

# Genetic Research Methodology Meets Early Childhood Science Education Research: A Cultural-historical Study of Child's Scientific Thinking Development

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The study reported in this paper aims to structure a cultural-historical understanding on how early childhood children experience science and how they develop scientific thinking as they interact with the social, cultural and material world. Moving beyond the cognitive dimensions of learning by interrelating different aspects of the process of children's scientific thinking development constitutes a research priority for the study. From a wide range of collected data, in the present article one qualitative empirical case study is presented. The detailed single example that is analyzed refers to a kindergarten female student, aged 5.2 years old, from an urban area of Greece. A developmental research methodology as specified from the requirements of cultural-historical theory framework is used. Following four of the main principles of the experimental genetic method, this study creates a fecund ground for a cultural-historical exploration and interpretation of the very processes of the child's development. The collection of the data was achieved through expanded, open-type conversations conducted at three concrete phases between the case study child, two of her peers and the educator. Drawing upon the system of theoretical concepts of cultural-historical theory the analysis is mainly based on the concept of *perezhivanie* as analytical tool as well as the concept of the developmental trajectories. The concept of the conceptualization of a precursor model as a theoretical tool that derives from the field of Science Education is also used. The analysis gives insights into how a certain social situation between children and educators in kindergarten settings becomes the unique social situation of a child's development. Using as a base the dialectic perspective that Vygotsky posed in the analysis of human psyche, the study in this paper offers a creative insight in order to elaborate on a broad and dynamic understanding of the child's development instead of an individualistic and static interpretation on her cognitive evolution. This cultural-historical reading is essential in capturing the child's thinking in all its complexity as well as the uniqueness of the child. Summarizing the above, in this paper, new directions are laid for a more fruitful and dynamic support of young children's learning and development in science through cultural- based educational practices and settings in kindergarten.

**Keywords:** cultural-historical theory, scientific thinking, development, early childhood, science education, *perezhivanie*, drama, genetic research methodology.

## Introduction

In the broad research field related to Social Sciences and Humanities and especially in the research field of Educational Sciences, a crucial issue that systematically rises is empirical documentation and development, selec-

tion and use of appropriate methodological principles and tools. A significant part of research practices in this field is based, in general, on an analytic type methodology in which results and conclusions arise from the analysis and synthesis of partially discrete elements like experimental procedures based on hypotheses or behavioral observa-

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tions. This prevailing practice and its deterministic character, refers mostly to methodological options borrowed from the field of Science. However, the complexity of the research object itself, the human consciousness, cognition and behavior, constantly highlights the need for an adoption of a more complex approach.

### Theoretical Framework

An essential methodological insight to the study of human psyche: the cultural-historical theory perspective

Vygotsky [69] touches upon the problem of structuring a methodology framework matching the context of the academic disciplines related to the study of human psyche. Focusing on the study of the process of genesis of higher mental functions he poses the above issue at the center of the research attention of human psychology. As he argued the analysis of human consciousness, cognition and behavior should not be limited to the study of concrete factors and elements of human action. On the contrary, a holistic conceptualization of the individual is foregrounded. Vygotsky [72] noted the significance of decentralizing the study of the process of the development of human psyche from the dominant during his time dualistic approaches and the adaption of a dialectical approach [62; 12; 10; 11; 67]. As Dafermos [11, p. 17] clarifies a dialectical approach refers to a method that «focuses on the examination of things in their mutual connections, movement and development».

Based mostly on vygotskian and post-vygotskian interpretations of human development cultural-historical theory focuses on a systemic research approach. Towards this direction, the release of research targeting and practice from a one-dimensional system of description, interpretation and explanation of human development in either purely cognitive or purely psychological or epistemological terms is intended. Human consciousness, cognition and behavior is studied in its entirety by highlighting the multiple aspects of human psyche, the evaluation of its various and complex influential parameters, by capturing and overall assessment of its developmental phases and, mainly, by highlighting vital relationships and correlations between the individual and his environment. In this framework, the management and analysis of data in integrated units is foregrounded as a dominant methodological choice [69; 71]. This systemic research framework aims to a dialectical understanding of the complexity of the development of human personality.

### Indicative qualitative methodologies in the framework of cultural-historical approach

In recent year international literature, there exist specific and distinct methodologies that denote a shift of the research interest towards a systemic approach based on a dialectical conceptualization of the processes of learning and development. Overviewing those methodologies, the dynamic of three integrated analytical schemes and interpretation models can be revealed,

constituting reference points to the cultural-historical framework. These methodologies are: a) the 'three foci of analysis' multi-level method developed by Rogoff [53]; b) Hedegaard's model of approaching young children's learning and development [36]; and c) the use of the theoretical concept of perezhivanie as a methodological analytical tool introduced by Vygotsky [71] and developed by other theorists as Rubinshtein [54], Bozhovich [5] as well as contemporary researchers as Vasilyuk [63], Gonzales-Rey [31], Blunden [4], Ferholt [15].

These methodologies are indicative of the way research with a dialectic background can access the whole developmental process of the individual and his interconnections with the social and cultural environment [45]. The choice and usage of each such methodology, serves the concurrent approach of multiple variables in order to study the multiple dimensions of a single psychological-social activity or situation. However, depending on each proposed methodology's targeting, the character as well as the analysis and interpretation manner is different.

In the present study, the theoretical concept of perezhivanie is used as a methodological analytical tool. However, regardless of the multiple readings of perezhivanie, the meaning of this concept remains hard to approach and still leads to contradictory understandings [4; 57; 32; 67]. Regardless of this conceptual conundrum, the concept can gradually lead to new and dynamic insights into the Educational Science research field [19; 1; 7]. As it is noted by Brennan [6], it is important that the theoretical shift towards a cultural-historical understanding and the conceptual redefinition of the human development processes should be followed by a strong and clear methodological shift. Using the concept of perezhivanie research is in front of a theoretical and methodological challenge [6]. From a theoretical point of view, bringing together in a dialectical perception two aspects of the development of human psyche, the internal processes and the external circumstances, perezhivanie clarifies the dialectical character of human development. The significant relevance of the concept is that this dialectic relation is interpreted on the basis of the child's perspective. Moreover, perezhivanie as a theoretical concept creates a fertile ground for studying the process of development within a system of concepts of cultural-historical theory. From a methodological point of view, the concept represents the complex whole of human consciousness into a smallest but complete and entire unit. As Bozhovich argued [5] Vygotsky focused on this specific concept aiming at designating a unit of analysis of the processes of the development of human psyche reflecting a holistic view of the social situation of development. In the latter part of the article, the meaning of perezhivanie as it is conceptualized in the present study is determined in correlation with the use of this concept as an analytical tool.

### Reinforcing early childhood science education research through a cultural-historical approach

Over the last three decades, early childhood science education constitutes part of the educational reality in

kindergarten and is established in many educational curricula worldwide. Accordingly, early childhood science education research comprises a distinct research field in the educational research framework. Substantial empirical studies have been conducted on how young children's, aged 4 to 8 years old, explore concepts and phenomena from the natural world, how they develop scientific thinking and understanding and how reinforcing educational practices can be developed. Based on discrete theoretical traditions of children's learning and development, three basic models of research have commonly been used in the field [46]; a) approaches based on empiricist ideas [9], b) approaches arising from the piagetian paradigm [48] and c) approaches combining both post-piagetian and vygotskian views of learning in a socio-cognitive perspective [47].

However, little attention has been given in the early childhood science education research field on a theoretical conceptualization of child's consciousness as a whole and on a holistic view of child's scientific thinking development at a methodological level. Bringing together diverse aspects of child's learning and development in science and highlighting the interrelations between these aspects, remains an undiscovered dimension in this field. Whilst the traditional models of research approaches had laid the foundations for early childhood science education research, they did not manage to designate the complexity and uniqueness of child's scientific thinking development.

This lack of a systemic approach constitutes a fundamental problem for early childhood science education research. At theoretical level, the longstanding conceptualization of scientific thinking development and science learning as exclusively cognitive processes, has limited early childhood science education research to a conceptual change model [33; 34; 16]. At methodological level, through the linear approach of analysis used by the classical methodologies, important results according to the way that young children experience science and develop scientific thinking seem to be disregarded [21; 52]. At empirical level, a gap between research reality and educational reality is also noted [43; 50]. At pedagogical level, Didactics and Pedagogy for children's engagement with science also seems to be moving in a roundabout procedure without the expected results [2; 30; 24; 14]. These substantial contradictions have led to a kind of contemporary crisis projected in the early childhood science education research field. Thus, a main issue rose in the above rational is how these contradictions can be eliminated?

Drawing upon cultural-historical theory, a new research trend has lately emerged in early childhood science education research field. Seeking for dynamic ways to overcome the above contradictions, this trend aims at re-organizing the classic research procedures towards the recording of alternative and more dynamic types of results [44; 42; 23; 26; 21; 52; 61; 35; 55; 19; 17; 1; 56; 20]. This trend is focused on a systemic study of the procedures through which young children develop scientific thinking and the situational characteristics that act as a driving force of this development. In that framework, qualitative and flexible methodologies are replacing

quantitate linear approaches of concrete functions, static elements and isolated incidents and circumstances. Integrating everyday reality and real life phenomena, research leads to a better contextual understanding and to a deeper conceptualization of the process of individual's development as well as of the educator's mediating role as a cultural tool [25]. Through this methodological transition, new directions towards the study of young children's engagement with the concepts of the natural sciences and the phenomena of the natural world and new foundations are laid in the pedagogy of early childhood science education.

In line with this research orientation, the research study presented here aims to structure a cultural-historical understanding on how preschool children experience science and how they develop scientific thinking as they interact with the social, cultural and material world. Moving beyond the cognitive dimensions of learning by interrelating different aspects of the process of children's scientific thinking development constitutes a research priority the study. Namely, this cultural-historical study seeks to determine:

- a. Which are the dialectical relations between the personal characteristics and the situational characteristics that appear in a collective science experience in kindergarten?
- b. How children are experiencing their science activity?
- c. How children are experiencing their science activity across various social situations?

## **Methodological framework**

### **Research design**

#### *Method*

In order to study the experience as well as the process of the development of children's scientific thinking, in this present study the creation of specific experimental conditions is proposed. A developmental research methodology as specified from the requirements of cultural-historical theory framework is used. In the line with Vygotsky's [73] view on experimental methodology, the experimental procedure of this study follows some of the main principles of the experimental genetic method. According to Veresov [65; 66] genetic research methodology is based on five main and concrete principles which defer from those in classical experimental studies. The experimental procedure of the present study is organized on the basis of four of these principles. Firstly, the study explores young children's scientific thinking development identifying this higher mental function as a function being in an embryonic stage during the early childhood age (between 4 to 8 years old). According to the relevant literature although children of that age have already constructed substantial initial representations and their own interpretations about the concepts and phenomena of the natural world, they have not yet developed their scientific thought in a way compatible with the scientific as well as science education models [38; 22; 49; 3; 39; 8; 37; 29; 58]. Secondly, according to

the principle of category, the experimental procedure of the study is based on the dramatic events that young children experience while they are struggling with the understanding of a natural concept or phenomenon. That means that the experimental lens focus on the spontaneous or artificially created highly emotional events that take place between the children or between the children and the early childhood educator. Thirdly, according to the principle of the interaction of real and ideal forms, the organized experimental procedure is also based on the detection of the transition course of children's thinking from a primary point, a present form, towards a cultural mediated point, a more developed form. That means that the experimental procedure is involving and recording processes that enhance children's scientific thinking development. Finally, according to principle of the developmental tools, during the experimental procedure children have the opportunity to use a system of cultural signs such as language, drawings, songs etc. These tools are not given to children immediately and directly but children are enhanced to discover and use them in their own way.

#### *Procedure*

Drawing upon the experimental genetic method, the experimental data of the study emerged from the observation and elaboration of a collective science experience in kindergarten. Broad, open-type conversations on the subject of the natural phenomenon of clouds were held between pairs or small groups of children and educators into separated instances. The experimental process was conducted in three phases. At the first phase, the conversations were held between one child and the educator. At the second phase, a pair of children and the educator took part at the conversations. At the third phase, the conversations were held between a pair of children, in different combination, and the educator or between a four children team and the educator. As it can be observed the structure of the experimental process has some characteristics also compatible with the structure of the experimental micro-historical methodology [59; 60]. The protocol of the semi-structure conversation sessions was comprised of four main open-ended questions that aimed at highlighting the process of children's thinking about the nature, the formation, and the movement of clouds as well as the correlations of the phenomenon with their everyday activity. Tools and signs free manipulation as well as interaction and co-operation between the interlocutors had been promoted during the whole experimental procedure.

#### *Participants & data collection*

The initial research sample consisted of 101 kindergarten students aged 4.5–6 years, who were attending seven different kindergartens classes in an urban area in Western Greece. The research field has been accessed through the planning, actualization and assessment of a seminar training program aiming at professional development of a seven early childhood educators network in an urban area of Western Greece. The program lasted one school year. The main scope of the program was to

familiarize educators with some of the basic concepts and principles of cultural-historical theory. On that basis, educators were encouraged to organize and enhance collective science experiences during the everyday reality in kindergarten in order to explore and reflect on how young children construct and develop their thinking about concepts and phenomena from the natural world and to reconsider their mediating role in that procedure. Data were extracted from one hundred and eighty transcripts of recorded conversations between the educators and children. Complementary data were collected through educators' field notes and children's drawings made during the experimental procedure.

#### *Data analysis*

Drawing upon the system of theoretical concepts of cultural-historical theory the analysis is based on the concept of *perezhivanie* as analytical tool. In line with Veresov's and Fler's [64] definition of the meaning of *perezhivanie*, the concept is captured in relation to the process of development, the role of the environment and the laws of development. Accordingly, Vygotsky's theorization about higher mental functions as social relations [73] and the dramatic nature of human development [70] provides the framework of the analysis. Episodes that record the dramatic social interactions that children of the study are experiencing are foregrounded as the core of the data to be analyzed as well as are used as the starting point for the analysis. Thus, the concept of *perezhivanie* is correlated in the analysis with the dramatic nature of children development. In their article «*Perezhivanie as a theoretical concept for researching young children's development*» [64] Veresov and Fler also underscore the conceptualization of *perezhivanie* as a refracting prism and as a unit of environmental and personal characteristics. In 1994, Vygotsky [71] introduced the conceptualization of *perezhivanie* as a refracting prism. According to this conceptualization, environment determines the child's development. Yet, the kind of this determination is the result of how the child refracts the environment. Thus, the concept of *perezhivanie* is correlated in the analysis with the supportive concept of the unity between affect and intellect [69] as well as the unity of affect, intellect and act [7] in order to interpret the process of the individual's internalization, the individual's «entering into» [63, p. 187] of an ongoing living experience. The concept of the unity between environmental and personal characteristics supports the above conceptualization. As Vygotsky [71] noted, personal and situational characteristics cannot exist or be understood in separation during the psychological development of the child. Due to the above remark, *perezhivanie* is used as a unit of environmental and personal characteristics.

Additionally, another main concept of the system of concepts of cultural-historical theory used in the research as an analytical tool is the concept of the developmental trajectories [74]. Vygotsky used this concept in order to determine the potential developmental lines in child's development taking into consideration the child's social situation of development. The developmental outcomes of the dialectic relation between the individual

and environment are the crucial factors that determine the individual's developmental trajectory.

Finally, the concept of the construction of a precursor model [41; 51] is also used as a main analytical tool of the present study. The concept of precursor model is a theoretical tool that derives from the field of Science Education. According to Lemeigman and Weil-Barais [41], precursor models are educational constructions caring a number of characteristic elements of the scientific models. These models are designed to help students access the scientific models.

These basic concepts are used in the study as analytical tools in order to answer the three research questions. Within this framing, the dialogues and the interactions between children as well as between children and educators are analyzed. Moreover, the process of concept formation by each child is analyzed in a historical perspective. From the overall collected data the analysis was focused on specific case studies. Two basic criteria were posed in order to designate the cases to be analyzed. The existence of dramatic events recorded during the children's science experience constitutes the first criterion. The development of children's scientific thinking as a result of these dramatic events constitutes the second criterion. Both the criteria must be met for a case to be analyzed in the research. A qualitative discursive micro-analysis of the set of data extracted from each chosen case (meeting the two criteria) was made. Field notes were also included in this analysis. The qualitative analysis of the data was encoded using NVivo qualitative data analysis software. The results presented in the following section are based on the above analytical process.

The above methodological framework is structured as part of a broad research project initiative to a cultural-historical understanding of early childhood scientific thinking [28; 29]. From a wide range of collected data, in the present article one qualitative empirical case study is chosen to be presented. This methodological choice is compatible with the proposed in this article qualitative analysis. The multilayer and in-depth analysis of a single case study data can bring forth fruitful and dynamic findings in contrast to traditional methodologies, commonly used on the field of Science Education research, that struggle with numerous data sets. According to the scope of this present article, a detailed individual example is used in order to illuminate the complexity and the uniqueness of the child's consciousness.

### Findings

The detailed single example that is analyzed refers to a girl, aged 5 years and 2 months, denoted as child D. The transcripts, the field notes and child's drawings rose from the three experimental phases that child D took part were examined. The findings presented here emerged from the analysis of a dramatic social interaction between child D and one of her peers (child K). The dramatic event took place during the conversation that child D and her peer hold at the third phase of the experimental procedure. The whole conversation lasted approximately 30 minutes. The two children and the educator were sitting on the floor in a quite corner of the

classroom while the other students were engaged with other tasks. The event is recorded at the following extract (Extract 1).

Extract 1: A dramatic social interaction between two early childhood children.

**Educator:** *How can clouds come up from the rain (. expressed earlier that explanatory scheme)? Have you ever thought about it?*

**K:** *No, you haven't ...*

**D:** *I have!!*

**K:** *Tell me! Tell me now...*

**D:** *Alright! I'll sing... I'll sing you a song which is about clouds!*

**E:** *Yes... We would love to hear it...*

**D:** *(sings to the beat of a traditional counting-out game)*

*Once upon a time... clouds came out amid the dust, the round dust... (gesturing her hands cycle). And sky comes out when it drizzle... (Child K. recognizes the rhythm and tries to follow the song). When it drizzle then comes the rainbow, and when the rainbow comes here comes the cloud, too... (afterwards, they illustrate together the story).*

In the above extract the two children were discussing with the educators about the phenomenon of clouds creation. At the beginning of the conversation child D seemed to hold an explanatory scheme based on phenomenism according to Laurandean's and Pinard's codification of children's pre-causal thinking in science [40]. Namely, she had expressed the idea that clouds are a kind of dust correlated somehow with the sky and the air as a moving force. Child D experienced a contradiction when her peer disputed her by saying that she had not thought about the idea that clouds come up from the rain (child K.: «*No, you haven't*», «*Tell me! Tell me now*»). This collision seems to have provoke a challenge for child D (child D: «*I have!!*») and have created the conditions for her to struggle with a new and more complex explanatory scheme referring to the phenomenon. In line with Vygotsky's conceptualization of human development as drama [70], the analysis uses this concrete dramatic event as a starting point in order to provide a cultural-historical understanding of how child D developed her scientific thinking by experiencing this collective science activity. In the subsections that follow, the analysis provides findings that answers to the three research questions based on the dramatic nature of the child's development.

*First Research Question: Which are the dialectical relations between the personal characteristics and the situational characteristics that appear in a collective science experience in kindergarten?*

According to the first research question the study attempts to determine the unity of the personal and the situational characteristics that appear in a collective science experience about clouds in kindergarten settings. In other words it attempts to analyse the unity between the child and her social, cultural and material environment at the process of the development of the child's sci-

entific thinking. Accordingly, in this part of the analysis, the concept of *perezhivanie* as a unit of personal and environmental characteristics is used as analytical tool.

At the above dramatic event between child D and her peer it can be observed that D is facing a kind of collision. In order to overcome the collision she chose to sing an improvised song following the rhythm of a Greek traditional counting-out game (child D: «*Alright! I'll sing I'll sing you a song which is about clouds!*»). In that moment it seems that she uses the song as a mean to reinforce herself in expressing an advanced conceptualization. While D is singing, a qualitative change in her thinking can be observed. There is a transition of her thought from an initial explanation about clouds creation to a more relevant explanation on the scientific model of the phenomenon connecting clouds with relevant natural entities and phenomena as sky, rain and rainbows. During the song the child also used gestures trying to catch the swirly movement of dust in order to present in a more descriptive way her idea. The song was also familiar to child K. This seems to motivate her to participate in the song, trying to support child D. When the two girls finished the song, they decided to cooperate in order to make a common illustration of the song. During the whole conversation the two girls used drawing to take down notes as a recording process. So, they represented their ideas in a developmental perspective. Child D illustrated the right part of the following drawing (pic.). Child D started her drawing by illustrating in the middle of the paper sheet a man holding a little box. The illustration is correlated with an idea expressed in a previous phase of the experimental procedure. However, as it can be observed, during the conversation the child added drawings according to her conception about clouds correlation with sky as well as rain, drizzle and rainbows. As it can be noted the mediating tool of drawing along with the mediating signs of speech and gestures appeared to be a significant cultural amplifier in the process of the development of the child's explanatory scheme. According to Vygotsky's [69; 75] conceptualization of semiotic mediation, tools and signs are dynamic components of the transition course of thinking from the intermental to the intramental level underlining the unity between the individual and the environment.



Pic. The outcome of a cooperating illustrating activity

It is through the above contradiction, manifested as a collision, a dramatic event, that child D started destabilizing her initial representation of the phenomenon. The child experienced a contradictory process and this drama acted as a key to the process of her scientific thinking development [70]. However, which were the form and the moving force of this concrete developmental process? In order to answer this question the analysis has to encompass another main concept of the system of concepts of the cultural-historical theory: the concept of the interaction between the ideal and the real form [71; 74]. In the above extract, D's initial representations about the natural phenomenon can be identified as the natural, the present form of her thinking, constituting the real form. A more developed form is presented by her peer. Although this is not a model fully compatible with the scientific model, it is a form that acts like a model close to what should be achieved at the end of the developmental period [71], constituting the ideal form. These two forms are present in the above episode. The child herself and also the educator created the tools and the means for the interaction of these two forms. In the beginning of the episode the educator presented the ideal form by mentioning to D the explanatory scheme that K had expressed earlier (E: «*How can clouds come up from the rain? Have you ever thought about it?*»). This reference was the starting point for the interaction between the two forms. Child D made use of tools and signs such as the gestures, the illustration activity and material artefacts such as the paper and the coloured pens in order to make a transition of her thinking towards her peer's explanation. The child also cooperated with her peer. Her new explanation probably would not have been developed if she had not been engaged in this joint activity. The whole social interaction between the children and the educator constitutes an interaction between the ideal and real form. The above extract is indicative of the way that environment can function as the source of the child's scientific thinking development [74].

*Second Research Question: How children are experiencing their science activity?*

According to the second research question the study attempts to interpret the way that children experience their science activity. In other words it attempts to analyse the processes through which children are refracting the significant components of their environment and gaining developmental outcomes. Accordingly, at that part of the analysis, the concept of *perezhivanie* as a refracting prism is used as analytical tool.

The analysis referring to the first research question has shown how personal and situational characteristics are dialectical related in the process of development capturing the organic unity between the child and the environment. Hence, an in depth analysis of the process environment functions as the source of the child's development should, in parallel, take into account the way that the child *perezhivayet* the forces of the environment [74]. In order to answer this question the analysis has to encompass another main concept of the system of concepts of the cultural-historical theory: the concept of

the unity between affect and intellect [69] as well as the unity of affect, intellect and act [7].

Analyzing the above extract, it can be observed that child's D main intention was to struggle with the introduced idea (D: «*I have!!*»). Her will seemed to force her into thinking about how to come closer to an explanation (D: «*Alright! I'll sing... I'll sing you a song which is about clouds!*»). Afterwards, during the improvised song, the child used her imagination and creativity in order to structure a more developed explanatory scheme about the phenomenon. Namely, she tried to combine specific elements such as the natural entities of clouds, dust, sky, drizzle and rainbow in a meaning making complex. As it has been noted by several researchers the imagination and creativity are functions that dynamically reinforce the process of the concept formation in childhood [76; 13; 18; 27]. Moreover, she tried to externalize her thinking by making gestures and body movements. What is important in this part of the analysis is the highlighting of child's D «entering into» aspects and the process through which the child became aware of, interpreted and related to her environment during this concrete experience [71].

*Third Research Question: How children are experiencing their science activity across various social situations?*

To answer the third research question, the study attempts to determine the way children are experiencing their science activity across various social situations in kindergarten settings. Namely, it attempts to analyse the qualitative changes that occurs at children's scientific thinking during the whole explanatory process. In this part of the analysis, a combination of three concrete analytical tools is used. These concepts are: the concept of the developmental trajectories, the concept of the relationship between every day concept formation and scientific concept formation as well as the concept of the construction of a precursor model.

In order to answer the above research question, the analysis is gradually focused on the three phase of the experimental procedure. These phases are conceptualized as different social situations because of the different combination of the participants and the different moment in time that each phase took place. The findings emerging from the three phases that child D took part shown different qualitative levels of her scientific thinking about the phenomenon. Namely, a different qualitative level was noted in each phase. In particular, at the first phase of the experimental procedure, the conversation between the child and the educator, the child's main explanation was that clouds are a kind of magical dust that comes from gold jewelries which are kept in a box. At the second phase of the experimental procedure, the conversation between child D, a peer of her and the educator, the explanatory scheme of child D was based on the conception that clouds are a kind of dust correlated with sky and air as a moving force. Finally, at the third phase, the conversation between child D, child K and the educator, D's explanatory scheme was based on the conception that clouds are correlated with sky as well as rain, drizzle and rainbows.

According to Laurandean's and Pinard's codification of children's pre-causal thinking in science [40], the above three explanatory schemes corresponds to three different categories of children's pre-causal scientific thinking. The first explanatory scheme is based on imagination. That means that the child used her imagination and creativity in order to make causal relations that support her to conceptualize the phenomenon. The second explanatory scheme is based on the concept of phenomenism. That means that the child collated three natural entities clouds, sky and air using as a criterion the space closeness between the entities. The third explanatory scheme is based on the principle of the natural causality. That means that the child managed to make causal relations between the natural entities of clouds, sky as well as rain, drizzle and rainbows using the criterion of their physical relation in nature. Incrementally, the explanations that the child expressed became more compatible with the scientific model. According to Leimeigman's and Weil-Barais's model [41] the child's scientific thinking made transitions from an insufficient scientific model to a precursor model. These developmental changes towards a more advanced explanatory model, more compatible with the scientific one, constitute concrete phases to the process of concept formation in the child's mind. It is noted that this transitions occur although a didactical intervention was intentionally deflected. Thus, it can be observed that the several interactions between the everyday concepts and scientific concepts occurring within powerful social contexts were the key concept for the child's development. According to Vygotsky [69] everyday concepts lay the foundations for the understanding of scientific concepts. Namely, it is through the dialectical relations between these two concepts that conceptions are made and children's scientific thinking is developed. Moreover, it is highlighted that the development of child's thinking is studied and understood in relation to different periods and in different social situations. Thus, mapping the child's scientific thinking pathway the analysis provides an insight to the child's developmental trajectory. As Hedegaard [36] noted, in a cultural-historical perspective on children's development the study of the formulation of the individual's developmental pathways is crucial for a holistic understanding.

## Discussion

The present study aimed to examine how early childhood children experience a collective science activity and how they develop their scientific thinking through various social situations in kindergarten settings. Following four of the main principles of the experimental genetic method the study created a fecund ground for a cultural-historical exploration and interpretation of the very processes of the child's development. The findings that emerged from one case study have shown how social and cultural framed scientific situations in kindergarten can create the conditions for the development of child's scientific thinking. The analysis of a concrete dramatic event revealed empirical data according to the dialectical relation between the child and the environment, the

unity between affect, intellect and act as well as the formulation of individual developmental pathways in the course of the child's scientific thinking development. In this framework, research lens captured specified moments that acted as «turning points» in the individual developmental trajectory, thus, reorganizing child's thinking of the natural phenomenon of clouds.

Following the general genetic law of cultural development [73] the study gives prominence to two important points: the conceptualization of the higher mental functions as social relations and the conceptualization of development as a complex and contradictory process [67; 64]. In that regard, the process of the development of scientific thinking is understood as a transition from the interpsychological to intrapsychological level. Dramatic social interactions are highlighted as the form, the moving force of development of scientific thinking. Drawing upon the concept of the social situation of development [5; 74] the study designates how a certain social situation between two children and the educator becomes the unique social situation of a child's development [67; 64].

Drawing upon functional methodological choices, this study constructed a systemic framework for capturing

the child's mind as a whole. This systemic view highlighted several aspects of early childhood children development in science. The whole developmental process of the individual, the interconnections with his social and cultural environment as well as the historical perspective of his experience were highlighted on the basis of a dialectical research background [45; 11]. This dialectic perspective Vygotsky [72] posed in the study of human psyche offers a creative insight in order to elaborate on a broad and dynamic understanding of child's development instead of individualistic and static interpretation on his cognitive evolution. This cultural-historical reading is essential in capturing children's thinking in all its complexity as well as the uniqueness of each child. Therefore, foundations are laid for a more fruitful and dynamic support of young children's learning and development in science through cultural-based educational practices and settings. Towards a new insight, the study suggests classical methodologies are not one-way option in the field of Early Childhood Science Education Research. A re-conceptualization and a new theorization towards an in depth cultural-historical reading of children's learning and development in science is required.

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