o PC, respectivamente. Dunha banda, o cuarto capítulo aborda os resultados da análise de prácticas científicas no currículo de infantil, así como nos plans de formación inicial e permanente do profesorado desta etapa educativa. Doutra banda, no quinto capítulo, preséntase unha análise das e intervencións de PC en educación superior co fin de identificar como se promove o PC para, *a posteriori*, comparalos coa noción de PC e os ambientes de aprendizaxe que o promoven declarados polos/as formadores/as de mestres/as de infantil.

Unha vez realizada a diagnose inicial das prácticas científicas e de PC en educación infantil, dáse resposta ao segundo e terceiro obxectivos de investigación. Para iso analízanse as interaccións dialóxicas entre a mestra e os/as nenos/as durante o desenvolvemento dunha actividade sobre a fricción do aire e a gravidade na caída dos obxectos. En concreto, para abordar o segundo obxectivo, examínase o rol da mestra e como este inflúe no desempeños prácticas de indagación e argumentación por parte do alumnado. Mentres que no sétimo capítulo, discútense os resultados do terceiro obxectivo examinando o rol da mestra e a súa influencia no desenvolvemento de destrezas e disposicións de PC por parte do alumnado de infantil.

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4. A INTEGRACIÓN DAS PRÁCTICAS CIENTÍFICAS NO CURRÍCULO DE EDUCACIÓN INFANTIL E NOS PLANS DE FORMACIÓN DOCENTE

Neste capítulo preséntanse os resultados relativos ás dúas primeiras preguntas de investigación do primeiro obxectivo, *caracterizar o estado da cuestión das prácticas científicas e do pensamento crítico*, as cales son:

RQ1) *Como se integran as prácticas científicas no currículo de educación infantil?*

RQ2) *Como se presentan ditas prácticas nos plans de formación inicial e permanente do profesorado de infantil?*

Con estas preguntas pretendemos diagnosticar a integración das prácticas científicas no currículo de infantil (Xunta de Galicia, 2009), así como nos plans de formación inicial e permanente do profesorado desta etapa educativa. Para iso identificáronse, en primeiro lugar, as prácticas científicas nos elementos prescritivos (obxectivos, competencias básicas, contidos, criterios de avaliación e métodos pedagóxicos) das tres áreas de coñecemento do currículo, empregando a rúbrica presentada na táboa X (presentada no apartado 3.2.1. da metodoloxía). En segundo lugar, analízanse os plans de formación inicial do sistema universitario de Galicia, prestando atención a tres dimensións: 1) número de materias relacionadas coa ciencia e a súa didáctica, 2) compoñentes do currículo, e 3) mención explícita ás prácticas científicas no programa da materia. En terceiro e último lugar, examinouse o Plan Anual de Formación Permanente 2015-2016 (Xunta de Galicia, 2015) a tres niveis: 1) identificación e reconto do número de accións formativas, 2) identificación dos destinatarios/as e cantas destas accións destínanse a mestres/as de educación infantil, e 3) identificación das competencias nas accións e se existen referencias explícitas ás prácticas científicas.

Desta análise xorden os resultados que se presentan a continuación en dous apartados, cada un relacionado cunha pregunta de investigación. Os resultados deste capítulo ? están parcialmente desenvolvidos en Bargiela et al. (2018).

4.1. Resultados: As prácticas científicas no currículo da educación infantil de Galicia

Os resultados da análise das prácticas científicas no currículo de educación infantil resúmese na táboa 8, que amosa o número de operacións relacionadas con cada unha das tres prácticas científicas presentes nos elementos prescritivos do documento analizado. Hai que sinalar que algúns epígrafes incluídos nos elementos prescritivos do currículo poden presentar máis dunha operación, de tal maneira que poden incluír destrezas de indagación e de argumentación ao mesmo tempo.

Táboa 8. Prácticas científicas no currículo de educación infantil

Prácticas científicas	Total	Operacións	Desglose (nº de operación)	O	C	C. A.
Observación	31	Observar	8	2	2	4
		Formular preguntas	3	0	0	3
		Emitir hipóteses	3	1	1	1
		Deseñar experimentos	0	0	0	0
		Experimentar/manipular	8	1	3	4
		Investigar	3	1	1	1
		Explorar	3	1	1	1
		Recoller datos	3	0	1	2
		Interpretar información	0	0	0	0
Modelización	11	Explicar fenómenos (naturais)	6	1	2	3
		Representar entidades ou fenómenos mediante debuxos, maquetas, etc.	5	0	2	3
		Usar modelos	0	0	0	0
Argumentación	6	Usar e identificar probas	5	1	2	2
		Xustificar respostas ou enunciados	0	0	0	0
		Extraer conclusións	1	0	0	1

O: obxectivos; C: contidos; C. A.: criterios de avaliación.

Malia que as tres prácticas científicas aparecen recollidas no currículo desta etapa, hai que sinalar que non se distribúen de maneira homoxénea. Tal e como amosa a táboa 8, a indagación predomina sobre a modelización e a argumentación, destacando as operacións de *observación* e de *experimentación/manipulación*. A *observación* aparece con maior frecuencia dentro dos criterios de avaliación. Un exemplo representativo sería o que segue: "A observación lévao a formular interrogantes e a buscar explicacións" (Xunta de Galicia, 2009, p. 135). Esta operación aparece estreitamente vinculada co contido dos seres vivos (características, comportamentos e funcións vitais) e os fenómenos ou elementos do medio natural do segundo bloque de contidos, achegamento á natureza.

A operación de *experimenta/manipular* tamén está presente de xeito notable nos criterios de avaliación, con exemplos como: "Experimenta con obxectos e materiais para obter información e observar as reaccións" (Xunta de Galicia, 2009, p. 129). Esta operación relaciónase con contidos do currículo vinculados coas propiedades dos obxectos.

A modelización é a segunda práctica máis frecuente no currículo. As operacións máis numerosas son as relacionadas con *explicar fenómenos* (naturais) e *representar entidades ou fenómenos mediante debuxos, maquetas*, etc. É nos criterios de avaliación onde se mencionan maior número de operacións de modelización. Por unha banda, *a explicación de fenómenos* (naturais) aparece plasmada deste modo: "Sabe diferenciar e describir consecuencias de fenómenos atmosféricos habituais (sol, choiva, xeo...)" (Xunta de Galicia, 2009, p. 135). Doutra banda, a operación relacionada coas representacións dos modelos, recóllense da seguinte forma: "Representar con debuxos o observado ou experimentado." (Xunta de Galicia, 2009, p. 136). Así mesmo, cabe destacar que o uso de modelos non se contempla a nivel curricular nesta etapa educativa.

A argumentación é a práctica científica menos frecuente, destacando a operación de *usar e identificar probas*. Esta aparece recollida en todos os elementos prescritivos, cunha maior presencia nos contidos e criterios de avaliación. Recóllese, por exemplo, nun dos criterios de avaliación: "Identificar e nomear algún dos seus compoñentes [do medio natural], establecendo relacións sinxelas de interdependencia" (Xunta de Galicia, 2009, p. 135).

Inclúense, ademais, oito competencias básicas das que cabe destacar a *competencia no coñecemento e na interacción co mundo físico*, que fai referencia á "habilidade para interactuar co mundo físico, de modo que facilite a comprensión de sucesos, a predición de consecuencias, así como o coidado do medio ambiente e a proteción da saúde individual e colectiva" (Xunta de Galicia, 2009, p. 188). Nesta competencia, exponse ademais, a necesidade de iniciar ao alumnado no pensamento científico e crítico, potenciando habilidades de investigación que, na súa meirande parte, coinciden coas recollidas neste estudo baixo as operacións de indagación ("... formular hipóteses, observación, formular interrogantes, verificar...", p. 189) e argumentación ("... recoñecer probas...", p. 189). Unha das estratexias didácticas que se propón a nivel curricular en educación infantil é a formulación de interrogantes de temática social, para cuxa resolución o alumnado debe planificar a súa acción, prever os posibles resultados, buscar información, valorar a pertinencia das solucións propostas, desenvolver procedementos de intervención e estimar as posibles consecuencias. Estas operacións atópanse estreitamente relacionadas coas incluídas nas prácticas científicas, salientando a necesidade de traballar as temáticas científicas e/ou socio-científicas desde idades temperás, ademais do carácter globalizador da educación infantil.

4.2. As prácticas científicas nos plans de formación docente

Os resultados da análise dos plans de formación inicial do profesorado de infantil na nosa comunidade autónoma resúmese na táboa 9.

Táboa 9. Prácticas científicas nos plans de formación inicial das universidades galegas

Universidade	Nº de materias	Elementos prescritivos	Mención explícita ás prácticas científicas
A	2	Competencia específica (E.36)	Tema 4: A ensinanza-aprendizaxe das ciencias da natureza na educación infantil
B	2	Non se menciona	Avaliación – proba mixta
C	2	Competencia específica (E.36)	Non se menciona

O Grao de Mestre/a de Educación Infantil na universidade A consta de 240 ECTS, dos cales 111 son de carácter obrigatorio (OB), 102 de formación básica (FB) e 27 optativos (OP). No seu plan de formación contempla dúas materias relacionadas coa ciencia e a súa didáctica: "Aprendizaxe das ciencias da natureza" e "Educación ambiental e a súa didáctica". A primeira é de 6 ECTS de carácter obrigatorio e sitúase no cuarto curso do grao. Así mesmo, na competencia específica (E.36) menciónase unha operación de indagación: "Coñecer a metodoloxía científica e promover o pensamento científico e a experimentación". Recóllese a mención explícita ás prácticas científicas no programa, concretamente no tema 4: "4.4. Aprender a investigar. As explicacións e os modelos teóricos". A segunda materia, "Educación ambiental e a súa didáctica" (4,5 ECTS), tamén se imparte no último curso do grao, se ben non as prácticas científicas non se mencionan dun xeito explícito no seu programa.

O grao na Universidade B conta cun total de 240 ECTS, distribuídos en 102 de carácter obrigatorio, 102 de formación básica e 36 optativos. No segundo curso ofertan a materia de carácter obrigatorio "Ensinanza das ciencias da natureza" (6 ECTS) e no último curso "Didáctica da educación ambiental e para a sustentabilidade", de 4,5 ECTS e carácter optativo. Atopamos unha mención explícita ás prácticas científicas na avaliación da materia "Ensinanza das ciencias da natureza": "Realizarase ao finalizar o cuadrimestre e ten por obxecto avaliar [...] e a súa capacidade para resolver cuestións, analizar situacións concretas, argumentar fundamentada e criticamente". Na materia relacionada coa educación ambiental, as prácticas científicas non se atopan presentes nos documentos normativos analizados.

Na outra universidade, a C, o número total de ECTS son 240, dos que 120 son de carácter obrigatorio, 102 de formación básica e 18 optativos. A materia "Aprendizaxe das ciencias da natureza" (OB) impártese no segundo curso e "Coñecemento do medio natura" (OP), de 6 ECTS cada unha. A competencia específica (E.36), xa mencionada con anterioridade, é a única referencia nos compoñentes do currículo sobre as prácticas científicas na materia de "Aprendizaxe das ciencias da natureza". Na optativa, ao igual que nos casos anteriores, as prácticas científicas non aparecen explicitadas no programa da materia. Respecto á formación permanente dos/as docentes de educación infantil, na táboa X recóllense as accións formativas do plan de formación anual permanente 2015-2016 relacionadas coa ciencia, as competencias que nestas se traballan e os seus destinatarios/as. Estas accións son optativas, é dicir, os/as docentes non están obrigados/as a cursalas, nin tampouco se desenvolven nos propios centros escolares. Cabe sinalar que existe duplicidade de ditas accións por impartirse tanto no Centro Autónomo de Formación e Innovación (CAFI) como nos diversos Centros de Formación e Recursos (CFR) do territorio galego, polo que só se mencionan unha vez.

Táboa 10. Actividades de formación permanente no Plan Anual de Formación do Profesorado 2015-2016 (Xunta de Galicia, 2015)

Acción formativa	Competencias	Destinario(s)
Traballando o currículo no ámbito matemático, científico e tecnolóxico	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Programación, seguimento e avaliación. 3. Especialista na súa materia 4. Coñecemento nas áreas, materias e módulos curriculares	Profesorado de ciencias de secundaria
A xestión e tratamento dos residuos urbanos no modelo Sogama	1. Centros saudables e seguridade integral 2. Xestión e promoción de valores e convivencia 3. Compromiso persoal e ético	Catedráticos de ensinanza secundaria Profesorado de ciencias de secundaria
Ciencia e indagación na aula	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Didácticas específicas 3. Metodoloxías e TAC 4. Especialista na súa materia 5. Coñecemento nas áreas, materias e módulos curriculares	Profesorado de ciencias de secundaria
A xestión e tratamento dos residuos urbanos no modelo Sogama	1. Centros saudables e seguridade integral 2. Xestión e promoción de valores e convivencia 3. Compromiso persoal e ético	Mestres/as de educación infantil e primaria
Emprego de Moodle no ámbito científico-matemático-tecnolóxico	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Didácticas específicas 3. Metodoloxías e TAC 4. Competente en TIC – Software	Profesorado de ciencias de secundaria

Acción formativa	Competencias	Destinario(s)
Emprego de dispositivos móbiles na realización de proxectos científicos	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Didácticas específicas 3. Metodoloxías e TAC 4. Competente en TIC – Software	Profesorado de ciencias de secundaria
Ensinar e aprender ciencias no MUNCYT	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Didácticas específicas 3. Metodoloxías e TAC 4. Especialista na súa materia 5. Coñecemento nas áreas, materias e módulos curriculares	Profesorado de ciencias de secundaria
Actividades experimentais nas materias do ámbito científico	1. Educador/a guía no proceso ensinanza-aprendizaxe 2. Programación, seguimento e avaliación. 3. Especialista na súa materia 4. Coñecemento nas áreas, materias e módulos curriculares	Catedráticos de ensinanza secundaria Profesorado de ciencias de secundaria

O Plan Anual de Formación do Profesorado 2015-2016 (Xunta de Galicia, 2015) contén 226 accións formativas, sen considerar outras modalidades de formación como os grupos de traballo, os seminarios de formación e as convocatorias para o Programa Erasmus+. O número de accións formativas vinculadas á ciencia e/ou a súa didáctica é de 13, das que dúas se relacionan co uso das tecnoloxías da información e comunicación (TIC) aplicadas ao campo científico-educativo. As competencias que se indican na táboa 10 son as recollidas no documento analizado para cada acción formativa, malia que neste non se proporciona unha definición de que entenden por cada unha destas competencias. Cómpre destacar pola súa elevada presencia as seguintes: *i*) educador/a guía no proceso de ensinanza-aprendizaxe; *ii*) programación, seguimento, avaliación; *iii*) especialista na súa materia, e *iv*) coñecemento nas áreas, materias e módulos curriculares. Respecto aos/ás destinatarios/as das actividades, cabe sinalar que só 1 das 226 actividades, a denominada “A xestión e tratamento dos residuos urbanos no modelo Sogama”, está dirixida a mestres/as de educación infantil. O resto de accións están dirixidas a profesorado de ciencias de secundaria, así como a catedráticos/

as. En ningún caso existen referencias explícitas ás prácticas científicas dentro das competencias a traballar.

4.3. Discusión e conclusións parciais

Tras os resultados comentados, puidemos comprobar que a práctica de indagación é a que aparece con maior frecuencia, seguida da de modelización e a de argumentación. O feito de que a indagación sexa a práctica científica que cobra máis importancia no currículo é coherente co sinalado por Metz (2004, 2008), que entende a indagación como un contexto e/ou potenciador para que o alumnado de infantil e primaria se inicie no traballo científico e, deste xeito, sexa quen de desenvolver coñecementos científicos.

Investigacións sobre prácticas científicas en infantil poñen de manifesto que o alumnado desta etapa é capaz de participar en procesos de indagación como os que implican os experimentos do grupo Torque (Monteira & Jiménez-Aleixandre, 2016). Estes experimentos involucran ao alumnado en prácticas de modelización como a representación mediante debuxos de obxectos ou fenómenos observados ou experimentados. A modelización, entendida deste xeito, aparece recollida no currículo nos bloques 1) Medio físico: elementos, relacións e medidas, e 2) Achegamento á natureza. Os debuxos cobran especial interese nesta etapa como vía que facilita a expresión de ideas científicas, axudando aos/ás nenos/as a achegarse a unha realidade pouco familiar para eles/as. A representación de entidades ou fenómenos mediante debuxos debería practicarse cunha finalidade, tratando de afastarse de aspectos procedimentais e actitudinais con comentarios como "que debuxo tan bonito" e que, a miúdo, son os máis frecuentes (Pujol, 2003). Brooks (2009) suxire que o profesorado empregue este medio de representación como parte do proceso de aprendizaxe, animando ao alumnado a que revise, descontextualice y refaga os seus debuxos, xa que isto axudará a que reflexione e, en última instancia, acade habilidades de pensamento de orde superior. A práctica científica con menor presencia no currículo foi a argumentación, especificamente a operación de identificar e usar probas. Isto está en liña coa falta de investigación de práctica de argumentación en idades temperás e contrasta coa proposta de Kuhn (2015) dun currículo de pensamento no que a argumentación é unha competencia independente para os/as estudantes, o que debería ofrecerlles a oportunidade de expor afirmacións, xustificalas, avaliar probas e reflexionar sobre a súa relevancia de acordo co tema que estean a investigar.

A aprendizaxe mediante prácticas científicas pode resultar pouco significativa se non se ten en consideración ao profesorado e, en consecuencia, a súa formación. Este foi o motivo polo que abordamos nesta tese a análise dos plans de formación inicial e permanente do profesorado. A análise destes plans amosa que as prácticas científicas apenas se integran dentro dos plans formativos das tres universidades públicas de nosa comunidade. Malia que este análise limítase ao marco curricular de Galicia e aos programas formativos das nosas universidades, podemos concluír que este marco non impulsa a aprendizaxe de ciencias mediante prácticas científicas. Ata onde puidemos saber, na revisión de literatura, encontramos que son escasos os estudos que abordan a identificación de necesidades formativas prioritarias nos plans de formación inicial nos graos de infantil. Esta cuestión foi sinalada por Cantó Doménech et al. (2016) nun estudo previo que destaca a necesidade de revisar os plans de formación inicial de acordo ás dificultades atopadas para a posterior transferencia á aula. Nunha liña semellante, a análise do Plan Anual de Formación do Profesorado 2015-2016 (Xunta de Galicia, 2015) levada a cabo neste estudo amosa que só unha acción formativa dirixida ao profesorado de infantil é de contido científico. Isto pon de manifesto a falta de formación do profesorado en activo en prácticas científicas.

5. CRITICAL THINKING: FROM THE LITERATURE TO THE CLASSROOMS

This chapter focuses on the second part of the first research objective, *to characterize the state of art of scientific practices and critical thinking*, regarding the state of art of CT practices. Particularly, in this results' section the research questions addressed are:

RQ3) How critical thinking interventions studies in higher education are characterised?

RQ4) How do pre-service teacher educators conceptualize critical thinking?

RQ5) What type of learning environments do pre-service teacher educators declare to implement in their instruction to promote critical thinking?

To answer the RQ3, as it was mentioned in the methods section, a literature review was carried out in order to identify and retrieve empirical data on CT interventions. The papers were searched in national and international databases (e.g., WoS, Scopus, Scielo) with content published both in English or in Spanish. The selected papers had to be (a) peer-reviewed articles regarding CT interventions in higher education and empirically based research as well as (b) present some kind of instructional intervention. The examination of RQ4 and RQ5 consisted of an analysis of semi-structured interviews to five pre-service teachers' educators (T), which aimed to explore their CT conceptualization and the type of CT learning environment that they implemented on their own classrooms. For the characterisation of RQ3 and RQ5, the CT interventions and the learning environments, a rubric was built jointly on the literature on CT interventions (e.g., Abrami et al., 2015; Ennis, 1989, 2016; Facione, 1990) and the data, in discussion with international CT experts. The rubric comprises 7 dimensions (type of study, CT aims, CT approach, type of interventions, teaching strategies, teaching materials, reported difficulties), previously described in section 3.2.3.

The findings related to the RQ3 presented in the next section have been partially published on Dominguez (2018).

5.1. Critical thinking interventions in higher education

After the selection of papers from the literature review, twelve studies, from the field of education, met the stablished criteria and were analysed. In table 11, we present a characterization of these studies.

Table 11. Characterization of critical thinking interventions (adapted from Dominguez, 2018)

Dimensions		Studies
Type of study	Quantitative	5
	Qualitative	4
	Mixed methods	3
CT aims	Skills	5
	Dispositions	0
	Skills and dispositions	4
	Not specified	3

Dimensions		Studies
CT approach	Immersion	9
	Infusion	3
	General	0
	Mixed	0
Type of interven-tion	Self-study	8
	Dialogue	5
	Authentic instructions	1
	Mentoring	0
Teaching strategies	LDT	4
	PBL	2
	LDT + PBL	3
	Not defined	1
	Others	2
Teaching materials	Texts (articles, essays…)	4
	E-learning activities	3
	Authentic problems	1
	Not specified	7
Reported difficulties		0

Almost half of the analysed studies (N=5) used quantitative methods; 4 qualitative; and 3 mixed methods. In addition, also 6 studies aimed to analyse CT skills and 4 opted for focusing on both, skills, and dispositions. No studies were carried out to only develop dispositions. Considering the skills promoted, analysis and evaluation as well as the dispositions of analyticity and systematicity were the ones that were targeted more frequently. For instance, Vertecchi et al. (2017) opted to exclusively target the skills of interpretation and analysis, whereas Corcione et al. (2013) addressed the skills of inference, analysis, interpretation, evaluation, and explanation, as well as the dispositions of analyticity, systematicity, inquisitiveness and cognitive maturity. Last, there were three studies in which the CT aims were not specified.

Silva et al. (2016), de Souza (2014), and Vertecchi et al. (2017), among others, opted to implement an immersive CT approach, being this the most common one (9 out of 12). The infusion approach was the second more frequently with a total of three studies (e.g., Janulevičiene & Kavaliauskiene, 2012; Klimoviene et al., 2006). Concerning the types of intervention, self-study was the most frequent (N=8), followed by dialogue (N=6). Some examples can be found on Silva et al. (2015, 2016) tudents needed to analyse a scientific paper and write an output that lately would be submitted to peer-review. Poce et al. (2012) and Vertecchi et al. (2017) asked the students to learn about classical authors such as Rousseau and develop an argumentative essay that in the case of Poce et al. (2012) was presented in public. In general, it can be said that dialogue is related with argumentative practices in different forms. Mentoring was not reported in any study. In line with the type of intervention are the findings related to the teaching strategies as they pointed out that Lecture-Discussion Teaching (LDT) was present in 4 studies, whereas a combination of LDT and PBL was only present in 3 studies. Most of these studies promoted an argumentative context through the use online platforms, texts, or the delivery of lectures. It should be noted that other teaching strategies were proposed on the research, namely: peer-observation and self-assessment (Janulevičiene & Kavaliauskiene, 2012), and cooperative learning (Klimoviene et al., 2006).

The reviewed papers provided diverse contexts and teaching materials for the promotion of CT, with most of them implementing writing activities and debates. Some (Corcione et al., 2013; Poce et al., 2012; Silva et al., 2016) used virtual learning environments and one of them used a weblog (Janulevičiene & Kavaliauskiene, 2012). Torres Merchán and So lbes (2016) reported the use of authentic problems through texts about socio-scientific issues. Despite 7 studies did not mention which learning materials were used, 5 of them (e.g., Torres Merchán & Solbes, 2012; Silva et al., 2016) mentioned articles, texts, and essays as teaching materials. No difficulties during the implementation were reported.

5.2. The contribution of pre-service teacher educators to the development of critical thinking

The analysis of interviews allowed us to identify the CT conceptualisation by pre-service teachers' educators, along with the type of CT learning environments that they declare to implement in order to promote it. In the tables that are presented in the next sections, categories with no examples (e.g., systematicity) have been omitted.

5.2.1. Critical thinking conceptualisation by pre-service teachers' educators

The analysis of interviews pointed out that participants (T) considered CT as a set of skills and dispositions. Two of the CT definitions given by the participating educators were coherent with Facione's definition (1990), making explicit that CT is comprised of several sub-skills, (T1: '*I think that it is a thinking attitude and also a skill that may consist of several sub-skills or processes that characterise this […]*'), or that it implicitly integrates skills, (T2: '*It is the capacity to use our own vision to respond to problems and situations that we face in our most immediate context, as well as in others*'). On the other hand, T3 and T4 characterised CT as a 'thought' or a 'process', respectively, with both emphasising that it can be used to question the established or normalised ideas. The last interviewee, T5, defined CT as a '*methodology that leads students to think critically*'.

Critical thinking aims. Table 12 summarises the results of the CT skills and dispositions which were mentioned by the participants and a representative quote is provided for each category. The participants referred to all the skills, however they stressed that they considered inference and evaluation to be the most important skills for students to develop. Educators associated the evaluation skill with the assessment of sources of information, discussing the possible consequences of different students coming up with diverse solutions and how they should '*investigate in order discover that there is no one truth*' (T5). This last aspect was closely connected with the skill of inference, which the interviewees linked with the idea of questioning the androcentric order, the reality we live in, the established norms and 'the *students' own thinking*' (T3). To a lesser extent, the interviewees also cited the skills of explanation, self-regulation, analysis, and interpretation. Their analysis referred to the identification and examination of ideas and arguments that help pre-service teachers to '*question the male normality*' (T4). The examination of the previously mentioned skills also revealed a reference to relevant problems in different contexts (e.g., cultural, scientific) and information sources in order to be aware of their '*intention or who has put it there*' (T1). Self-regulation was considered as a necessary skill, given that to an extent, it must influence, modify, or control the students' own thoughts and behaviours in the aforementioned questioning process. Last, by linking the educator's answers with the materials and the teaching strategy they used, an explanation could be found.

Table 12. Critical thinking aims (skills and dispositions) promoted by educators (N=5).

CT aims		F	Quotes
CT Skills	Interpretation	1	"*It's not enough to give the truth, students have to investigate to know that there isn't one truth*" (T5)
	Analysis	2	"*CT has to be built researching how things happened in environment*" (T5)
	Inference	5	"*[…] it's very important the questioning of the androcentric order, everything that has to do with the questioning of male normality in this society; that's a way to develop CT*" (T4)
	Evaluation	4	"*[…] interpretation of several information sources […], it's necessary for students evaluate them*" (T1)
	Explanation	3	"*I put students in the context to imagine they were going to go to a congress or write an article as their final work […]. Students also had to elaborate their speech and present it in front of their classmates, who could make objections and raise different points of view*" (T2)
	Self-regulation	2	"*I try to put examples that are contrary to the orthodox, that is to say, they create bewilderment, reflection […]*" (T2)

CT aims		F	Quotes
CT dispositions	Truth seeking	3	*"It's not enough to give the truth, students have to investigate to know that there isn't one truth"* (T5)
	Open-mindedness	4	*"They [students] should have an open and flexible mind as well as be reflective about the reality"* (T3)
	Analyticity	3	*"I usually start by asking the students questions about how they see the landscape they have in front of them (a picture), how they interpret the territory or some of the processes that occur in it or which he main problems that affect the territory they live in are [...]"* (T1)
	Other (dispositions)	3	Motivation: *"To motivate students, you have to stimulate students, just so you get them to engage in the subject and they change their ways of thinking [...]"* (T5)

F=frequency of appearance

In terms of the CT dispositions, no reference was made to systematicity, self-confidence, inquisitiveness, and cognitive maturity. Educators considered open-mindedness as the most important disposition for pre-service teachers to develop. They identified this disposition with the idea of having an open and flexible mind (see example in table 1), something that is necessary in order to '*foster in the students the ethical or political dimension*' (T1), as well as the capacity to accept that there are several ways to see the world. This capacity can be related to another disposition, truth-seeking, as T3 affirmed the importance of students '*learning how to question themselves*', and T1 implied on accepting '*some degree of distrust in the commonly accepted ideas*'. Analyticity was associated with the materials mentioned by educators, implying the use of reasoning when solving tasks. For instance, when developing a project, students should search for information, contrast the information, and ultimately use it to solve the task at hand. Other dispositions that did not fit into Facione and Facione's (1992) framework were awareness, the idea that according to T1 most problems or solutions have an ethical or political dimension as well as students' motivation and feelings when teachers engage them in a topic.

5.2.2. Critical thinking learning environments

This section presents the characteristics of the CT learning environments that pre-service teacher' educators declared to design and implement on their classrooms. The type of interventions is illustrated indicating the frequency and representative quotes in table 13.

Table 13. Summary of the analysis of the learning environment declared by the educators (N=5)

Type of intervention	F	Quote
Individual study	4	*"… we can also ask an individual reading, an interpretation, an analysis or an evaluation of something."* (T1)
Dialogue	4	*"… I put students in the context to imagine they were going to go to a congress or write an article as their final work. […] They had to discuss […] and present it in front of their classmates, who could make objections and raise different points of view"* (T2)
Authentic situations	1	*"Some topics [I work with] are the landscape (its evolution, the influence of humans, etc.) and historical memory, because, in textbooks, there is some information but just from a point of view"* (T5)
Mentoring	3	*"I don't like to teach theoretically, I want them to discover the reality, that's why I teach some lessons in the street (outside). There, I can ask about; Why is this building here? Since when? So, students start to ask people about that building and they start an investigation"* (T5)
Teaching strategies		
Problem-based lecture (PBL)	2	*"Each group has to do an empirical work: field work to gather information, […] analyse and present some results to their classmates. As all groups worked in the same topic, they discussed about it."* (T5)
Lecture discussion teaching (LDT)	3	*"Discussions, argumentation, the contrast of points of view, the access to materials that help to discuss. These are all examples of activities I use to promote the development of CT"* (T1)
Teaching materials		
Articles, texts, letters, and books	5	*"Basically, I use texts. It's clear to me that the classics are a good source of CT, especially in the times we are living."* (T4)
Graphic document	3	*"I also work with visual graphic documents such as videos, films, and that shows different realities to ours"* (T3)

F=frequency of appearance

Teaching approach. The teaching approach that was implemented in all of the interviewees' classes was immersion. According to three participants (T1, T2, T5), despite CT not being explicit in their classes, they fostered it through questioning, as well as through different activities, which were part of the development of a project (e.g., looking for information, contrasting it with different sources, among others). Two of the interviewees (T3, T4) agreed that they tried to stress to their students the importance of adopting critical stances.

Types of intervention. The interviewed educators mentioned four types of interventions, although individual study and dialogue were the most common. Individual study was associated with the individual reading of texts that offer different points of view on the same issue (T3) or, for instance, on postmodernity (T4). Most of the educators affirmed that students discussed (T3, T4), argued (T2) or established a dialogical stance (T1) in their classrooms. Interviewees placed great importance on ensuring that they did not impose their knowledge or a dogma on the pre-service teacher, but instead helped them to '*discover the reality*' (T5) or '*build their own thinking […], their own line of action*'. They declared to promote authentic situations through a project-based learning methodology to deal with issues such as landscapes or historical memory (T5).

Teaching strategies. Lecture-discussion teaching was the most common teaching strategy, which was in line with the types of interventions, given that the interviewees associated this strategy with the idea of holding argumentative discussions in the classroom. Problem-based learning was used less frequently than LDT, with the interviewees stating that they implement this strategy when dealing with authentic situations.

Teaching materials. Educators asserted to use different learning materials, however, texts in the form of articles, letters, and textbooks were the most frequently used as resources for promoting CT. For instance, a participant considered the importance of using these materials to show students different points of view (T3), or to engage them by using texts with a great emotional load (T5). Graphic documents were the second most commonly used materials. This category was comprised of videos or pictures, which were used to show students a different reality to the one they live in (T2), or to prompt questioning (T1). Some of the interviewees highlighted the use of '*unorthodox texts*' (T2) or texts that enabled students to access '*unusual information*' (T1). In general, all of the learning materials were in line with the type of intervention and the aforementioned teaching strategies.

CT assessment. All educators agreed that CT assessment was not implemented formally in their own instruction and that they did not have specific assessment rubrics for this purpose. Furthermore, they all referred to summative assessment, meaning that they assessed not just a product, but also '*the process*' (T3). In particular, they paid attention to the students' final work (T2, T5) and their oral discourse (T4), taking into account whether or not they had argued critically (T1, T2). In the words of one of the interviewees: '*I assess CT by reading their works and observing their behaviours. Do I have any rubrics that can be used to assess CT skills or dispositions? Not specifically, but for now I am trying to look into it from a cross-sectional perspective […]* (T2)'.

5.3. Discussion and partial conclusions

Characterising the CT studies in higher education, we were able to provide an overview of how CT was being taught to pre-service teachers. The importance of this lies within the fact that pre-service teachers will teach children in a medium term, thus, having developed certain CT skills and dispositions is of importance.

The analysis of the literature (RQ3) pointed out that most of the interventions in the field of social sciences focused on teaching CT skills rather than dispositions, which is line with the findings of RQ5, in which pre-service teachers' educators indicated this very same question. Furthermore, both findings are in accordance with the findings of Saiz and Rivas (2017), who affirmed that dispositions tend to be underrated. Analysis and evaluation were the most frequently addressed skills according to the literature, almost aligning with the skills the educators declared to promote in their classrooms, as evaluation was the second most recurrent. Despite previous reviews on CT (Tiruneh et al., 2014) indicated that CT skills and dispositions were not addressed in instructional designs, this overview showed that both CT skills and dispositions seem to be the aim of several interventions on the literature. The limited attention shown to dispositions in both the literature and by the educators may be related to the fact that all the interventions mentioned in the review were short-term, making their appropriate development a difficult task, as it is affirmed by Saiz and Rivas (2017). In the literature review, the most common teaching approach identified was immersion, once again, coinciding with the educators as all of them affirmed that CT was not being taught explicit in their classrooms. These findings are in accordance with previous reviews (Abrami et al., 2008; Behar-Horenstein et al., 2011) and also points to a tendency of encouraging the embedding of CT within specific subject-domains as a way to of helping students to become critical thinkers, rather than teaching CT as a separate subject. Nonetheless, Tiruneh et al.'s (2014) review concluded CT skills seem to be more effectively promoted when either the general or the mixed approaches are implemented, rather than an immersive approach.

The review made explicit that individual study and dialogue were the most common reported types of intervention, findings in line with the data from educators' interviews. They affirmed that the key for the pre-service teachers is to discuss, argue, or stablished a dialogical context in their classrooms. This combination might have an influence on CT instruction in terms of its effectiveness and the teachers' and students' performances, however, research is no conclusive regarding this matter (Tiruneh et al., 2014). Furthermore, individual study seems to be in line with the few reported teaching materials on the literature and by the pre-service educators that were used, such as articles, texts, books, and essays. Dialogue is too in consonance with the use of an LDT strategy which encourages active learning in students; an approach that is supported by the CT literature review (Dominguez, 2018; Pithers & Soden, 2000) and which is more in line with modern day needs, given that students are required to assume this position in their day-to-day lives (Ching Sing et al., 2019; Niu et al., 2013). Lecture-discussion teaching was the most frequent reported strategy in the literature review. The reviewed papers provided different instructional designs for the promotion of CT, implementing mostly writing activities, debates, some virtual learning environments as well as the use of a weblog. The interviewed educators, however, associated the lecture-discussion teaching strategy with holding argumentative discussions in the classroom. These results reinforced the connection between CT and the scientific practice of argumentation, as some authors (e.g., Jiménez-Aleixandre & Puig, 2022) already proposed.

The examination of RQ4 uncovered the interviewed educators' conceptualization of CT. Two of the five notions were in line with Facione's definition (1990), making explicit that CT is comprised of several sub-skills, or that it implicitly integrates skills as analysis. Other two educators affirmed it was a 'thought' or a 'process', respectively, with both emphasising that it can be used to question established or normalised ideas. The last interviewed defined CT as a '*methodology that leads students to think critically*'. Literature pointed out to different CT conceptualizations and how they can hinder teachers to have a clearer idea about what this term encompasses (Schmaltz et al., 2017). Our view also coincides with their proposal about educators having a clear CT definition, and that in addition to teaching CT, a robust focus should be placed on teaching students how to think like scientists.

6. INQUIRY-BASED TEACHING: TEACHER ROLE IN CHILDREN'S ENGAGEMENT IN INQUIRY AND ARGUMENTATION PRACTICES

Findings related to the second research objective, *to identify didactic strategies, particularly teacher's questions that favour the participation of early childhood students in scientific practices through the analysis of teacher-students' interactions*, are discussed in this chapter. This objective is developed in two research questions:

RQ6) What is the nature of a teacher's guidance in an inquiry-based learning activity? Specifically, what kinds of driving questions does the teacher use to engage children in inquiry?

RQ7) How does teachers' driving questions influence students' enactment of inquiry and argumentation skills?

The activity under investigation sought to promote students' understanding on physical phenomena, particularly the effect of gravity and air friction in diverse daily objects. The task aimed to contribute to children's comprehension of scientific aspects of the world around them through the enactment of inquiry and argumentation practices. For this purpose, they were involved in a weekly session for 2 months about forces within an inquiry-based approach. The classroom recordings were first transcribed and then read several times to divide the whole transcript into episodes, defined by the object the students were testing (e.g., play dough, rock, sheet of paper). A total of 13 episodes were identified, as displayed in table 14.

Table 14. Identified episodes and the object tested on each

Episode	Object
1	Play dough
2	Cotton wool
3	Rock
4	Sheet of paper
5	Cotton wool vs rock
6	Two sheets of paper (open)
7	One sheet of paper vs one sheet of paper shaped in a ball
8	Book vs sheet (thrown separately)
9	Book vs sheet of paper on top
10	Two rocks
11	Feather *vs* sheet of paper
12	A balloon
13	Balloon, rubber. Drawing general conclusions

The analysis of the data was carried out in collaboration with Prof. Lucy Avraamidou under a research stay at the Institute for Science Education and Communication (ISEC), and it comprises a discourse-analysis (Gee, 2014) and open-coding techniques to identify patterns thar emerge from data. Therefore, two different coding frameworks were developed to code the utterances to address the two research questions, respectively: teacher's questions posed to children (RQ6), and students' inquiry and argumentation skills (RQ7), both with the purpose to explore how teacher's questioning affects students' engagement in the practices of inquiry and argumentation.

For RQ6, one hundred utterances were identified in Anne's discourse (see table 15), distributed unevenly in the episodes. The analysis focussed on the type of questions posed by her during the activity. It needs to be highlighted that in the same utterance, more than one question can show; therefore, it can be classified in different categories. The analysis of teacher's questions followed an inductive and iterative process, in which categories emerged in interaction with data and literature review (Mills et al., 2010). The coding scheme comprised the inquiry and argumentation questions that emerged from teacher's discourse. Data were analysed by the author of the thesis and further refined through group discussions with the supervisors of this thesis until an agreement was reached.

Regarding the RQ7, 103 utterances were identified in children's discourse, distributed unevenly in 13 episodes (table 15). To identify the different kinds and patterns of interaction in classroom talk, we traced the question asked by Anne, the responses they prompted on the children, and how she followed-up on them. For the analysis, we first identified the inquiry and argumentation skills enacted by students, which corresponded to the same categories defined for teacher's questions; and then, we compared in each episode the number and type of questions posed by the teacher with the number and variety of skills enacted by the students. It should be noted for analytical purpose that one utterance can comprise several questions.

Table 15. Number of teacher's and students' utterances identified in each episode

Episode (utterances)	Duration	Object	Teacher's utterances	Students' utterances
1 (1-5)	24 seconds	Play dough	2	3
2 (6-7)	5 seconds	Cotton wool	1	1
3 (8-17)	51 seconds	Rock	3	6
4 (18-20)	12 seconds	Sheet of paper	1	2

Episode (utterances)	Duration	Object	Teacher's utterances	Students' utterances
5 (21-26)	48 seconds	Cotton wool vs rock	4	2
6 (27-32)	25 seconds	Two sheets of paper (open)	3	3
7 (33-56)	2 minutes 20 seconds	One sheet of paper vs one sheet of paper shaped in a ball	12	12
8 (57 -76)	2 minutes 25 seconds	Book vs sheet (thrown separately)	9	11
9 (77-110)	3 minutes 44 seconds	Book vs sheet of paper on top	20	16
10 (111-116)	30 seconds	Two rocks	4	2
11 (117-126)	33 seconds	Feather vs sheet of paper	5	5
12 (127-163)	4 minutes 38 seconds	A balloon	17	20
13 (164-203)	6 minutes 23 seconds	Balloon, rubber. Drawing general conclusions.	19	20
Total number of utterances (N=203)			100	103

6.1. Results: teacher's questions to guide students' engagement in an inquiry task

The teacher, Anne, followed an inquiry teaching cycle that emerged from her own practice and students' answers, that allowed her to help them in the construction of scientific knowledge about gravity and air friction. Her teaching cycle can be characterized by a 'closed guidance' that included ten types of driving questions, who whose main features and goals behind are described below in table 16.

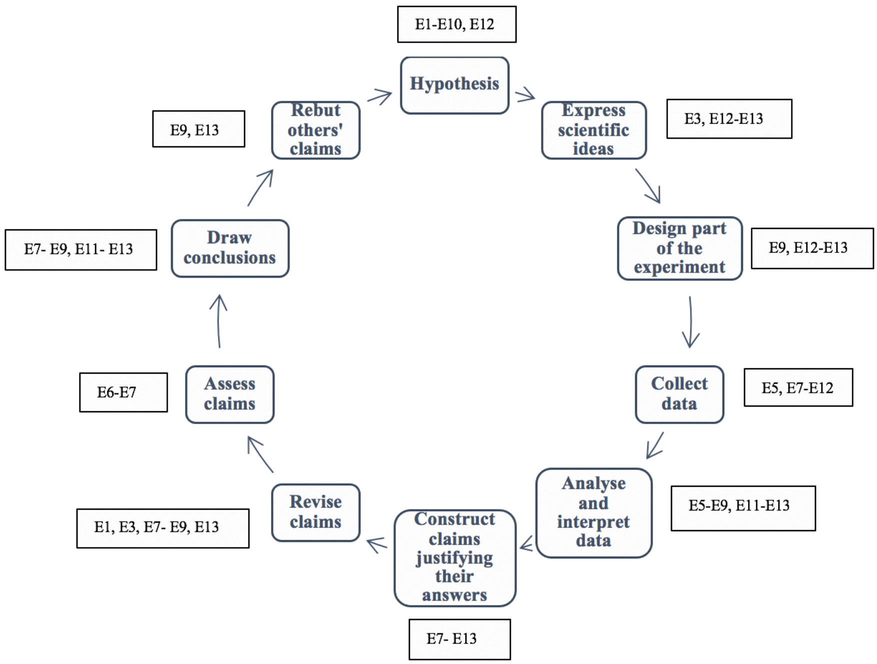
Table 16. Features of driving questions posed by the teacher

Type of question	Features
Hypothesis	To state the expected outcome of the experiment, which goal is to answer the questions "why it happens?" and "what will happen if we let an object fall?". The teacher usually started the episodes introducing this type of questions.

Type of question	Features
Express scientific ideas	The teacher asked this type of questions to explicit and get a better understanding of their personal ideas about scientific knowledge. Children can express them through verbal, gesture, iconic or graphic language.
Design part of the experiment	Children were prompted to think about how other variables (e.g., force, height, mass) might affect the outcome of the experiment and to take initiative of proposing ways to prove their new hypothesis.
Collect data	This process was guided through dialogue, prompting children to go to the middle of the circle and test the object. These kinds of questions helped children understand that they needed to collect data to later justify their claims.
Analyse and interpret data	The teacher posed these types of questions usually after the data collection process in order to guide children on the process of interpreting the meaning of the collected data, while looking for similarities or differences with the other objects as well as what they could mean.
Construct claims justifying their answers	The teacher asked students 'why…?' as a way to prompt them to justify their analysis or interpretation of the data using evidence.
Revise claims	This type of question attempted to build an environment in which the teacher prompted the students to rethink, debate and cooperatively construct a new and revised claim. The questions that aimed to revise students' claims were formulated by the teacher after students stated their hypothesis or their data analysis and interpretation.
Assess claims	The teacher posed these questions to prompt students to question if their previous claims provided a good explanation for the phenomena.
Draw conclusions	This type of question helped students to come up with a conclusion that attempts to summarise the findings of the testing.
Rebut others' claims	The teacher formulated this type of question to prompt students to think there might be another plausible explanation or answer to the phenomena. Therefore, they should refute the previously stated and propose with counterevidence and reasoning a new possible explanation.

The sequence of these questions allows us to infer the inquiry teaching cycle displayed in figure 3.

Figure 3. Inquiry cycle of the teacher (Episodes: E1, E2…E13)



At the beginning of the inquiry-based activity, Anne started presenting the objects, which were previously kept in a plastic tray covered up by a piece of cloth. When the students were seated in a circle, she told them 'Hey, look what I've got here! […] A surprise', trying to engage them from the first moment. After the cloth was lifted, the teacher stated right away 'Wow! Look, what is this?', while lifting a sheet of paper. Children identified it and proceeded to present the other objects they were going to test. Afterwards, Anna asked them if they knew what the experiment could be about and, Gerardo, gestured as if he picked an object and let it fall. Once Anne was sure the students had identified the objects correctly and knew about the procedure, she began the inquiry teaching cycle.

We identified the type of questions presented by the teacher in each episode (corresponding to a cycle stage). As figure 3 shows, the most frequent episodes with a greater duration comprised the skills of (a) *hypothesis,* (b) *collect data*, (c) *analyse and interpret data*, and (d) *construct claims for justifying their answers*. Table 17 shows the frequencies of each type of question in each episode and the total number of questions posed by the teacher.

Table 17. Frequencies of teacher's driving inquiry questions identified in the teaching cycle

Questions	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	Total
Hypothesis	1	1	1	1	2	2	2	1	6	1		7		25
Express scientific ideas			1									2	5	8
Design part of the experiment									1			1	3	5
Collect data					1		3	1	3	1	1	1		11
Analyse and interpret data					1	1	3	1	4		3	1	1	15
Construct claims justifying their answers							2	3	3	2		3	3	16
Assess claims						1	1							2
Revise claims	1		1				2	2	1				1	8
Draw conclusions							3	1	3		1	1	1	10
Rebut others' claims	1								1				2	4
Number of inquiry operations	**3**	**1**	**3**	**1**	**4**	**4**	**16**	**9**	**22**	**4**	**5**	**16**	**16**	**104**

E= episode

Most of the questions formulated by Anne were related to *posing hypothesis* (N=25), which were present at the beginning of almost every episode and used as a strategy to engage children in the inquiry activity. Specially, during the first four episodes, in which she explored children's scientific ideas about what would happen if they let an object fall. In the next episodes, the number of these questions increased progressively but not constantly.

The questions that aimed at the *assessment of claims* (N=2) or the *rebuttal of others' claims* (N=3) were the least formulated. They appeared in E6 and E7 as well as E9 and E12, respectively. In addition, questions that prompted students to *collec*t (N=11), *analyse and interpret of data* (N=16), *construct claims for the justification* of children's answers (N=16) as well as *conclusion drawing* (N=10), were the most present from episodes 7 to 13. The *revision of claims* (N=8) was introduced early in the activity and was usually associated to prompt children to rethink their hypothesis or claims.

As table 17 shows, whenever children dived into the activity testing more objects, the questions became more frequent and complex, emerging as the ones related to the design of the experiment, the expression of scientific ideas, or the rebuttal of others' claims. Although, in episodes 10 and 11, this tendency reverse, and only four and five questions respectively were posed by the teacher. A possible reason for this might be the number of turns of said episodes, as it was already exposed in table 15.

It should be mentioned that episode 13, intended for conclusions, comprised the three types of questions mentioned above -design of the experiment, the expression of scientific ideas and rebuttal of others' claims- as well as the ones intended to draw conclusions, since students were asked to engage in a dialogical process to convey all the scientific notions (e.g., concept of gravity) they had acquired during the activity.

With more detail, we described the context in which the questions appeared in Anne's discourse, exemplifying each category with excerpts from the transcript as examples. The categories were presented following the frequency of appearance, from more to less frequent.

- *Hypothesis* (N=25)*:* These questions were found at the beginning of almost every episode asking, for instance, 'What do you think will happen?' or 'How will it [sheet of paper] fall?', when children were testing the fall of a book versus a sheet of paper situated on top of it (E9) and a balloon (E12).

- *Analyse and interpret data* (N=15) *and construct claims to justify their answers* (N=16): Questions that aimed to guide the analysis and interpret the data went almost hand in hand with the process of collection of data and the construction of claims to justify children's answers. Although their distribution was slightly different, both had a higher frequency during the testing of the book and the sheet of paper situated on top of the book (E9), when comparing it with other episodes since it was the longest episode in terms of durations (see table 15). It should be highlighted that Anne asked questions to prompt students to justify their answers mostly when they formulated a hypothesis or were stating the results. An example of this can be found when the teacher asked 'What do you think it happened? [...]', trying to prompt children to analyse the data obtained during the test. Immediately, a student answered, 'The book landed first…because the book is heavier', not only interpreting the data but also justifying her answer.
- *Collect data* (N=11): This process was guided through dialogue, prompting children to go to the middle of the circle and test the object. These kinds of questions helped children understand that they needed to collect data to later justify their claims. It appeared mostly from episode 7–12. In E7, a child asserted 'But hard things fall faster, and soft things fall more slowly', and to cue her on collecting more data through observation, she asked her 'But is this [ball of paper] soft?', alluding to the properties of the object.
- *Draw conclusions* (N=10): This type of question helped students to come up with a conclusion that attempts to summarise the findings of the testing. She usually asked '[...] what happened?' after students tested the objects, to which they reached a conclusion together. At the end of each inquiry testing cycle, she asked 'Oh, so what happened to it? What happened when it fell?' to induce children to draw a conclusion.
- *Revise claims* (N=8): These questions were introduced by the teacher to guide students and make them think about their

claims. Their presence in the first episodes (1, 3) aimed to the reformulation of children's hypothesis (e.g., 'Are you sure it will fall?'). Whereas, in the last episodes (7, 8, 9, 13), they were linked to the reformulation of children's analysis and interpretation of the data (e.g., 'What do you mean if the book falls, it makes more air?').

- *Express scientific ideas* (N=8): These questions did not appear much, although they held valuable information for both, teacher, and peers. Children can express their ideas through verbal, gesture, iconic, or graphic language. An example can be found when Anne asked the students 'What will happen if I drop the rock?' and completed it with 'Are you sure? This type of questioning triggered a few answers in which students presented a more elaborated explanation about why they thought the rock will fall faster and even eliciting that two other peers mentioned the role of gravity in the falling objects. This was key for the development of the session because it hinted the teacher that she could move forward into a more elaborate inquiry process, trying to help students understand which variables (e.g., height, mass) influenced in the fall of the objects. Other examples that prompted the expression of their ideas were 'and what is gravity?', replying that 'it is a force that…that pull us down', which in turn, led to another question: '[…] where is that force?'. We acknowledge gravity is a property of material objects and not a force as the child stated, nonetheless, this subtle appreciation is far too advance for 5 years old.
- *Design of the experiment* (N=5): Questions like '[..] what do we have to do to let the balloon go?' and '[…] to be able to pull, what do we have to do?' focused on allowing the students to decide and direct their attention on how the variables of the testing and others they could introduce might affect the testing. These questions appeared in the latest episodes.
- *Rebut other's claims* (N=3): These types of questions were scarce and mostly appeared at the end of the activity, during the conclusions. Anne wondered '…does every single thing fall if we

drop it?' or 'Don't balloon fall?' to prompt students to think about if there could be another possible answer.

- *Assess claims* (N=2): These types of questions were scarcely posed, and when Anne formulated them, it was to question students if their previous answers or claims provided a good explanation. The most illustrative example can be found in E6 and E7, as she asked them 'Do they weigh the same?' to evaluate if both sheets of papers weighed the same when they were open and when one of them was rolled into a ball of paper.

Based on these findings, the driving questions that were asked the most prompted children to pose hypothesis and justify their answers whereas the types that were asked the least cued students to rebut and assess claims. These results hinted that the teacher's role varied depending on the moment of the activity and, complex questions, even if they are not very frequent, appeared.

6.2. Children enactment of inquiry and argumentation skills

This section addresses the analysis of the RQ7. First, we present the inquiry and argumentation skills identified in students' discourse. Secondly, we show the relationships between teachers' questions and students' skills. Table 18 summarises children's inquiry and argumentation skills.

Table 18. Frequencies of students' skills identified in the inquiry-based teaching cycle

Inquiry and argumentation skills	Total
Hypothesis	26
Express scientific ideas	12
Design part of the experiment	6
Collect data	12
Observation	15

Analyse and interpret data	17
Construct claims justifying their answers	25
Revise claims	4
Draw conclusions	10
Rebut others' claims	9
Total	**136**

The inquiry and argumentation skills that students enacted the most were the *formulation of hypothesis* (N=26) and the *construction of claims to justify their answers* (N=25). An example of the latter skill can be found in E8 and E9, where students kept stating that the reason why the sheet of paper would float longer than the book was because 'the air hits it [the sheet of paper]'. On the other hand, the least frequent skill was *revise claims* (N=4). It appeared when students reflected on their previous answers. For instance, in E8, a child stated, 'the first and last pages [of the book] are heavy', an idea that Anne wanted to revise and complete; therefore, she asked '[…] aren't the other ones too?'. The student had to rethink his claim. 'Mmmm…a bit', he said after thinking for a few seconds.

A comparison between the frequency of teachers' questions and students' inquiry and argumentation skills is displayed in table 19.

Table 19. Comparison between the frequency of teacher's questions and students' enactment of inquiry and argumentation skills. (TQ: teachers' question; S: student)

	E1		E2		E3		E4		E5		E6		E7		E8		E9		E10		E11		E12		E13	
	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S	TQ	S
Hypothesis	1	2	1	1	1	1	1	2	2	1	2	2	2	1	1	1	6	5	1	2			7	8		
Express scientific ideas					1	1																	2	5	5	6
Design part of the experiment																	1	1					1	2	3	3
Collect data									1	1			3	3	1	1	3	3	1	1	1	1	1	2		
Observation										1				2		1		4		1		1		2		3
Analyse and interpret data									1	1	1		3	2	1	1	4	4		1	3	1	1	2	1	3
Construct claims justifying their answers										1		1	2	5	3	1	3	2	2			5	3	1	3	1
Revise claims	1				1	3							2	1	2	8	1	5				1		3	1	4
Assess claims											1		1													
Draw conclusions													3	4	1	1	3	3			1		1	1	1	1
Rebut others' claims		1												1		1	1	1						2	2	3

There is a higher number of skills enacted by students than teachers' questions. Nonetheless, these differences might be due to the nature of some episodes, which were already shorter (see table 15). A representative example of this are episodes 9, 7, 12, and 13. Anne guided the students through questions the most during the development of these episodes; however, they were also the longest ones in terms of duration. In these episodes, she prompted students to engage in diverse skills, such as express their scientific ideas, analyse, and interpret data, construct claims to justify their answers, revise their claims, and draw conclusions. In E9, for instance, her prompts for posing the hypothesis (N=6) were linked to the revision of their claims (N=5). The high number of questions to guide children to express their scientific ideas in the last episode, when drawing conclusions, is also noteworthy. The questions that aimed at the design part of the experiment, although they did not present a high frequency, were only identified in E9, E12 and E13. Coincidentally, in these two episodes, E12 and E13, students also showed a greater enactment on skills when compared to the frequency of the teacher's questions. Nonetheless, this comparison seems to direct our attention on specific skills and not episodes. This suggests that the chosen object to test and thus, the nature of the episodes, only has an impact on the frequency of skills enacted by the children and not the diversity of skills they engaged in. Therefore, in the next paragraph, we decided to explain further the comparison between the enacted skills and the teacher's questions providing a brief overview of them along the development of the session.

In the first six episodes, there was a similar frequency in teacher' questions and the students' inquiry skills, emerging new skills when children constructed claims to justify their answers. From E5, students began to test the objects, developing skills like data collection and observation. E7 onwards, the number of inquiry and argumentation skills increased in comparison with the teachers' questions and the previous episodes.

The formulation of hypothesis was present in every episode but at E11 and E13 since the teacher focused on drawing conclusions of the session. The construction of claims to justify students' answer was present E5 onwards, showing a higher frequency in E7 and E11. The following excerpt from the former episode is an example of how both actors engaged in all the skills mentioned through a dialogical process.

> A: '[…] how does the balloon go down? Slowly or fast?'
> S1: 'Fast'
> A: 'So, Damián, what do we do?'
> S2: [We tied the balloon] without a knot'
> S3: 'Because that way the air goes inside and so it goes…It propels it up'

In this dialogue, the teacher asked a question that prompted a child to formulate a hypothesis. Afterward, she proceeded to query him about what they should do, trying to cue him to the design part of the experiment. However, it was not the first student who answered but the other, stating that the possible way of testing this object was not tying the balloon. Right away, another peer was prompted by that answer and provided a justification for it.

The assessment of claims appeared in the teachers' cycle; however, students did not enact this skill and usually led to a closed answer. Anne asked them 'So, do they [both sheets of paper] weigh the same or not?', while she unwrapped the ball formed by one of them. Students' answer was a timid 'Yes…'. Observation was a skill developed by the children that derived questions on the data collection process from the teacher.

The most frequent connections between teacher's questions and students' skills were, once again, related to the formulation of hypothesis skill, followed by data collection as well as the analysis and interpretation of data. On the contrary, the least frequent was the assessment of claims and the rebuttal of other's claims. These two skills were more complex for children, therefore, presented lower frequencies and, mostly, at the last episodes (7–13) of the session.

6.3. Discussion and partial conclusions

The findings have offered insights into how teacher questioning prompted students' enactment of inquiry and argumentation, which can be summarised into two main assertations: (a) Anne's driving questions, therefore, role change during the development of the activity prompting more, complex skills in the children; and (b) children's enactment on inquiry and argumentation skills were related to the questions prompted by the teacher and displayed a higher complexity as the activity developed.

Concerning the type of guidance offered by the teacher, the analysis showed that an inquiry cycle emerged from her own practice, and she guided students offering a varied repertoire of questions that helped them construct scientific knowledge. These findings concur with van Uum et al.'s (2016) pedagogical framework, who found out that teaching strategies, such as questioning, static scaffolds, and making relevant connections with their everyday life events, would promote students' scientific understanding. The degree of guidance that students need during inquiry-based instruction is an ongoing debate in science education. Even though we position ourselves in a continuum, it could be considered that the teacher provides quite a structured guidance. We believe this tie well with the work of Biggers (2018), who conveyed the idea that students should start from a structured inquiry to challenge themselves regarding content and the amount of autonomy they have and move progressively toward a more open inquiry. As Hmelo-Sliver et al. (2007) and Vorholzer and von Aufschnaiter (2019) stated, to help students build content knowledge, a high degree of autonomy may not be effective. Therefore, inquiry-based instruction provides an ample body of scaffolding as students solve tasks collaboratively. This context allows the teacher to be flexible and adapt the guidance as the children need it. For instance, Anne posed ten types of different questions depending not only on the stage of the cycle, but also on students' understanding.

The fact that the most common question Anne posed was to prompt the formulation of 'hypothesis', followed by the 'analysis and interpretation of data' and the 'construction of claims to justify students' answers' suggests that more importance was placed on processes that are key to understanding the activity and concepts to draw conclusions at the end of the session. These types of questions led students to a greater enactment during most episodes, aligning with previous research (Chin & Osborne, 2008; Ramnarain, 2011), which showed that teachers' questions could stimulate students' thinking and helped them hypothesise, predict, or explain why or how a phenomenon works, co-constructing knowledge. The teacher posed a few questions related to the rebuttal of claims, which is an expectable finding from authors, as this consists of the most complex form of argumentation (Foong & Daniel, 2013).

The analysis of the RQ7 shows that more and diverse inquiry and argumentation skills were enacted by the students in comparison with the teacher's questions. In general, as the session develops, children engage in more complex skills, usually involving the mobilisation of previous knowledge acquired through the testing of other objects. This finding is in line with Kuhn et al.'s (2013) work, who affirmed that students had the capability to mobilise theoretical and practical knowledge and use them to reason. Another finding pointed out to the relationship between teacher's questions and children's skills. The most frequent was, once again, related to formulating hypothesis, followed by data collection as well as the analysis and interpretation of data. On the contrary, the least frequent was the assessment of claims and the rebuttal of other's claims, meaning the teacher posed less or none driving questions but still students engaged in those skills. As far as we know, no other study has previously addressed the dialogical interactions on/between teacher's questioning and students' enactment on inquiry and argumentation skills, contributing to addressing this gap in early science years' research.

7. A PRÁCTICA DE PENSAMENTO CRÍTICO POLO ALUMNADO DE EDUCACIÓN INFANTIL. O PAPEL DAS PREGUNTAS NA ACTIVACIÓN DE DESTREZAS E DISPOSICIÓNS

Este capítulo aborda e discute os resultados relativos ao terceiro obxectivo de investigación*, identificar as destrezas e disposicións de pensamento crítico no discurso da mestra e do alumnado nun contexto de ciencias*. Este obxectivo concrétase en dúas preguntas de investigación:

> *RQ7) Como son as cuestións dunha mestra que activar destrezas e disposicións de pensamento crítico polo alumnado de educación infantil?*

> *RQ8) Cal é a relación entre as cuestións da mestra e o práctica do pensamento crítico polos/as estudantes?*

Co fin de responder ás preguntas de investigación examinamos as interaccións dialóxicas entre os axentes educativos implicados. En particular, poñemos o foco no rol da mestra e a súa influencia no desenvolvemento de destrezas e disposicións de pensamento crítico por parte do alumnado de infantil durante o desenvolvemento dunha actividade sobre a fricción do aire e a gravidade na caída dos obxectos.

A actividade analizada é a presentada no capítulo anterior, de xeito que a transcrición e os episodios establecidos son os xa mencionados, mais neste capítulo centrámonos no pensamento crítico. Para a RQ8 identificáronse 99 enunciados no discurso da docente distribuídos de forma desigual ao longo dos 13 episodios. A análise centrouse nas preguntas expostas pola mestra durante a actividade. Cabe resaltar que nun mesmo enunciado pódense amosar máis dunha pregunta; por tanto, poden aparecer distintas destrezas e disposicións de pensamento crítico. Seguindo a Mills et al. (2010), a análise das cuestións da mestra seguiu un proceso indutivo e iterativo, no que as categorías emerxeron en interacción cos datos e a revisión da literatura (Facione et al., 1995; Facione, 2000).

En canto á RQ9, identificáronse 101 enunciados no discurso dos/as nenos/as, distribuídos de forma desigual en 13 episodios. Para a análise, primeiro identificamos as destrezas e disposicións expresadas polo alumnado, que correspondían ás mesmas categorías definidas para as cuestións da mestra. A continuación, examinamos a relación entre o número e tipo de preguntas feitas pola mestra co número e variedade de destrezas e disposicións postas en práctica polos/as estudantes.

En ambas preguntas de investigación, despois de interpretar individualmente o tipo de preguntas formuladas, os resultados refináronse e finalizáronse a través de discusións grupais entre a doutoranda e as directoras.

7.1. Categorización das preguntas da docente e desempeño do pensamento crítico do alumnado

Neste apartado preséntanse os resultados do estudo que concirnen a ambas preguntas de investigación, debido á gran interrelación entre elas.

Coa finalidade de contextualizar a análise, recordamos ao/á lector/a que a actividade de indagación na que participa o alumnado é a descrita no capítulo anterior. Esta tiña como obxectivo contribuír á comprensión por parte do alumnado dos aspectos científicos do mundo que os rodea a través do desempeño de prácticas científicas e pensamento crítico. Nesta actividade identificárase que a mestra seguía ciclos de ensinanza baseados indagación e cada un deles correspondíase coa comprobación da caída dun ou varios dos obxectos. Durante o desenvolvemento dos ciclos de indagación, establecidos durante a análise das indagación, identificamos 5 destrezas de PC (interpretación, análise, inferencia, explicación, e autorregulación) e 3 disposicións de PC (sistematicidade, ser inquisitivo/a, apertura de mente), que se resumen nas táboas 20 e 21.

As destrezas favorecidas pola intervención docente recóllense na táboa 20. Nesta se presentan as frecuencias de aparición das preguntas formuladas pola docente, seguidas de exemplos, e a frecuencia coa que dita destreza se percibe no discurso do alumnado.

Táboa 20. Frecuencia e exemplos de preguntas que activan destrezas no alumnado

Destrezas promovidas	Frecuencia de aparición	Exemplos de preguntas	Frecuencia de destreza percibida no alumnado
Inferencia	24	"¿Que credes que caerá primeiro?" "Entón así, como caerá?"	27
Explicación	29	"E, por que voa?" "Como que se cae o libro colle máis aire?"	34
Análise	23	"Que pasou entón?" "A goma chegou despois?"	25
Inter-pretación	8	"Se [o globo] impulsa con que?, que hai dentro?" "Que quere dicir desincharse?"	11
Autorregu-lación	5	"Seguro?" "Ah! Pero seguro que é porque… entón é que as cousas duras se caen antes que as cosas branditas?"	-

A *inferencia* preséntase ao comezo de cada ciclo ao longo de todos os episodios agás do último cando os/as nenos/as extraen conclusións. Asóciase coa petición de formulación ou revisión de hipóteses se algún alumno/a propón unha explicación alternativa. Un exemplo representativo atopámolo cando a mestra formula a pregunta "¿[...] que vai pasar se o [anaco de plastilina] solto?", ao que unha alumna responde que caerá, sen embargo, algúns negan esta posibilidade e propoñen que "voa e vaise caendo". Das 91 intervencións da docente, 24 estimulan ao alumnado a realizar as 27 inferencias percibidas, nas cales se perciben diferente seu grao de concreción en maior ("vai caer o libro e o papel vai estar voando") ou menor ("[chegarán] igual") medida.

As cuestións asociadas á destreza de *explicación* tamén se presentan ao longo dos episodios, cunha maior presencia a partir do momento no que a docente lles demanda comparar a caída de dous obxectos, o cal resulta máis complexo e incita a xerar máis explicacións. Esta destreza asóciase á petición de explicacións nas que o alumnado presenta argumentos relacionados coas hipóteses previamente formuladas coas que intentan explicar o observado. A continuación, presentamos un extracto do diálogo onde se exemplifica esta destreza asociada á argumentación dunha hipótese.

> "Mestra: vós que credes que…?
> Alumna: a goma vai chegar antes porque pesa máis que o globo.
> Mestra: pero seguides pensando que é porque pesa máis? É porque pesa? Todos tedes claro que é porque pesa?
> […]
> Alumna 2: non, porque a sostén o aire.
> Mestra: aaaah! Por que o aire sostén máis a que?
> Alumno: porque a goma pesa moito e… e… e… a goma ten moita máis forza que o…
> Mestra: a goma ten máis forza? Pero onde ten forza a goma?
> Alumno 2: porque pesa moito
> Mestra: pero a goma ten forza?
> Alumno: non, é polo peso que o aire non a pode empuxar."

O diálogo, ademais, reflexa a co-construción do coñecemento científico entre docente e alumnado. Isto require un proceso dialóxico, traducíndose nun número elevado de cuestións formuladas por parte da docente (N=29), fomentando que o alumnado desenvolva explicacións mediante as súas participacións (N=34).

O apoio proporcionado pola mestra respecto á destreza de *análise* é máis evidente no intre do ciclo de indagación cando se analizan os resultados dos seus experimentos, sobre todo en aqueles episodios nos que teñen certa complexidade para os/as nenos/as e requiren que os repitan. Así mesmo, esta axuda adoita a aparecer cando hai comparacións de obxectos ou introducen algunha nova variable (ex., deixar caer o obxecto desde máis altura). A docente formula un total de 23 preguntas, activando 25 intervencións que promoven o desenvolvemento da destreza de análise no alumnado. Un exemplo deste tipo de cuestións formuladas, que promoven que os/as nenos/as identifiquen propiedades como a dureza ou a masa dos obxectos cos que están experimentando, atopámolo cando unha alumna argüía que "as cousas duras cáense máis rápido e as cousas branditas cáense máis a modo". Esta idea provoca que a mestra introduza a cuestión "pero isto [folla de papel], é brandito?", ao que a nena responde afirmativamente e comeza un novo experimento co obxectivo de que ela comprobe a validez das súas ideas. Outro exemplo achámolo cando os/as nenos/as deixan caer dous folios ao mesmo tempo, un coa súa forma orixinal e outro con forma de bóla. A continuación, a mestra pregunta "[...] cal chegou antes?", promovendo que analicen os datos obtidos nos experimentos, como é o caso do alumno que resposta "ese, o plano". Sen embargo, a docente espera unha explicación máis razoada e pregunta "Ah, ¿entón a isto que lle pasou? Que ao caer había, que?", ao que unha nena contesta "Aire", de forma que contribúe a que a alumna exprese ideas coas que reforzar esas explicacións.

Atopamos a destreza de *interpretación* no primeiro e nos dous últimos episodios, onde a docente explora as ideas iniciais e finais do alumnado. Non é das destrezas máis frecuentes, atopando só 8 cuestións que activan 11 intervencións dos/as nenos/as nas que se percibe a destreza de interpretación. Este tipo de preguntas promoven no alumnado a expresión das súas ideas acerca de conceptos científicos coma o aire, ou a gravidade. Desta forma, cando a mestra cuestiona ao alumando como será a caída de calquera obxecto, razoa que esta caída deberase á altura. A partir dese momento, o concepto de gravidade co-constrúese entre dous compañeiros/as, refinando o mesmo, tal e como se pode observar no seguinte extracto:

> "Alumno: Porque ten…(dubida) gravidade.
> Mestra: Por que ten que? [...] Gravidade, e que é iso de gravidade?
> Alumna: É unha forza [...] que fai que che baixes.
> Alumno: É como unha corrente
> Alumna: É como unha corrente que fai que che baixes."

Outras cuestións fomentan esta destreza mediante a interrelación e expresión de ideas dos/as nenos/as respecto ás súas vivencias diarias e variables do experimento. Exemplo disto é a pregunta "O aire onde está? Onde temos aire?", respostando unha nena responde que "aquí", mentres sinalaba toda a aula.

Por último, a destreza de *autorregulación*, relacionada con procesos meta cognitivos, foi promovida ao longo de toda a actividade coas intervencións docentes, se ben só hai unhas poucas preguntas da docente que a reflexen explicitamente (N=5). Cuestións como "seguro?" e "pero, sube ou… quedará [o globo] no ceo? Non vai baixar?", teñen como obxectivo facer que el alumnado reflexione sobre as súas explicacións para que determinen se se axustan ao fenómeno explorado. É destacable que non se presenta unha correspondencia clara de dita destreza nas intervencións do alumnado, pois este responde ás preguntas da docente xerando unha nova explicación, pero non se auto regula, polo que non presenta un desenvolvemento claro desta destreza. Unha posible explicación é o contexto desta investigación, onde só presentamos a análise da primeira de dez sesións, entendendo que esta podería adquirirse co avance das mesmas.

A análise dos datos revelou que as preguntas da mestra tamén fomentan o desenvolvemento dalgunhas disposicións de PC. A táboa 21 amosa as frecuencias das cuestións que promoven as disposicións atopadas, exemplificacións das mesmas e a frecuencia de disposicións percibidas no discurso do alumnado.

Táboa 21. Frecuencia e exemplos de preguntas que activan disposicións no alumnado

Disposición	Frecuencia de aparición	Exemplos de preguntas	Frecuencia de disposición percibida no alumnado
Sistematicidade	8	"Pois agora vou a enrollar a folla de papel así (ruído). Apreto, apreto, apreto, apreto, apreto, apreto, apreto, apreto…e agora? Cal chegará antes [das dúas follas de papel]?" "A ver Damián, como facemos? Damián, Damián, cóntanos."	4
Ser inquisitivo/a	2	"Mirade, que é? ¿que é isto?" "Escoitade, entón imos probar con dúas cousas...un libro e un folio"	2
Apertura de mente	-	Reflíctese no discurso da docente. Non se atoparon preguntas específicas.	-

Entre estas atopamos a disposición relacionada coa *sistematicidade*, é dicir, as preguntas da docente axudan ao alumnado a percibir e reflexionar acerca de posibles variables que podan afectar ao desenvolvemento da indagación, en concreto, na parte do deseño experimental. Esta disposición, en termos de preguntas formuladas, é a máis frecuente (N=8), e aparece durante toda a actividade. Sen embargo, ten un menor impacto no desempeño do alumnado quen só interveñen en 4 ocasións. Un exemplo característico achámolo cando a mestra lles cuestiona acerca de dúas follas de papel: "Dúas follas igualitas, vós cal credes que pesará máis?", servindo como ferramenta non só para promover que os/as nenos/as reflexionen sobre a variable masa e como afectaría á caída do obxecto, senón tamén para coñecer a súa noción de conservación. Noutras ocasións é o propio alumnado quen introduce unha nova variable, como é o caso do alumno que afirma que na caída a folla de papel chegou despois que o libro xa que "[...] non lle dou tempo a que se movese [...]". Este afirmación provoca que volvan a realizar o experimento, para o que a mestra pregunta "Probamos? Ana (ela) é máis alta? [...] Tíroo eu?", procedendo a realizar o experimento con esta nova variable.

A disposición de *ser inquisitivo/a* é promovida pola docente en escasas ocasións (N=2), as cales teñen como obxectivo fomentar a curiosidade do alumnado para motivalos coa actividade ou manter a súa atención. Na introdución ao presentar os obxectos a mestra preguntaba "Mirade, que é? Que é isto?", así como ao afirmar "Escoitade, entón imos probar con dúas cousas...un libro e un folio". Un alumno manifesta curiosidade en diferentes momentos da actividade por como o cambio na forma do folio ("ou tamén poderíase facer un avión de papel…") y la variable altura ("e agora desde o teito") influiría nos resultados dos experimentos. Por último, como se aprecia no seguinte extracto, o discurso da docente promove en varias ocasiones la *apertura de mente* do alumnado.

> "Mestra: Pau, ti que cres que vai pasar?
> Alumno3: a primeira páxina [do libro] e a última pesan.
> Mestra: a primeira páxina e a última, as outras non pesan?
> Alumno: eh...un pouco.
> Mestra: (ruído de voces) Eu non me estou enterando. A ver, Ismael, Ismael.
> [...]
> Alumno3: o que pesa do libro é a portada e a contraportada.
> Mestra: e por que pesa a portada e a contraportada?
> Varios: porque son máis duras
> Alumna2: non, porque son máis gordas
> Mestra: porque son máis gordas. Entón, credes que se tiro o papel e o…Sara, a ver [...]."

A diferencia das outras disposicións, a docente non fomenta esta disposición a través de preguntas específicas, senón que o fai mediante o seu discurso, especificamente, mediante o intercambio de opinións, promovendo a participación de todo o alumnado, e tendo en conta as súas ideas para a co-construción de coñecemento.

7.2. Discusión e conclusións parciais

Os resultados ofrecen información sobre como as preguntas da docente activan o desempeño de destrezas e disposicións de PC nos estudantes de educación infantil. Estes resultados reforzan a idea da idoneidade das preguntas como estratexia de andamiaxe que facilita o PC e a comprensión de coñecementos científicos polo alumnado (van Uum et al., 2016). Biggers (2018) afirma que os/as docentes deben iniciar aos/ás nenos/as na indagación partindo de situacións estruturadas para desafiarse a si mesmos/as con respecto con respecto ao contido e a autonomía. En liña con esta autora, coincidimos en que debido a que o desenvolvemento do PC é dependente do contexto da tarefa na que o alumnado está implicado (Greene & Yu, 2016) e á complexidade das destrezas e disposicións de PC para este, especialmente en infantil, é preciso que a mestra se mova dentro dun contínuum bastante estruturado. Neste sentido, León (2015), e Hmelo-Sliver et al. (2007) afirmaron que para axudar ao alumnado a desenvolver o PC un alto grao de autonomía podería non ser efectivo. É por isto que resulta relevante coñecer as estratexias que emprega a docente para introducir ao alumnado de educación infantil neste tipo de prácticas.

A comparación entre as destrezas promovidas pola docente coas percibidas no alumnado pon de manifesto unha concordancia entre ambas. En liñas xerais, podemos afirmar que as preguntas guían a participación do alumnado. A maioría das destrezas desenvolvidas polo alumnado amosan un leve incremento na súa frecuencia con respecto ás cuestións formuladas pola docente. Exemplo disto é a destreza de explicación, a cal garda unha estreita relación coa práctica científica de argumentación pudendo ambas desenvolverse de forma conxunta, como demostrou o estudio con estudantes de secundaria de Glassner e Schwarz (2005). Sen embargo, ata onde sabemos, non se coñecen investigacións que aborden estes aspectos en educación infantil. A destreza de inferencia, asociada á formulación de hipóteses, foi a segunda máis promovida pola docente. Chin e Osborne (2008) examinaron a formulación de hipóteses nesta etapa educativa e a vinculan coa estratexia de cuestionamento para promover a construción de coñecemento científico, ambas vinculadas ao PC.

En canto á destreza de análise tamén foi promovida pola mestra á hora de solicitarlles que analicen os resultados obtidos nos experimentos. Unha procura na literatura non revelou estudos que se centraran en examinar esta destreza no alumnado de educación infantil. A destreza de interpretación, relacionada coa explicación de ideas e conceptos científicos, non ten unha presencia maioritaria pese a que o alumnado si é quen de interpretar os resultados apelando a coñecementos científicos tales como o aire, o peso ou a gravidade. A diferencia das anteriores destrezas, a autorregulación foi promovida pola docente, mais non se percibe nas intervencións do alumnado.

Outras destrezas de PC que consideramos importantes, como a de avaliación, non están presentes no discurso da docente ou dos/as nenos/as. Esta relaciónase co axuizamento dun texto xa que, tal e como Glassner e Schwarz (2005) afirmaron, o uso deste recurso didáctico eventualmente levará ao alumnado a cuestionar non só a información senón tamén os motivos do/a autor/a e os motivos contextuais da súa produción.

A comparación entre as disposicións promovidas pola docente coas percibidas no alumnado pon de manifesto unha diferencia entre ambas. Estas atopáronse en menor número que as destrezas, sendo a máis presente no discurso da mestra a de sistematicidade, cun impacto relativamente positivo no desenvolvemento do alumnado, e en menor medida a disposición de ser inquisitivo/a. Sen embargo, a apertura de mente reflíctese durante o desenvolvemento da actividade no discurso da mestra, mais non se percibe no discurso do alumnado. Este escaso desenvolvemento de disposicións pode ser debido a que as disposicións requiren de maior tempo para desenvolverse e que a partir dos dous anos os seus efectos a nivel interpersoal tenden a desaparecer (Saiz & Rivas, 2017). Coincidimos coa percepción destes autores quen sinalan que o PC é unha habilidade que se desenvolve ao lo largo do tempo. Desta forma, a función dos/as docentes en educación infantil é comezar a fomentalo desde a implementación de actividades e co traballo diario de aula para desenvolver aspectos máis relacionados coa dimensión actitudinal. Concordamos, ademais, con León (2015) e Daniel et al. (2017) en afirmar que o deseño e implementación de actividades baseadas nun enfoque dialóxico e o uso de estratexias como o cuestionamento e a repetición das ideas expresadas polo alumnado axuda ao desenvolvemento do PC nestas idades.

Estes resultados suxiren que o rol da docente promove o PC a través dunha actividade de indagación en tres momentos clave. O primeiro momento ten lugar durante a formulación de hipóteses, creando oportunidades de que o alumnado desempeñe a destreza de inferencia e a disposición de apertura de mente. O segundo momento ocorre ao analizar os resultados e buscar explicacións aos mesmos, nos que predominan as destrezas de análise y de explicación, se ben tamén se percibe a disposición de sistematicidade para valorar a adecuación no deseño do experimento. O terceiro momento transcorre ao extraer conclusións da investigación, favorecendo que a docente promova la destreza de interpretación e, deste xeito, a co-construción de coñecementos científicos tales como a presencia del aire, o papel do peso e da gravidade na caída dos obxectos.

CONCLUSIONS AND FINAL CONSIDERATIONS

8. CONCLUSIÓNS, IMPLICACIÓNS EDUCATIVAS E CONSIDERACIÓNS FINAIS

8.1. Introdución

A organización deste capítulo comeza presentando en primeiro lugar as principais conclusións deste estudo. En segundo lugar, as implicacións educativas derivadas das conclusións, xa que un dos propósitos desta tese consiste en identificar formas de mellorar o ensino e aprendizaxe de ciencias en educación infantil desde un enfoque baseado no desenvolvemento de prácticas científicas e PC. E, en terceiro lugar, algunhas consideracións finais relativas ás: (a) limitacións do estudo; (b) aqueles aspectos que poderían mellorarse; e (c) futuras liñas de investigación baseadas nos resultados obtidos nesta tese.

O obxectivo principal desta tese é analizar os desempeños do alumnado de educación infantil nas prácticas científicas e de PC na aprendizaxe de ciencias mediante unha actividade de indagación, así como o papel dunha docente na activación destas prácticas e no fomento de PC. O estudo pretende contribuír ás investigacións empíricas sobre PC e prácticas científicas no ensino de ciencias en infantil, etapa educativa apenas explorada pola investigación en didáctica de ciencias.

Para a consecución do obxectivo principal, establecéronse tres obxectivos específicos de investigación e as súas respectivas preguntas de investigación:

Obxectivo 1. *Caracterizar o estado da cuestión das prácticas científicas e do pensamento crítico.*

RQ1) Como se integran as prácticas científicas no currículo de educación infantil?

RQ2) Como se presentan estas prácticas nos plans de formación inicial e permanente dos/as mestres/as de educación infantil?

RQ3) Como se caracterizan as intervencións de pensamento crítico en educación superior?

RQ4) Que noción de pensamento crítico manexan os/as educadores/as de mestres/as?

RQ5) Que tipo de ambientes de aprendizaxe os/as educadores/as de mestres/as declaran traballar nas súas aulas para promover o pensamento crítico?

As conclusións 1, 2 (RQ1), 3 (RQ2), 4-6 (RQ3), 7 (RQ4), e 8-11 (RQ5) refírense a este obxectivo, abordado nos capítulos 4 e 5.

O2. *Identificar estratexias didácticas, en particular preguntas da docente que favorezan a participación dos/as estudantes de educación infantil en prácticas científicas mediante a análise das interaccións docente-alumnado.*

RQ6) Cal é a natureza da guía docente nunha actividade de indagación? Especificamente, que tipo de "driving questions" emprega para involucrar ao alumnado na indagación?

RQ7) Como afectan estas cuestións no desempeño de destrezas de indagación e argumentación polo alumnado?

As conclusións 12-13 (RQ6), e 14-16 (RQ7), fan referencia a este obxectivo, presentado no capítulo 6.

O3. *Identificar as destrezas e disposicións de pensamento crítico no discurso do alumnado nun contexto de aprendizaxe de ciencias*

RQ8) Como son as cuestións da mestra que logran activar determinadas destrezas e disposicións de pensamento crítico no alumnado de infantil?

RQ9) Cal é a relación entre as preguntas da docente e os desempeños do alumnado na práctica de pensamento crítico?

As conclusións 17-18 (RQ8), e 19-21 (RQ9) refírense a este obxectivo, abordado no capítulo 7.

8.2. Conclusións

Os resultados presentados nos capítulos 4, 5, 6, e 7, en conxunto coas súas respectivas discusións e discusións parciais, permitíronos propoñer as seguintes conclusións relacionadas coas seguintes preguntas de investigación formuladas:

RQ1) Como se integran as prácticas científicas no currículo de educación infantil?

1. *A indagación é a práctica científica que máis atención recibe no currículo de educación infantil na comunidade autónoma de Galicia.*

O currículo de infantil (Xunta de Galicia, 2009) céntrase na indagación no senso de que esta é a práctica científica e, en concreto, as destrezas de observación e experimentación as que aparecen con maior frecuencia no documento. Estes resultados están en concordancia con estudos anteriores como o de Fernández-Monteira e Jiménez-Aleixandre (2016), que revelou que a observación cun propósito pode facilitar a elaboración e uso de probas para comprobar ideas no contexto dunha actividade sobre caracois. Sen embargo, cómpre destacar que esta práctica científica non aparece recollida en relación con outras no currículo.

2. *A práctica científica menos presente a nivel curricular é a argumentación.*

O documento curricular analizado revelou que a argumentación, especificamente, destrezas relacionadas coa xustificación de enunciados e extracción de conclusións, é a práctica científica con menos presencia no currículo. Isto podería explicar as escasas intervencións de argumentación nesta etapa educativa e a falta de estudos que profunden na análise das destrezas argumentativas por parte do alumnado no noso contexto. Autores como Krajcik e Czerniak (2018) mostran que os/as nenos/as de educación primaria son quen de razoar proveendo xustificacións, sendo preciso para isto, deseñar un currículo que promova as destrezas argumentativas (Kuhn & Moore, 2015), ademais da súa introdución na aula mediante unha adaptación dun modelo semellante ao proposto por McNeill et al. (2006) .

RQ2) Como se presentan ditas prácticas nos plans de formación inicial e permanente do profesorado de infantil?

3. *Os plans de formación inicial e permanente non ofrecen formación en prácticas científicas para Mestres/as de infantil.*

A aprendizaxe mediante prácticas científicas pode resultar pouco significativa se non se ten en consideración ao profesorado e, en particular, a súa formación inicial e permanente. Ese foi o motivo polo que abordamos nesta tese a análise dos plans de formación inicial e permanente do profesorado de educación infantil. A análise destes plans amosa que as prácticas científicas apenas se integran dentro dos plans formativos das tres universidades públicas de nosa comunidade. Malia que esta análise limítase ao marco curricular de Galicia e aos programas formativos das nosas universidades, podemos concluír que este marco non impulsa a aprendizaxe de ciencias mediante prácticas científicas, xa que logo a posible transferencia a aulas de educación infantil require que estes/as profesionais posúan unha formación axeitada para promover dita aprendizaxe. Ata onde puidemos saber, son escasos os estudos que investigan sobre as necesidades formativas prioritarias incluídas plans de formación inicial nos graos de educación infantil; Un estudo realizado por Cantó Doménech et al. (2016) pon de relevo a necesidade de revisar os plans de formación inicial tendo en conta ás dificultades atopadas polos/as docentes para lograr a transferencia efectiva de prácticas científicas ás aulas. Nunha liña semellante, a análise do Plan Anual de Formación do Profesorado 2015-2016 (Xunta de Galicia, 2015) levada a cabo no marco desta tese amosa que só se inclúe unha acción formativa de contido científico está orientada ao profesorado de infantil o que pon de manifesto a falta de plans de formación en prácticas científicas para o profesorado en activo desta etapa. As investigacións sobre a formación permanente do profesorado de infantil non son abundantes e as existentes abordan traballos sobre a ensinanza de ciencias desde unha perspectiva teórica (e.g., Hong et al., 2013) ou focalizan a súa atención na aplicación de accións sobre o perfeccionamento de conceptos e prácticas de STEAM (e.g., Hapidin et al., 2020).

RQ3) Como se caracterizan os estudos empíricos do pensamento crítico na educación superior?

4. *A literatura revela que a meirande parte das intervencións de PC son de corta duración e focalizan a súa atención nas destrezas de pensamento crítico e non nas disposición de PC*

A revisión sistemática da literatura pon de manifesto que case todos os estudos analizan destrezas de PC ou destrezas e disposicións. En concreto, as destrezas de análise e avaliación foron obxecto de estudo nestes traballos, o que está en liña con investigacións anteriores, sendo os de

Kuhn (Kuhn & Angelev, 1976; Kuhn & Ho, 1980; Kuhn et al., 1995, entre outros) unha gran aportación neste eido. Estes estudos mostraron que as intervencións de longa duración poden influír nas estratexias analíticas dos/as estudantes, promovendo a adquisición e a meta-comprensión de novos coñecementos.

Pola contra, a análise da literatura amosou que ningunha das investigacións realizadas abordan o estudo de disposicións. Un posible motivo é o feito de que para desenvolver disposicións cómpre deseñar intervencións a longo prazo, xa que as disposicións tardan máis tempo en poder desenvolverse. Ademais, a partir dos dous anos os seus efectos a nivel interpersoal tenden a desaparecer (Saiz & Rivas, 2017). Isto introduce outra conclusión derivada da análise desta pregunta: todas as intervencións analizadas son de corta duración, o que ten limitacións para lograr un desenvolvemento progresivo e efectivo do PC .

5. *A meirande parte das intervencións non fan explícitos os principios de pensamento crítico, fronte a unha minoría que combina a ensinanza implícita e explícita.*

A análise da literatura do PC en educación superior dos últimos dez anos permitiunos identificar que 9 das 12 intervencións presentadas usan un enfoque de ensinanza por inmersión. É dicir, os principios de ensinanza do PC non se fan explícitos ao alumnado, senón que este se integra de maneira implícita nas tarefas. Estes resultados coinciden con previas revisións da literatura (e.g., Abrami et al., 2008; Behar-Horenstein & Niu, 2011). Isto apunta a unha tendencia a apoiar a integración do PC en áreas de coñecemento específicas como unha forma de axudar aos/ás estudantes a ser pensadores críticos, no canto de ensinar o PC como unha materia separada. A este respecto, Tiruneh et al. (2014) e Saiz e Rivas (2017) sinalan que a efectividade dunha intervención para desenvolver destrezas e disposicións de PC dependen de (a) usar un enfoque de infusión, e (b) definir e integrar o PC dun xeito claro nos obxectivos, actividades, e avaliación do curso. Tamén, o rol dos/as docentes é clave á hora de deseñar actividades que promovan as destrezas e disposicións de PC, tal e como indican Abrami et al. (2008). Por este motivo nesta tese decidiuse abordar unha análise sobre a noción de PC que presentan educadores/as de mestres e ambientes de aprendizaxe que fomentan.

6. *A estratexia LDT (lecture-discussion teaching) baseada no diálogo e apoiada en actividades de tipo individual é a máis común nas intervencións de PC analizadas.*

A LDT consiste nun coloquio ou conversa acompañada da lectura dun texto, e asóciase normalmente a unha ensinanza de carácter máis tradicional centrada no docente (Saira et al., 2021). Os resultados da análise de intervencións de PC mostran que a LDT ou a combinación desta co PBL (problem-based learning) é a estratexia didáctica preferente para promover o PC. Estes resultados están en coherencia con anteriores revisións da literatura (e.g., Abrami et al., 2008, 2015): mais, en termos de efectividade e de mellora nas actuacións docentes e de alumnado, Tiruneh et al. (2014) sinalan que non hai estudos concluíntes. Cremos convinte salientar que dado que o PC é dependente da área de coñecemento e contexto no que se desenvolve, sendo a maioría de estudos desenvolvidos no campo da medicina (e.g., Afrasiabifar & Asadolah, 2019; Alaagib et al., 2019), e non podemos concluír como son estas intervencións en educación.

A estratexia didáctica LDT ponse en práctica mediante intervencións que favorecen o diálogo e a lectura de textos, ensaios ou artigos. Ponse de manifesto a creación de contextos que favorecen a práctica científica de argumentación.

RQ4) Que noción de pensamento crítico manexan os/as educadores/as de mestres/as?

7. *Os educadores coinciden en entender o PC como unha noción que engloba diversas destrezas e disposicións, porén, as definicións que presentan son variadas*

Os/as educadores/as expresaron unha noción de PC que engloba unha serie de destrezas e disposicións, o que é acorde ao o marco teórico proposto por Facione (1990). Definen o PC de distinto modo como un "pensamento" ou "proceso" no cuestionamento de ideas preestablecidas ou como unha "metodoloxía que leva ao alumnado a pensar criticamente". Estes resultados son coherentes co sinalado por Pithers e Soden (2000), que indican que os/as docentes de educación superior adoitan presentar distintas nocións de PC e esta diversidade de nocións non facilita a súa transferencia ás aulas. A natureza complexa e multifacética de PC fai que sexa difícil lograr un consenso en canto a como definir esta noción e obter unha definición operativa que permita promover a súa práctica na aula.

RQ5) Que tipo de ambientes de aprendizaxe os/as educadores/as de mestres/as declaran traballar nas súas aulas para promover o pensamento crítico?

8. *As destrezas de PC máis valoradas polos/as educadores/as son a inferencia e a avaliación, mentres que as disposicións reciben unha menor atención, o que está en consonancia cos resultados atopados en estudos previos analizados.*

As destrezas máis valoradas polos/as educadores son as de inferencia e avaliación. Para os/as participantes a inferencia fai referencia ao cuestionamento do orde preestablecido na sociedade e a de avaliación coa valoración de fontes de información, así como os seus contidos e posibles motivacións da mesma. Ambas destrezas asemellan gardar unha gran conexión entre si, tal e como sinala a literatura (Elen et al., 2019; Frerejean et al., 2016), aparecendo ademais asociadas á resolución de problemas. A revisión da literatura tamén vén a reforzar esta conclusión, xa que a destreza de avaliación foi a segunda máis frecuente, se ben os contextos de instrución difiren da resolución de problemas. Cómpre sinalar que a destreza de avaliación aparece recollida en estudos empíricos que refiren á práctica científica de argumentación, máis concretamente, ao desempeño do alumnado en PC cando estes/as deben avaliar os argumentos diversas noticias online, xustificando os seus propios tanto en niveis de educación secundaria (e.g., Marttunen et al., 2021) como en educación superior (e.g., Lin, 2014).

Outra conclusión que apoia a revisión da literatura é a limitada atención ás disposicións. Se nesta ningún estudo tiña por obxectivo desenvolver as disposicións de forma independente das destrezas, os/as educadores son máis conscientes de desenvolver estas últimas. Isto está en concordancia co argumentado por Saiz e Rivas (2017), quen afirmou que as disposicións teñen tendencia a estar minusvaloradas, malia que son características persoais altamente valoradas e estudos como o de Stupnisky et al. (2018) demostrou que teñen un efecto positivo nas cualificacións.

9. *O pensamento crítico intégrase de forma implícita na formación do profesorado, o cal implica o seu desenvolvemento mediante a práctica*

Os/as educadores/as declararon empregar un enfoque de ensinanza de PC por inmersión (Ennis, 1989) nas súas aulas, dado que parten da idea de que os/as estudantes poden desenvolver o PC mediante a práctica unha vez que se involucren na instrución. A conclusión 5 sobre a revisión literatura, está en liña co expresado polos/as participantes, dado que ambos apuntan ao uso preferente deste enfoque. Non obstante, segundo Saiz e Rivas (2017), para que as intervencións de PC sexan efectivas, cómpre que as destrezas e disposicións estean claramente definidas e integradas no programa da materia. Lograr unha maior efectividade mediante a ensinanza explícita dos principios do PC require dun maior nivel de coñecementos e conciencia acerca de como integrar o PC na instrución. Isto se traduce en maiores oportunidades de formación específica en PC para os/as docentes (Janssen et al., 2019), aspecto que destacaron tamén os participantes deste estudo.

10. *O diálogo e as discusións son consideradas de gran importancia polos/as educadores/as como medio para promover o PC, o que pon de manifesto a conexión que establecen entre o PC e argumentación.*

Os/as participantes expresaron que é clave que os/as futuros/as mestres/as de educación infantil establezan debates e discusións na aula, é dicir, procuren crear un contexto que facilite a práctica dialóxica na aula para o fomento do PC. Se ben as revisións en materia de PC non son concluíntes sobre que tipo de intervencións son as máis efectivas de cara a lograr un maior desenvolvemento de destrezas e disposicións (Tiruneh et al., 2014), si destacan a estreita relación do PC coa argumentación (Kuhn, 2019), pudendo considerar este como unha práctica dialóxica. A investigación de Pezaro (2018) suxire que os/as futuros/as mestres/as melloraron o seu razoamento, adquirindo ademais unha maior apertura de mente cando se implicaron en procesos de debate e argumentación sobre temas socio-científicos.

11. *A avaliación de PC non se integra de maneira explícita na instrución dos educadores/as e nos programas das súas materias, senón que se integra como un elemento máis da avaliación sumativa destas*

A totalidade de educadores/as, se ben valoran o PC, expresaron non integrar a súa avaliación dun xeito formal nas materia(s) que imparten. Así mesmo, manifestaron que o feito de non coñecer e/ou dispor dunha ferramenta de avaliación para este propósito explica esta cuestión. A meirande parte indicou que o PC procuran avalialo dentro do proceso de avaliación sumativa que levan a cabo nas súas materias, utilizando como indicador a capacidade do alumnado para argumentar de maneira crítica. Haynes et al. (2016) apunta como posible razón disto, a falta de formación do profesorado no deseño e aplicación de ferramentas que permitan avaliar maneira efectiva o desenvolvemento de destrezas e disposicións de PC polo estudantado. Diversos estudos (e.g., Dominguez et al., 2015; Tiruneh et al., 2017) revelan o uso de tests estandarizados coma o Cornell Critical Thinking Test (CTTT-Level X) ou o Critical Thinking skills in Electrycity and Magnetism (CTEM) para este proceso. A avaliación explícita e adaptada ao contexto de instrución, especialmente de corte cualitativa, segue a ser un desafío na ensinanza de PC (Puig et al., 2020).

RQ6) Cal é a natureza da guía docente nunha actividade de indagación? Especificamente, que tipo de "driving questions" emprega para involucrar ao alumnado de infantil na indagación?

12. *A tipoloxía de preguntas enunciadas pola docente repítese ao longo dunha tarefa para explorar a gravidade mediante a caída de distintos obxectos creando un ciclo de indagación estruturado creado a partir da súa experiencia docente e as interaccións co alumnado.*

A docente formula 10 tipos de preguntas e estas repítense cada vez que o alumnado realiza unha comprobación cun obxecto diferente ou introduce variables novas. Deste xeito, emerxe un ciclo de indagación caracterizado por unha guía que conta cunha variedade de cuestións que xorden da súa práctica docente e da interacción co alumnado, axudándoo na construción de coñecementos científicos sobre a gravidade e fricción do aire. Son varios os estudos que vinculan o cuestionamento coa activación de coñecementos previos (e.g., Chinn, 2006; Kawalkar & Vijapurkar, 2013; Saalbach & Schalk, 2011), mais son, entre outros, os de Gilmore e McKinney (1986) e van Uum (2016) os que sinalan a función das preguntas como unha estratexia didáctica efectiva para promover a adquisición e comprensión de coñecementos científicos e articulación de enunciados. Asemade, a guía da docente sitúase dentro do contínuum de maior ou menor grao de autonomía proporcionada ao alumnado. O traballo de Biggers (2018) apoia esta gradación, afirmando que os/as estudantes deben partir dunha indagación estruturada para desafiarse a si mesmos con respecto ao contido e á cantidade de autonomía para avanzar progresivamente cara unha indagación máis aberta. Así mesmo, debido á idade dos/as nenos, un alto grao de autonomía podería non ser tan efectivo para a comprensión do coñecemento do contido (Hmelo-Sliver et al., 2007; Vorholzer & von Aufschnaiter, 2019). Esta tarefa de indagación proporciona amplas oportunidades ao alumnado para resolvela de forma cooperativa e gradual. O rol da mestra neste contexto de instrución cambia e adáptase dependendo do momento da actividade, promovendo a aparición de destrezas máis complexas progresivamente. Ata onde sabemos, son escasas as investigacións sobre o rol docente na etapa des educación infantil durante o desenvolvemento de actividades de ciencias. Cómpre salientar os traballos desenvolvidos por Osborne e Freyberg (1985) sobre os catro roles docentes para a ensinanza de ciencias en nenos/as, posteriormente ampliados por Crawford (2000) nun contexto de indagación. Esta última autora mostra que o profesorado é quen de adoptar unha gran variedade de roles durante unha actividade de indagación, algo que os resultados desta investigación permiten confirmar. Se ben, a súa análise excedía o foco de atención desta tese.

13. *As preguntas máis frecuentes poñen de manifesto que a docente salienta os procesos clave para a comprensión da actividade e de conceptos para a extracción de conclusións.*

A análise revelou que as cuestións formuladas pola docente con maior frecuencia están encamiñadas a establecer hipóteses, analizar, e interpretar datos e elaborar enunciados para xustificar as respostas. Estas preguntas revelan que a docente pon o énfase na comprensión dos procesos relacionados coa actividade polo alumnado, así como nos conceptos clave para poder establecer conclusións. Ata onde puidemos saber, os estudos que analizan a relación entre as preguntas dos/as docentes e o seus obxectivos de aprendizaxe son escasos. Chin e Osborne (2008) e Ramnarain (2011) fan referencia á importancia do cuestionamento docente e a como este pode estimular o pensamento do alumnado e favorecer o establecemento de hipóteses, predicións ou á formulación de explicacións acerca de porque ou como un fenómeno funciona. Asemade, os resultados desta tese poñen de manifesto a diferencia entre o nivel curricular e o que acontece nunha aula. A práctica de argumentación non aparecía recollida no currículo e, pola contra, a mestra deste estudo formula un alto número de cuestións que a promoven a presentación de xustificacións por parte do alumnado.

RQ7) Como afectan as preguntas da docente no desempeño de destrezas de indagación e argumentación no alumnado?

14. Existe unha relación positiva entre a tipoloxía das preguntas formuladas pola docente e as destrezas mobilizadas polo alumnado.

A análise revela que, en termos xerais, as preguntas da docente fomentan a activación de destrezas de indagación e argumentación polo alumnado. Isto é especialmente notable nas destrezas de construción e xustificación de respostas, e na revisión de enunciados ou respostas. Respecto á primeira, a construción e xustificación de respostas, existe unha maior énfase nos episodios 7 e 13, mentres que a segunda destreza, a revisión de enunciados, é promovida en maior medida nos episodios 8, 9, 12 e 13. Unha posible explicación é a natureza das actividades levadas a cabo neses episodios que implican operacións cognitivas de maior complexidade. Así, no E7 teñen en conta a variable forma ao comparar a caída do mesmo obxecto con distinta forma; no E8 focalizan a atención na masa dos obxectos, sendo un destes o empregado no experimento anterior. Os episodios restantes (12, 13) axudan ao alumnado a repasar os coñecementos adquiridos e formular conclusións. Na literatura atopamos estudos que poñen de manifesto como os “prompts” verbais axudan ao alumnado á xustificación de enunciados (Herrenkohl et al., 1999; Zembal-Saul et al., 2013), e proporcionan oportunidades para que o alumnado poida compartir as súas respostas/enunciados cos/as compañeiros/as para a co-construción de coñecemento (Erduran et al., 2004; McNeill, 2011). O modelo CER (Krajick & McNeill, 2015) é sinalado por diversos investigadores/as como axeitado para traballar este tipo de cuestións cos/as nenos/as xa que lles proporciona unha estrutura guía. Porén, ata onde sabemos, non atopamos na revisión da literatura estudos empíricos que analicen a tipoloxía de preguntas e o seu impacto na activación de destrezas indagación e argumentación na aula de infantil.

15. O xeito de formular as preguntas fomenta determinadas destrezas de indagación.

O discurso da mestra e, en concreto as preguntas formuladas por ela, variaron ao longo da actividade en función ao obxectivo que pretendía acadar. Deste xeito, cuestións como “que pensades que ocorrerá?” ou "como caerá?" promoven a destreza de formulación de hipóteses. Se a mestra expresaba "Que pensades que ocorreu?" despois da realizar o experimento servía ao alumnado como *prompt* para analizar e interpretar os datos. Ás veces, era preciso a revisión dalgunha hipótese ou interpretación de datos, para o que a docente preguntaba se "estaban seguros..." do enunciado que acabaran de manifestar. Por último, á hora de extraer conclusións a cuestión máis frecuente foi "que pasou?". O papel da docente neste contexto está vencellado á estratexia do cuestionamento, creando discusións produtivas e cooperativas para co-construír o coñecemento (Saleh et al., 2021).

16. *As preguntas formuladas pola docente promoven en maior medida as destrezas de indagación que de argumentación.*

A análise das interaccións discursivas mestra-alumnado pon de manifesto que, en liñas xerais, a mestra fomenta mediante as preguntas que formula destrezas de indagación con maior frecuencia que de argumentación. A formulación de hipóteses é a máis frecuente, seguida da análise e interpretación de datos e observación. Isto deriva da natureza da actividade e das cuestións procedentes do propio ciclo de indagación da docente. Neste senso, na literatura recóllense diversas investigacións sobre o desenvolvemento de destrezas en contextos de indagación (e.g.,; Hsin & Wu, 2011; Kambouri & Michaelides, 2014) nesta etapa educativa. Asemade, cómpre sinalar que a destreza de argumentación relacionada coa xustificación de respostas ten unha frecuencia semellante á de formulación de hipóteses. A literatura indica que os/as nenos/as de 6 anos son quen de formular conclusións baseándose nos datos obtidos nos experimentos (Koerber et al., 2005; Piekny & Maehler, 2013; van der Graaf et al., 2018), malia que o curríclo da nosa comunidade non inclúe esta destreza, existindo polo tanto unha fenda (gap) entre o nivel curricular e o de aula.

17. *As prácticas científicas de indagación e argumentación teñen solapamentos nos seus campos cognitivos e procesuais, ao promover unhas, promóvense outras tamén*

A análise das cuestións formuladas pola docente e o desempeño do alumnado nas prácticas científicas puxo de manifesto a interconexión destas. O alumnado ao implicarse nunha tarefa baseada na indagación deben non só elaborar hipóteses, senón construír argumentos válidos, contra argumentos, e mesmo refutacións, xa que todas estas destrezas deben ser desempeñadas e desenvolvidas (Kuhn & Pease, 2008). Tal e como afirman Jiménez-Aleixandre e Brocos (2021) a argumentación pódese caracterizar como a avaliación de enunciados baseándose en probas, mentres que a indagación é o proceso de construción de coñecemento mediante a formulación de preguntas, a interpretación de datos, e a extracción de conclusións. Afirmamos que cando o alumnado se implica nunha tarefa de indagación é quen de desenvolver ambas prácticas xa que existe un solapamento no dominio procesual, se ben consideramos clave o rol da docente neste proceso.

18. *O cuestionamento axuda ao alumnado a mobilizar coñecementos de ciencias adquiridos previamente e durante o desenvolvemento da actividade.*

A análise mostra que o alumnado mobiliza un maior e máis variado número de nocións científicas conforme avanza a sesión. Os/as estudantes comezan mobilizando coñecementos previos coma a velocidade na caída dos obxectos ou o concepto de gravidade, e dos que adquiriron nos experimentos que realizaron con relación ao efecto desta e da fricción do aire.

Estes resultados coinciden cos do traballo de Kuhn et al. (2013), no que se mostra que os/as estudante de primaria teñen a capacidade de mobilizar coñecementos de tipo teórico e práctico e aplicalos para elaborar razoamentos. As cuestións formuladas polo alumnado constitúen outra forma de activar os seus coñecementos previos, por ende, o rol da mestra no contexto dialóxico é de gran importancia, o que se mostra nesta análise realizada.

RQ8) Como son as cuestións da mestra que activan certas destrezas e disposicións de pensamento crítico polo alumnado de infantil?

19. *Non existe un patrón catro entre as preguntas formuladas pola docente e a articulación de destrezas e disposicións de PC polo alumnado. As preguntas da docente non parecen dar lugar a unha variación significativa nas destrezas e disposicións do alumnado nin en número nin en variedade.*

As cuestións formuladas pola mestra amosan unha frecuencia moi semellante ás destrezas e disposicións que o alumnado articula no discurso, mais non en variedade. No caso das destrezas de inferencia, explicación, inferencia e interpretación, o desempeño é algo maior se ben non significativo respecto ás cuestións que a docente formula. Pola contra, a destreza de autorregulación non se identifica nas intervencións orais do alumnado. A literatura indica que nenos/as de 3/4 anos comezan a interiorizar a guía e son quen de regular as súas emocións e comportamentos tendo un impacto en futuros desenvolvementos (McCabe et al., 2004). Porén, continúa a ser unha das destrezas máis complexas para o alumnado desta etapa educativa e precisa dunha atención sostida no tempo para poder desenvolverse.

En canto ás preguntas formuladas que buscan fomentar disposicións de PC no alumnado, tampouco se aprecia un patrón claro en canto ao número e tipo de preguntas e número e variedade de disposicións. Na destreza de sistematicidade, a docente formula o dobre de preguntas que número desta disposición percibidas nos/as nenos/as e no caso de ser inquisitivo/a as preguntas e disposicións desempeñadas polo alumnado presentan a mesma frecuencia. Tal e como se argumentou na conclusión 4, unha posible explicación pode ser a necesidade de dispor de tempo para desenvolvelas (Saiz & Rivas, 2017) se ben esta cuestión, ata onde sabemos, non foi analizada nunha aula de infantil.

RQ9) Cal é a relación entre as preguntas da docente e a práctica de pensamento crítico do alumnado?

20. *A destreza de explicación, ligada á práctica científica de argumentación, presentouse con maior frecuencia.*

A análise amosa que a docente promove o PC en tres momentos clave do ciclo de indagación que se establece na actividade: (a) a formulación de hipóteses iniciais; (b) a análise de resultados e busca de posibles explicacións e (c) a extracción de conclusións. No primeiro, predomina a destreza de inferencia e a disposición de apertura de mente. No segundo, favorécense as destrezas de análise e explicación, así como a disposición de sistematicidade para valorar a adecuación do deseño do experimento e no terceiro, a destreza de interpretación xa que o alumnado co-constrúe xunto a docente os coñecementos científicos.

A destreza de explicación foi a que o alumnado logrou articular cunha maior frecuencia no seu discurso, en concordancia co número de preguntas formuladas para tal fin pola docente. Esta destreza ten unha maior presenza nos episodios 7 e 8, nos que a mestra demanda ao alumnado comparar a caída de dous obxectos; proceso que incita a construír un alto número de posibles explicacións polo alumnado. Relaciónase, asemade, coa petición de explicacións nas que os/as nenos presentan argumentos vencellados ás hipóteses previamente formuladas. Isto relaciónase co sinalado por Glassner e Schwarz (2005) sobre a relación entre esta destreza e a argumentación. Tamén, investigacións como a de Macagno e Kinstantinidou (2012) con alumando de etapas superiores, recomendan promover a formulación de explicacións tentativas que precisan ser comprobadas mediante discusións guiadas por cuestións críticas. Porén, ata onde sabemos, non se coñecen investigacións que aborden estes aspectos na etapa de infantil.

21. *A destreza de avaliación, de vital importancia para a análise critica da información, non é promovida pola docente e non está presente no discurso do alumnado*

Os resultados amosan que a destreza de avaliación non é promovida pola docente nin desempeñada polos/as nenos/as. Na nosa opinión, esta destreza é clave no desenvolvemento na capacidade crítica do alumnado xa que se atopa vencellada a procesos tan importantes como a avaliación de información (van Zyl et al., 2020), problemas, e situacións da vida cotiá (Braun et al., 2020), entre outros

22. *As disposicións promóvense en menor medida que as destrezas de PC e hai un escaso impacto das preguntas relativas a estas no discurso do alumnado.*

A análise pon de manifesto que as disposicións de PC atopáronse en menor número que as destrezas, sendo a disposición de sistematicidade a que amosa un maior desempeño por parte dos/as nenos/as. Como xa indicamos ao longo deste capítulo, as disposicións requiren de accións prolongadas no tempo, polo que a función do/a docente é comezar a implantar actividades para este fin e crear ambientes de aprendizaxe que tamén desenvolvan a dimensión actitudinal. Neste senso, concordamos con León (2015) e Daniel et al. (2017) que o deseño e implementación de actividades baseadas nun enfoque dialóxico e o uso de estratexias coma o cuestionamento e a repetición das ideas expresadas polo alumnado pode favorecer ao desenvolvemento do PC nestas idades.

8.3. Implicacións educativas

As implicacións educativas derivadas das conclusións preséntanse a continuación.

Das conclusións 1, 2, e 3, vencelladas co primeiro obxectivo de investigación, *Caracterizar o estado da cuestión das prácticas científicas e do pensamento crítico,* a implicación educativa relacionada coas prácticas científicas é:

A análise do currículo de educación infantil e plans de formación docente na nosa comunidade autónoma pon de manifesto a necesidade de deseñar e implementar un currículo baseado no desempeño de prácticas científicas desde a educación infantil e acorde ás capacidades do alumnado de idades temperás para a construción de coñecementos científicos, así como integrar a ensinanza de ciencias mediante prácticas científicas na formación inicial e permanente do profesorado desta etapa. Malia que as prácticas científicas están presentes a nivel curricular, sendo a indagación a que máis atención recibe no noso currículo, os plans de formación inicial e permanente do profesorado analizados non contemplan actividades que permitan o seu desenvolvemento. Tendo en conta a importancia que ten a formación de mestres/as en ciencias en prácticas científicas de cara a lograr a transferencia efectiva destas nas aulas, suxerimos, en liña coa proposta de Nordine et al. (2021) articular plans de formación docente nos que se priorice o desenvolvemento dun pequeno e robusto corpo de ideas mediante o exercicio de practicas científicas. Estender este enfoque a todo o sistema educativo a nivel curricular e formativo, require da participación de diversos axentes e institucións educativas e dunha maior investigación nesta etapa educativa. Consideramos de especial interese propostas curriculares baseadas na indagación de Krogh & Morehouse (2014) e argumentación de Kuhn (2015). Partindo de estudos sobre prácticas científicas en formación de profesorado e alumnado noutras etapas educativas (e.g., Brand, 2020; Enghah et al., 2018) propoñemos desenvolver actividades de indagación na etapa de educación infantil que impliquen á formulación de preguntas sobre fenómenos observables, a presentación de hipóteses e a elaboración de conclusións en base a probas, tal e como propoñen Lowell e McNeill (2019).

Das conclusións 4, 5, 6, 7, 8, 9, 10, e 11 correspondentes ao primeiro obxectivo de investigación, *Caracterizar o estado da cuestión das prácticas científicas e do pensamento crítico,* as implicacións educativas relacionadas co PC son:

O enfoque de ensinanza do PC denominado de infusión mediante o cal se fan explícitos os principios de ensinanza ten unha presencia case nula nas intervencións revisadas na literatura, así como nos ambientes de aprendizaxe declarados polos/as educadores/as participantes. Porén, diversos estudos mostran que o alumnado obtén máis ganancias mediante este enfoque de ensinanza de PC en termos de desenvolvemento de destrezas e disposicións (Abrami et al., 2008; El Soufi & See, 2019;

Tiruneh et al., 2014). Os contextos máis empregados polos/as educadores para promover o PC implican procesos de argumentación e debate o que revela a conexión que establecen entre o PC e a argumentación. Neste senso, concordamos con Giry e Paily (2020) e D. Kuhn (2019) en que a argumentación debe integrarse nun ambiente de aprendizaxe de ciencias para promover o PC. Dado que ambas engloban habilidades de pensamento de orde superior, a súa ensinanza conleva que o alumnado as exercite mediante a práctica na aula. Alén disto seguindo na liña da anterior implicación, cremos que a formación inicial e permanente activa, cun propósito concreto, do profesorado en PC é de vital importancia para lograr activar o seu desenvolvemento polo alumnado de infantil. Por último, a revisión das intervencións e as entrevistas puxeron de manifesto que debe profundarse na avaliación do PC. En especial na avaliación cualitativa mediante instrumentos/rúbricas que o permitan. Unha implicación é a necesidade de desenvolver estudos que permitan a elaboración de ferramentas útiles para o profesorado que poidan ser integradas na planificación formal.

Das conclusións 12, 13, 14, 15, 16, 17, e 18 correspondentes ao segundo obxectivo de investigación, *Identificar estratexias didácticas, en particular preguntas da docente que favorezan a participación dos/as estudantes de educación infantil en prácticas científicas mediante a análise da interacción docente-alumnado,* as implicacións educativas son:

A existencia dunha relación positiva entre as preguntas formuladas pola docente e as destrezas de indagación e argumentación desempeñadas polo alumnado revelou que os contextos dialóxicos e a estratexia do cuestionamento son de gran utilidade para fomentar un desenvolvemento efectivo das mesmas. As preguntas son consideradas o eixe vertebrador da indagación na aula (Kawalkar & Vijapurkar, 2013), e o rol do/a mestre/a consiste en guiar as negociacións, implementando a argumentación mediante as xustificacións en base a probas para co-construír o coñecemento. Este estudo puxo de manifesto que determinado tipo de cuestións promoven determinadas destrezas entre os/as nenos/as, o que facilita deseñar actividades e levar a cabo estratexias por docentes. Deste xeito, cuestións como "que pensades que ocorrerá?" ou "como caerá?" promoven a destreza de formulación de hipóteses ., Cando a mestra preguntaba "Que pensades que ocorreu?", despois da realizar o experimento, esta pregunta servía ao alumnado como *prompt* para analizar e interpretar os datos. Porén, hai que ter en conta que, non todo o profesorado dispón dun coñecemento didáctico suficiente sobre formas efectivas de promover o PC e as prácticas científicas. Unha formación docente sostida ao longo do tempo -ademais da experiencia- xogarían un papel crucial á hora non só de adoptar este rol, senón de adaptalo durante á actividade segundo o alumnado o demande.

O alumnado desempeñou, en liñas xerais, máis destrezas de indagación que de argumentación. Cabe salientar a xustificación de respostas, unha destreza das máis frecuentes e vencellada á argumentación. Isto podería suxerir que o alumnado de infantil é quen de comezar a xustificar as respostas apoiadas no uso de probas, polo que adaptacións do modelo CER (Krajick & McNeill, 2015) no que se fai explícito a conexión entre estes elementos centrais da argumentación podería ser de gran axuda en idades temperás. En particular, cando o alumnado non está afeito a proporcionar xustificacións e/ou a guía mediante o cuestionamento docente non é suficiente.

Da conclusión 19, 20, 21, e 22 relacionado co terceiro obxectivo de investigación, *identificar as destrezas e disposicións de pensamento crítico no discurso do alumnado nun contexto de aprendizaxe de ciencias*, as implicacións educativas son:

A complexidade da práctica do PC fai que o alumnado desempeñe as disposicións en menor medida que as destrezas, sendo a de explicación a máis desempeñada por estes. A explicación aparece vencellada á xustificación de respostas e, por tanto, á práctica científica de argumentación. Isto pon de manifesto unha fenda (gap) co currículo, onde esta destreza non aparecía recollida e coa literatura onde non se coñecen investigacións que aborden estes aspectos en educación infantil. Os resultados veñen corroborar a investigación de Glassner e Schwarz (2005), quen afirmaron que a práctica de argumentación e o PC poden desenvolverse de xeito conxunto. Neste senso, cremos de gran importancia que o profesorado coñeza esta relación e a traballe de maneira explícita. Pola contra, a destreza de avaliación non foi promovida pola mestra nin desempeñada polo alumnado. Opinamos que dado que os/as nenos/as son consumidores de información desde idades temperás, deberían comezar a desenvolver esta destreza, vencellándoa á práctica da argumentación e dentro dos límites da súa experiencia, tal e como Delamain e Spring (2021) demostraron no seu estudo con alumnado desta etapa.

Ademais, respecto ás disposicións de PC, cabe sinalar que debido á súa natureza actitudinal e o tempo que precisan para desenvolverse, non se abordan de maneira explícita, sendo difícil identificar estas na práctica do alumnado. Porén, cremos convinte promover o seu desenvolvemento desde a educación infantil mediante intervencións longas, como por exemplo proxectos, que se integren no currículo

Por último, a análise do discurso da docente e do alumnado puxo de manifesto que o deseño e o contexto da tarefa debe ser tidos en conta á hora de promocionar as destrezas e disposicións de PC, dado que o seu desenvolvemento depende en gran medida destes. Unha tarefa baseada na indagación e de contido relacionado coa física posúe unhas características propias e, en consecuencia, o alumnado desenvolve determinadas destrezas e disposicións que, seguramente variarían se a tarefa fose outra. É dicir, o desenvolvemento do PC é dependente da contexto no que o alumnado está implicado (Greene & Yu, 2016). Ademais disto, o deseño da tarefa condiciona a practica de PC. Como xa se sinalou no capítulo 3, a actividade analizada nesta tese forma parte dun proxecto máis amplo de na indagación sobre os submarinos e flotación. Isto é de gran importancia porque a unidade e, por tanto, as tarefas e conceptos que se pretenden que os/as nenos/as aprendan, non son "simples" actividades, senón que o seu deseño xira ao redor de fenómenos, pudendo ter integradas diferentes ideas científicas e empregando as mesmas como elemento central motivador e de guía. Lowell e McNeill (2019) indican que este tipo de deseño pode axudar a fomentar o PC no alumnado e o rol dos/as mestres/as neste contexto é formular preguntas sobre o(s) fenómeno(s) para guiar ao alumnado cara a extracción de conclusións.

8.4. Consideracións finais

O último apartado da tese discute as limitacións do estudo atopadas durante o proceso de investigación, así como as futuras liñas de investigación que emerxen dos resultados obtidos.

8.4.1. Limitacións do estudo

As limitacións deste estudo correspóndense na súa meirande parte co deseño metodolóxico. Os estudos de caso xeralmente implican unha análise detallada dun evento, situación ou unidade social delimitada por un contexto particular (Miles et al., 2014), o que nos permitiría obter unha mellor comprensión sobre o papel dunha docente e os desempeños do alumnado de educación infantil nas prácticas científicas e de PC. As limitacións dos estudos de caso radican na imposibilidade de controlar certos factores coma o currículo ou o alumnado, o que ten como consecuencia unhas achegas moi específicas do contexto e, dese xeito, a xeneralización non é posible (Cohen et al., 2007; Yin, 2009).

En segundo lugar, deseño e implementación da tarefa levadas a cabo polo grupo Torque e unha mestra de aula integrante deste, respectivamente poden ser consideradas outra limitación. O currículo de infantil (Xunta de Galicia, 2009) é bastante flexible respecto ao tempo que se lle pode dedicar a cada materia, sen embargo, a presión por parte de diversos axentes para que o alumnado desenvolva a lectoescritura, é un factor a ter en conta.

A terceira limitación atópase vencellada á toma de datos, na que non foi posible realizar gravacións de vídeo. Isto impediu realizar unha análise multimodal da tarefa, moi relevante para as interaccións profesorado-alumnado na que poden mediar elementos contextuais e de tipo xestual que as gravacións de audio non captan. Co fin de reducir esta limitación empregáronse notas de campo.

En cuarto lugar, este estudo enmárcase dentro do proxecto CRITHINKEDU, o que supuxo grandes beneficios e oportunidades de aprendizaxe, porén, a elección do marco de análise tamén se viu condicionado ao ser consensuado entre os/as participantes do proxecto.

Por último, somos conscientes de que a análise das destrezas desempeñadas polo alumnado é un proceso interpretativo e, como tal, malia a obxectividade da investigadora, é frecuente atopar dificultades vencelladas á intencionalidade con relación ao discurso da mestra e os/as nenos/as. Para reducir a interferencia evitamos o máximo posible libres interpretacións, mantendo o significado expresado ao contexto natural do desenvolvemento da actividade.

8.4.2. Futuras liñas de investigación

A continuación, discútense as futuras investigacións con relación aos resultados e as conclusións do estudo:

A primeira relaciónase coa formación do profesorado en prácticas científicas e PC. Este traballo analiza o estado da cuestión relativa a ambas, malia no seu desenvolvemento púxose de manifesto que cómpre seguir investigando e formando aos/ás docentes de infantil durante a súa formación inicial e continua. Suxerimos o emprego dunha metodoloxía investigación-acción na que diversos axentes e institucións se implicasen polo posible impacto significativo a distintos niveis educativos.

A segunda garda relación co desenvolvemento de destrezas e instrumentos de avaliación do PC para contextos formais. A investigación puxo de manifesto que tanto a literatura no eido educativo coma os/as educadores/as non posúen as estratexias necesarias para avaliar o PC nas súas aulas. Para isto propoñemos unha dobre vía. Dunha banda, a nivel de investigación, explorar e caracterizar o que acontece nas aulas para deseñar instrumentos. Doutra banda a nivel formativo, dotar ao profesorado dos coñecementos e destrezas suficientes para que non só participen na elaboración destes instrumentos senón sexan quen de elaborar outros, adaptalos, e aplicalos ás súas aulas.

A terceira liña de investigación refírese ao cuestionamento como estratexia didáctica nesta etapa educativa. Esta tese pode servir como punto de partida para futuros estudos que profunden no tipo de preguntas con relación ao desempeño de destrezas de prácticas científicas e de PC en infantil. Especial énfase merece a argumentación dada a interrelación co PC e a escasa atención que recibe nesta etapa educativa.

A cuarta e última liña fai referencia á necesidade de desenvolver estudos orientados á capacitación dos/as docentes de infantil co obxectivo de integrar as prácticas científicas e o PC en deseños de indagación como os presentados nesta investigación.

Esperamos que a investigación levada a cabo nesta tese contribúa a unha mellor comprensión sobre o rol dos/as docentes e o desempeño de destrezas de prácticas científicas e de PC polo alumnado de infantil, non só para a investigación da didáctica de ciencias, senón tamén para o ensino e aprendizaxe destas nas aulas.

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ANNEX

ANNEX 1

Relación de artigos:	1-Bargiela, I., Puig, B., & Blanco Anaya, P
Título:	Una aproximación al análisis del currículum y planes de formación del profesorado de Galicia
Ano:	2018
Revista:	Enseñanza de las Ciencias
Volumen, Páxs.:	36(1), 7-23
Contribución da doutoranda:	A doutoranda redactou parte do artigo e analizou os datos, en concreto, o currículo e os plans de formación
Índices/s de calidade:	Indexada en JCR- WOS SSCI (ISI), Scimago, Scopus. Índice de Impacto JCR. Factor de Impacto 2018: 0,814. Cuartil: Q4.
Relación de artigos:	2- Dominguez (coord.)
Título:	A European review on Critical Thinking educational practices in Higher Education Institutions.
Ano:	2018
Revista:	Vila Real: UTAD.
Volumen, Páxs.:	63
Contribución da doutoranda:	A doutoranda colaborou na redacción do informe e analizou os artigos que caracterizan as intervencións de pensamento crítico en educación superior en distintas áreas de coñecemento.
Índices/s de calidade:	Citas: 24 Os reports non posúen índices de calidade.

ANNEX 2

Entrevista aos/ás educadores
Interview to the pre-service teachers' educators

<u>Introdución</u>

O foro económico mundial (2016) no seu informe titulado "O futuro dos empregos" identificou un listado das 10 destrezas máis importantes para 2020. Resolución de problemas complexos, pensamento crítico e creatividade son as tres destrezas máis importantes nun futuro próximo. Estes datos baséanse nunha enquisa realizada a máis de 13 millóns de empregados e empregadas ao longo de nove sectores industriais relativos a economías en desenvolvemento e emerxentes.

1. Would you explain to me your concept/idea of Critical Thinking (CT)?

   Poderíame explicar cal é o seu concepto/idea de Pensamento Crítico (PC)?

2. What particular aspects of CT do you believe are most important for your students to develop? And Why?

   Que aspectos do PC cre que son os máis importantes para que desenvolvan os seus estudantes? Por que?

3. Could you describe practices (approaches/strategies/interven/tions) that you use in your classroom to foster CT? Please give an example

   Podería describir qué prácticas emprega na súa aula para fomentar o pensamento crítico? Por favor, proporcione un exemplo.

3.1. Which learning materials do you use to promote CT in your classroom?

Que materiais emprega para promover o PC na súa aula?

3.1. Do you assess the CT abilities of your students? And How?

Avalía as habilidades/destrezas de PC do seu alumnado? Como?

4. What challenges do you experience when developing CT in your students? And how do you try to address them?

Que dificultades experimenta cando trata que o alumnado desenvolva o PC? Como tenta abordalos?

5. What type of instruction (or other) do you think should be provided to your colleagues to support the development of their CT teaching practices?

Que tipo de instrución (ou outro) cre que se lle debería prover aos/**ás** seus compañeiros/as de profesión para apoiar que desenvolvan prácticas docentes de PC?

6. Are there any institutional barriers that limit the promotion of CT education?

Hai algunha barreira institucional que limite promover a educación en PC?

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Esta tese ten como obxectivo principal analizar as prácticas científicas e de pensamento crítico polo alumnado de educación infantil no contexto dunha tarefa de indagación. Para a consecución deste obxectivo, levouse a cabo un estudo de caso integrado de carácter cualitativo formado por seis unidades de análise: o currículo e os plans formativos do profesorado de infantil, entrevistas a educadores/as de futuros/as mestres/as e a aula de infantil. Os resultados amosan que as prácticas científicas e o pensamento crítico se mobilizan no discurso do alumnado cando a docente crea un ciclo de indagación guiado por preguntas que activan determinadas destrezas. Desta tese derivan implicacións que buscan estimular a integración do pensamento crítico na educación científica desde etapas temperás.