Applying dialogic pedagogy in science education learning environment in Early childhood education (ECE) in China

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ABSTRACT

This study focused on teacher-student interactions in process quality of learning environment in ECE. In the literature review, four dimensions of quality learning environments for ECE were defined.

In order to better understand whether these four elements constitute a quality teaching and learning environment in authentic teaching, and the interrelationship between these four elements in teacher-student interaction, I further placed the four elements into the context of ECE in science education in China, which focused on process-based learning as well as adopted action research as my methodological approach and thematic analysis as my data analysis. A total of three teachers and 94 children aged 3-6 years participated in the study.

The result of the study presents a high control power structure model under the ECE science education activities in China, which is still teacher driven. This power structure also reflects the reality that kindergartens have a strong control structure over teachers. Although there was cooperation between teachers and families in teaching activities, the level of cooperation was not high. This makes it difficult to develop a dynamic model of pedagogy with the physical, psychological, and social elements of ECE. It can also hinder the formation of a high-quality learning environment that integrates multiple subjects involved in the learning process.

In light of the interactions between the four systems of human development ecology theory (Ceci, 2006), there is an opportunity for further research to explore multiple subjects that can facilitate meaningful dialogue and co-construction of knowledge in a high-quality ECE learning environment.

Keywords: ECE, high-quality learning environment, science education, dialogue pedagogy

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1 INTRODUCTION

The topic of this study stemmed from my interest in early childhood education (ECE) learning environments. Human development ecology theory showed what elements were included in the environments and the relationship between environment and individual. While constructivist theory implied the precise elements of constructing a learning environment in the field of education.

As ECE belongs to the education field as well, and Sheridan and Samuelsson (2001) believe that the learning environment plays an important role in measuring the quality of education. Because the learning environment under quality education is child-centered and gives children a higher level of participation and autonomy. When children had greater autonomy, they developed their own ideas and form communities of learners with classroom teachers and peers, creating mutual influence. However, La Paro et al. (2012) suggested that the quality of early learning environments could be measured in terms of both structural quality and process quality. The existing ECERS-R (Clifford et al., 2010) and CLASS system (Sylva et al., 2006) were measures of structural quality, while less research had been conducted on process quality. With the competitive pressures of international education brought about by globalization, aspects of educational activity that did not lend themselves to explicit and quantitative measurement were increasingly difficult to sustain, and education was increasingly conceived as a delivery system for predetermined products (Broadfoot, 2000). This study therefore sought to focus on teacher-student interactions in process quality of learning environment, as teacher-student interactions is most common in formal teaching settings but difficult to quantify in a short period of time.

Based on the human development ecology and constructivist theory, I draw on the review of the literature on high-quality ECE learning environments (Piispanen et al., 2008), specifying the high- quality ECE learning environment as

one that had pedagogy at its core and linked three elements: physical, social and psychological. After identifying the elements of a high quality ECE learning environment, I have specified the pedagogical approach to dialogic pedagogy and placed it in the context of science education in ECE in China, taking into account the focus of the study.

The dialogic pedagogy had a fixed pattern of dialogue in traditional teaching spaces, but there were also three sequential structures of dialogue within this fixed pattern of teaching. Hennessy et al. (2016) presented the indicators of dialogic teaching in more detail, and they also developed a Teacher Scheme for Educational Dialogue Analysis (T-SEDA) based on this coding framework (Sara & Ruth, 2018), which could be used for teachers to reflect on their own teaching at the end of the lesson. I placed dialogue teaching in the context of ECE science education because the existing literature on ECE science education is scarce and most of the research has focused on science education in primary and secondary education. Therefore, to better understand what the components of ECE science education were, I selected literature on science education in schools to understand the current conceptual definition of science education and its conceptual trends. I then selected literature on the use of pedagogy in science education based on the previous definition of the learning environment, which further divided the concept of science education into two types of education: macro and micro (Scott, Mortimer & Ametller, 2011). It was important to note that the mode of communication and time scale used in science education can greatly impact the quality of the dialogue between teachers and students.

According to Scott et al. (2011), there were four modes of communication: interactive/dialogue, non-interactive/dialogue, interactive/authoritative, and non-interactive/authoritative, each with varying degrees of control. Additionally, there were three-time scales: micro, meso, and macro, which could

be used to form a continuum of knowledge between macroscopic and microscopic science education.

I chose three kindergartens in China for my study to better understand the dialogue between teacher and student interactions. In the analysis of dialogue in teacher-student interaction, two types of knowledge, macro and micro, were used as components of knowledge in science education. Prior to the activity intervention, the patterns of dialogue were used to understand how the current model of science education works and the corresponding teacher-student interactions in ECE in China, After using the dialogue teaching indicators listed by Hennessy et al. (2016), the four modes of communication and three time scales of science teaching theory and the three talk sequences of the dialogue approach were used to analyze the changing roles of teachers and students.

With a primary focus on the classroom level, to examine whether the pedagogy at the center could link the physical, social and psychological elements and, if so, how the four elements of a process-based, high-quality learning environment in ECE interact and influence each other. Through authentic teaching scenarios at the classroom level, it was possible to extend to explore the current policy and socio-cultural aspects of curriculum for ECE in China and what potential factors influenced the development of a quality ECE learning environment, thus suggesting further directions for future research.

2 LITERATURE REVIEW

2.1 Learning Environment

Human development ecology divides the environment into four systems from a macro perspective, which include two types of subjects: the individual and the group, and the theory that the environment and the subject are mutually influential. The theory of constructivism partially overlaps with human development ecology and further defines the learning environment from the perspective of the educational field by giving the subject the identity of a learner.

2.1.1 Human Development Ecology

The ecology of human development describes the relationship between humans and the environment from a macro perspective and further divides the environment into four systems.

Ceci's (2006) study elaborated the ecology of human development as the following:

> "The study of the process of mutual adaptation between a growing organism and the changing environment in which it finds itself, as influenced by the interrelationships between the various environments and the fact that these environments are also influenced by the larger environment. (p173)"

This theory also has three further characteristics: firstly, the person is affected by the environment in a given situation, but is not controlled by the influence and is able to reconstruct the entity of the environment at any time under the influence; secondly, the environment needs to be mutually adapted to the developing subject and the relationship between the two is reciprocal; thirdly, the environment associated with development is constantly changing. And the environment contains four system: Microsystem, Mesosystem, Exosystem, and Macrosystem. The Microsystem refers to the immediate environment in which

an individual interacts with daily, such as family, school, and peer groups. The Mesosystem refers to the interconnections and relationships between these Microsystems, the influence of the family on the child can indirectly affect the interaction between the teacher and the child. The Exosystem is the interconnections and relationships between different Microsystems. Macrosystem refers to the cultural, political and social environment where the individual lives (Crawford, 2020).

If we look at these four systems from a sociological perspective, a certain 'space' is created (Mercer & Hodgkinson, 2008). Space can be defined as concrete, multidimensional, lived, and experienced, or as relational, contestable and processual. But more importantly, the connections between objective things in space cannot be separated from their social context, and the connections between objective things are reflected in the interaction between people, groups, and other variables (Mercer & Hodgkinson, 2008).

In general, the ecology of human development abstracts the environment as a space in which people comprise the community. And the communities in four systems are interconnected, affecting organisms while also being influenced by them (Crawford, 2020).

2.1.2 Constructivist theory

In the ecological theory of human development, it is stated that the environment is shaped not only by the cultural and social backdrop but also by the connections formed by human interaction. Correspondingly, constructivist theory assumes that objective things are not absolute and divides the subject into learners and teachers from the perspective of the field of education (Simpson, 2002). The interaction between learners and teachers is reflected in the co-construction of knowledge based on the individual's prior experience (Kanselaar, 2002).

Kanselaar (2002) also mentioned that there are two main branches of constructivism: the first is the cognitive and individual level, in which Piaget's

theory of individual intellectual development is included; the second is the socio-cultural constructivist level, in which Vygotsky's theory is included.

Piaget (as cited in Blake, 2015) coined the terms assimilation and conformity. Assimilation refers to the ability of the learner's existing cognitive structures to absorb new information and experiences. While conformity refers to the construction of knowledge in a responsive manner when the learner is unable to cope with new information and experiences. Also, the collaborative construction of teachers and students is important, with the teacher being the guide for the construction of knowledge by students and teaching through dialogue and contextualization.

According to Vygotsky, as cited in Blake's (2015) work, he introduced the concepts of scaffolding and the zone of proximal development. The latter refers to the range of tasks that are too challenging for children to master on their own but can be learned with the help and guidance of an adult or mentor. The lower limit is the level of skill that the child can achieve independently, while the upper limit is the level of additional tasks that the child can take on with assistance. Scaffolding refers to the degree of support provided, with the teacher or mentor deciding whether to provide instruction based on the student's ability. He also considered that language as a mediator between the individual and society, in the context of a continuous, dynamic, interaction between the individual and society, the meaning of language is constantly changing and triggers changes in thinking. Also, the integration of language and thinking emerged in early childhood and shape the subsequent psychological development of the individual (Mercer, 2002).

The cognitive and individual dimensions included in constructivism, as well as the socio-cultural constructs, complement how subjects under the four systems mentioned in the ecology of human development influence and reconfigure their environment. Jonassen (1994) identified the following five characteristics of the

constructivist learning environment: Use different ways or forms of representing the real world; Construct knowledge according to context and content; Perform authentic tasks in meaningful contexts; Reflect on activities; And collaborate to build knowledge through social negotiation. “Social” refers to the transfer of individual knowledge construction to groups, which form communities, and individuals negotiate with these groups to reach commonly accepted knowledge. Collaborative knowledge building is the process of meaning-making.

2.1.3 Learning Environment in ECE

From Human development ecology theory shows what elements are included in the environments and the relationship between environment and individual. While constructivist theory implies the precise elements of constructing a learning environment in the field of education. As ECE belongs to the education field, different scholars have offered different explanations for the high quality of ECE learning environments.

According to the IRIS Center (2015), the ECE learning environment includes: physical environment, social environment, and temporal environment. The physical environment refers to the furniture and materials that are visible in the classroom. The classroom is divided into different areas, so the furniture not only serves to guide the children in choosing their own areas for activities, but also provides a certain amount of privacy for the children. Different types of play materials are placed in the different areas according to the age and developmental level of the children. The social environment refers to the ways in which the classroom environment influences or supports interactions between children, teachers, and family members (IRIS Center, 2015). The social environment is used to develop young children's social skills and to help them adapt to the social environment in which they live. Temporal environment refers to the type of classroom activity, time throughout the school day (IRIS, 2015). A fixed sequence of activities helps children to adapt quickly to life in the

kindergarten and allows teachers to adapt activities to the developmental level of the children in the classroom, thus promoting their development.

The two most commonly used scales for quantitative assessment of the learning environment in early childhood education are the Early Childhood Environment Rating Scale-Revised (ECERS-R) and the Early Childhood Environment Rating Scale-Extension (ECERS-E). The ECERS-R consists of 43 items that quantitatively assess children aged 2 1/2 to 5 years in six areas: physical environment, childcare, language, activities and interactions, activity structure, parents and staff. The ECERS-E is designed to be used in conjunction with the Early Childhood Environmental Rating Scale-Revised (ECERS-R), which not only complements the ECERS-R but extends the scale to provide additional insights into important aspects of literacy, mathematics, science and the environment, as well as practices related to diversity issues (Sylva et al., 2006). The CLASS system is also widely used in ECE, where this scale includes ten observable dimensions measuring three broader domains of classroom quality: emotional support, classroom organization and pedagogical support (Muhonen et al., 2016, p146).

However, the aforementioned theories and scales, focus more on the objective elements that should be present in a high-quality learning environment and less on the subjects involved in these objective elements and the relationships between them. La Paro et al. (2012) also mentioned:

> Historically, definitions of quality in Early Childhood Education (ECE) have included multiple proximal (e.g., curriculum and classroom interactions) and distal (e.g., program and state policies) features of classrooms that promote children's development in various domains. (p2)

While definitions of proximal and distal are broad or non-specific, as policies and contexts vary from country to country. Some researchers have conceptualized

quality in early education in terms of two main components: structural and process quality. Examples of structural quality indicators include classroom materials, curriculum, teacher education and teacher-to-child ratios. These indicators are normative aspects that tend to be classrooms and programs. Indicators of process quality focus on more dynamic aspects of early childhood education, including the interpersonal interactions that occur in the classroom, such as teacher-child and peer interactions. With the process of globalization, education is becoming more of a product as one of the elements of competitive measurement and therefore the definitions of quality in ECE have connected with many quantitative scales such as ECERS and ECERS, with "process quality" being the least common quality category (La Paro et al., 2012). As a result, in addition to quantitatively analyzing the quality of ECE learning environments, it is essential to further define the aspects of a quality ECE learning environment from different viewpoints.

Piispanen (2008) proposed that a high-quality learning environment in ECE should have four dimensions: physical, psychological, social and pedagogical. These four elements correspond to three subjects: students, parents and teachers. Students spend the most time at kindergarten and therefore have the most direct experience of the physical environment. Parents are part of the community and therefore their ideas about the learning environment are influenced by the social culture. They also have a psychological inclination towards a high-quality learning environment that promotes their children's education and social development, which influences the learning environment to some extent. The pedagogical approach considers the physical, psychological, and social dimensions as important elements of an effective teaching and learning environment. These dimensions are interrelated and transferable, which allows teachers to support the individual needs of their students. The pedagogy also lies in the teacher's perception of his or her role and the interaction between him or

herself and the students to build a pedagogy that enhances the quality of the teaching and learning environment (Piispanen, 2008).

Havu-Nuutinen and Niikko (2014) conceptualized the high-quality learning environment of ECE in terms of both material and immaterial dimensions. They divided learning environment into three main pairs of dimensions: physical-aesthetic, psycho-social and pedagogic-ethical. The physical-aesthetic environment refers to the visible materials such as equipment and resources in the classroom, as well as the schedule of activities in the classroom. The psycho-social environment refers to the community atmosphere, communication and interaction, emotions and support for individual mental development; while the pedagogical-ethical environment encompasses classroom management, pedagogy, the curriculum, the overall development of the child and the development of the child as a member of the community (Havu-Nuutinen & Niikko, 2014). Learning environment in ECE not only focus on the materials in the classroom, but also the environment of ECE is closely connected to family and society, which is able to provide opportunities for children becomes an active learner and support children's high-quality learning. (Havu-Nuutinen & Niikko, 2014). Similarly, Sheridan and Samuelsson (2001) from a democratic perspective suggest that the initiative of children to participate and their autonomy in activities are important dimensions of a high-quality ECE learning environment. The degree of participation and autonomy is reflected in the formation of a community of learners among children and with teachers, in which children are expected to develop their own positions based on knowledge and experience and to use dialectical thinking and skills to argue for their positions. This high level of participation and autonomy influences not only children's perceptions of their roles and learning processes, but also the pedagogy and content of activities, shaping the child-centered learning environment. Therefore, in educational settings, teachers need to think about what content or knowledge is important to

children, and to create a pedagogical environment that stimulate children to engage in the activity and interact with others from their own perspectives.

Prochner et al. (2008) conceptualized educational setting as a space where the learning environment reflects the political, historical and socio-cultural context, as well as being influenced by the dialogue between family and school. Meanwhile, Male and Palaiologou (2015) subdivided the school into three components: pedagogy, learners and teachers. And he also introduced the term "community ecology" to categorize politics, history and social culture into two systems: the internal system and the external system. The internal system related to the values, culture, and rituals of a specific region and society, while the external system was concerned with the impact of globalization, policy documents, and evaluation models at the macro level. Pedagogy brings together teachers, learners, local communities and families as a core part of the community ecosystem, located in the overlap between the external and internal systems (Male & Palaiologou, 2015).

In general, taking into account different scholars' definitions of what constitutes a high-quality learning environment in the field of education, I wanted to divide the ECE learning environment into physical environment, psychological, social, and pedagogical. Based on the frameworks mentioned above, this study was centered on pedagogy and linked to social, physical and psychological. The social environment could be divided into two main bodies of family and community members (Male & Palaiologou, 2015).

2.2 Dialogic Pedagogy

A high-quality learning environment can be divided into proximal and distal aspects, in other words, structured and process oriented (La Paro et al., 2012). While language is a concrete expression of dialogue, which is conflictual, partial, ambiguous, perceptual and intentional (Rajala et al., 2013). Because dialogic pedagogy is an approach that considers how people's perceptions change as they

interact with each other in different cultures. The concretization of policies and the process of change in the interaction of subjects in dialogue spaces are therefore part of the high-quality learning environment.

Based on Vygotsky's 'Zone of Proximal Development' (ZPD), Mercer and Littleton (2007) considered that dialogue results from the close connection between human activity and the three dimensions of culture and history, psychology, and society. As a result, people's perspectives are constrained by external and internal factors, and they may converse in different social contexts in different roles and positions. The term loophole was proposed, which means to reserve a certain space for changing the position of one's own dialogue and creating new meanings from the different perspectives of multiple dialogues (Sullivan, 2007). Individual positions and role shifts may lead to conflicts and contradictions during the dialogue process, which is facilitated by interaction and empowerment.

In the theory of dialogue, Bakhtin (Sullivan, 2007) believes that personal development cannot be achieved without interaction with others. He divided the self and the other into three levels: I-for-myself, me-for-other and other-for-me. The me-for-other includes the meaning of me as seen by others, what others think of me or expect and say to me, others come to know me through the world and actions from their perspectives. While other-for-me includes the concept of how I understand others, how do I respond to them and how do I speak to them. I-for-myself refers to the future imagined of self, who do I want to be and who can I be and what opportunities do I have. These three elements therefore form a dynamic triangular pattern. The speaker and the listener become active constructors of knowledge through their participation in a dialogical interaction. The meaning of dialogue between the two parties is open and full of potential and may continue into the future.

Based on Bakhtin's theory, there is a term called chronotope, which attempts to relate the interaction between individuals and others to time and space. “Chrono” original from chronological and it refers to small time that contains three elements: past, present and future while “tope” refer to space that includes both formal and informal learning environments (Erstad & Sefton-Green, 2013). In addition to formal and informal learning, Risku (2022) added non-formal learning to the forms of education, which refers to a purposeful, organized activity carried out by an institution outside the school, but there is no specific accreditation to indicate that the student has completed the corresponding stage of learning. He also argued that informal learning, on the other hand, is not purposeful, there is no organized activity, and it is the result of everyday activities. Therefore, in addition to family and community members, the social components of the ECE learning environment also encompass the informal and non-formal learning environments.

As pedagogy not only puts teaching into practice, but also formalizes it into policy through a combination of practice and theory, and places it in culture (Daniels et al., 2008). The traditional dialogue in formal teaching context has two functions: The first function is for the students to answer the teacher's pre-determined answers and teachers provide feedback, and the second function is for the teacher and students to generate new knowledge through joint construction, forming a meaningful dialogue (Molinari et al., 2013). The Initiation-Response-Feedback (IRF) and Initiation-Response-Evaluation (IRE) patterns are frequently employed as dialogue teaching patterns (Bignell, 2019). Both patterns are in fact essentially the same.

Molinari et al. (2013) were motivated by the desire to capture a broader meaning of the interaction between teachers and students, thus they adopted Initiation-Response-Evaluation (IRE) pattern and to flesh out these three phases. The first phase is the function and form of the teacher's question; The second

phase is dominated by the students and the form, correctness and production of their answers; The third phase is an assessment of the teaching and learning process and the teacher-student relationship (Nystrand et al., 1998). Moreover, Myhill (2006) gives a more specific explanation and classification of the function and form of the question. In terms of the questions form, there are four categories: pre-determined questions; open-ended questions that are hypothetical and imaginative; procedural questions related to class organization and management, and process questions that explain the students' thinking process. And the function of the questions is divided into four categories: The first category is classroom management; the second is related to students' prior experience, where students need to recall facts and information and teachers can give certain clues to gather information for related topics; The third category is to push students to think and develop new ideas; The fourth category is a reflection on the learning process (develop vocabulary or related knowledge and skills and check students' understanding).

Although the structure of the IRE and IRF is fixed, participants can co-create and engage in meaningful dialogue during the response phase through three types of talk structures: the turn-taking (and turn-creation) system; the adjacency pair and the repair (Atwood et al., 2010). Turn-taking (and turn-creation) system as the first order in the conversation sequence relationship, it allows participants to look for the existence of a shared agreement in the process of coordinating and constructing knowledge content in turns. Usually turn-taking involves one or more speakers, in terms of sentence structure, vocabulary and intonation, as part of a turn-taking structure. The allocation of turns can be either by the current speaker choosing the next speaker or by the listener's self-selection, thus achieving a change of identity from listener to speaker. Turn-taking involves a link to the preceding content, a rotation or selection of the current content and a continuation of the subsequent content (Sacks et al., 1974).

Once the participants have negotiated, the speaker and the listener may form associated responses that can be explicit or implicit to specific types of events during the interaction, which belongs to adjacency pair. As the smallest unit in a conversation, an adjacency pair is not sufficient for the speaker and interlocutor to engage in multiple conversations. It has three characteristics: it consists of two discourses; the discourses are adjacent, as the second discourse is caused or determined by the first part of the discourse; and the discourse is produced by different speakers (Nordquist, 2020). Based on these three characteristics, different types of adjacency pairs are formed, such as: offer-acceptances or rejections.

In order to give meaning to the responses in the interaction, participators repair problematic turns or adjacency pair in the conversational interaction to re-establish a common understanding. Yang (2007) make a more specifically explanation in repair phrase from the point view of both the listener and the speaker. The speaker will rectify or supplementary herself or himself, and the listener has three roles in the speaker's repair: active, assisting, and passive. In a positive role, the listener corrects the speaker; in an assisting role, the listener prompts the speaker, for example, by repeating what the speaker has said; and in a negative role, the listener does not respond to the speaker. These three sequential talks are based on interactions based on listening to the ideas of others, and although language is not limited to these three types of conversation in the dialogue process, they can help us to understand how subjects position themselves and their roles in the interaction, and thus how they solve problems and construct knowledge with others through dialogue (Mercer, 2000).

Hennessy et al. (2016) proposed a coding framework with eight clusters to presents the indicators of dialogic teaching in more detail (see Appendix 4). These eight clusters correspond to a dynamic cycle of teacher and student responses and feedback in the dialogue teaching process. Hennessy et al. (2016) also

developed a Teacher Scheme for Educational Dialogue Analysis (T-SEDA) based on this coding framework, which can be used for teachers to reflect on their own teaching at the end of the lesson and to improve the subsequent use of dialogue teaching for different activities. I divided it into four categories: activities, format, evaluation, and plans for the next event (see Appendix 5).

Therefore, dialogue is in fact a mapping of the psychological dimensions of the subject, which prompts participants to think about their own identity in the context of their cultural contexts. While the dialogic approach formalizes and legitimizes teaching and learning, placing the participants in the corresponding context of time, space and social world by incorporating social purposes. Through this way, dialogue pedagogy extend teaching beyond the school and transforming it into education (Daniels et al., 2008).

According to the literature review, I draw on the structures of IRF and IRE to define the dialogue pedagogy. The initiation of the dialogue pedagogy can be classified by the function and form of the teacher's questions. Question functions include new questions, classroom management, elicitation of factual information, interpretation, skills development, relaunch and reflection. And the form of the questions can be divided into six types: authentic, focused, procedural, distributed, substitute and process. (Molinari et al., 2013; Myhill, 2006). (see Apendix 1). The mode of initiation can be used at the beginning of an activity when the teacher wants to change the topic of an activity or when the activity is moving to the next stage.

In general, the dialogue pedagogy uses the function and form of the student and teacher questions as an initiator, the coding framework with eight subsets as a response and feedback process in dialogue teaching. And three types of talk are used to analyze the changing identity roles of teachers and children under interaction.

2.3 Science Education in Schools

Cohen (1952) has argued that traditional science education focuses on giving students a lot of material to memorize and giving the curriculum certain functions that can be applied to society in the future. However, such rote learning is likely to be forgotten by students in the coming years. He believes that science education in 21st century should be a community-based social practice, and that if the content of science education is based on students' interests and on what they have learned and experienced, it will be continuous and creative, and will help students to develop a more comprehensive understanding of knowledge. Thus, different scholars have provided different definitions of how to define and form a continuum of science education.

As science education is concerned with the subject's perception of phenomena arising from the objective world. In other words, objective knowledge interacts with subjective knowledge (Osborne, 2007). This is corresponding to the ecological framework for learning. This ecological framework divides education into relational and co-constructive education. Relational education separates knowledge from practice and emphasizes conceptual understanding, that is, the cognitive dimension of learning, whether it is acquired or constructed. Teacher acting as a transmitter of knowledge (Bayliss & Dillon, 2010).

Co-constructive education, on the other hand, considers that the meaning generated by the interaction between people and their environment is fluid, and information is integrated with lived experience in processes that involve the continual construction, deconstruction, and reconstruction of knowledge. In co-constitutional transformations, situations ‘emerge’, behaviors and environments co-construct each other, and things happen ‘in the moment’ (Bayliss & Dillon, 2010). Scott et al. (2011) divided science education into macroscopic and microscopic. The former refers to the experiences of students in their daily lives

and to the concrete phenomena around them, science is relevant to their surroundings and to society, while the latter refers to the more abstract and theoretical terms of science. They also examined the function of dialogue in secondary science teaching and provided a matrix to distinguish between different types of communication. These four types of communication essentially reflect the power structures of teachers in teacher-child interactions, with interactive/ dialogue being a low control structure, non-interactive/dialogue and interactive/ authoritative being a medium control structure, and non-interactive/ authoritative being a high control structure. At the same time there are three forms of establishing pedagogical links in science education: Support knowledge building that involves conceptual, expressive and cognitive aspects; through macro, meso and micro these three-time scales to promote continuity. Micro refers to the connections made in a short period of time, which can be a few minutes, within a lesson; the meso level refers to the sequence of lessons, usually involving days and weeks as a unit of time; the macro refers to the different parts of a whole lesson, usually in months and years as a unit of time; encourage emotional engagement, which refers to the child's voluntary emotional state based on prior experience and stimulated by certain stimuli (Scott et al., 2011).

Lewis et al. (2014) proposed a scientific model of classroom discourse communities. In this model, the four areas of teaching, learning, writing and language development (everyday language and academic language) are listed to support children's learning process in science activities, mainly from the teacher's perspective. The details of this model can be found in the Appendix 6.

In the light of the above, I would like to divide science education into a macroscopic and a microscopic in my research (Scott et al., 2011). The former refers to the introduction of science into everyday life and the social environment, where the daily experiences of students and the phenomena associated with the

environment and society are at the macro level. The latter refers to theories related to science. The macro and micro dimensions of science education were ultimately presented in a multimodal way. Teachers and students could think about the connections between two types of knowledge and create a continuum of science education by using the three temporal scales of micro, meso, and macro as well as the four modalities of communication.

3 RESEARCH TASK AND RESEARCH QUESTIONS

The study aimed to comprehend how the current patterns of science education works and corresponding teacher-student interactions in ECE in China by using dialogue teaching patterns. The study applies the dialogue teaching indicators listed by Hennessy et al. (2016), the four communication modalities, three-time scales, and the sequences of three talk structures were utilized to analyze the shifting roles of teachers and students.

With a primary focus on the classroom level, the aim is to examine whether the pedagogy at the child center could be linked to the physical, social, and psychological elements and, if so, how the four elements of a process-based, high-quality learning environment in ECE interact and influence each other.

Therefore, this study aims to answer the following research questions:

1. What are the forms and functions of teachers' questions in science education?
2. What kind of talk structures of student-teacher before and after the use of the dialogue method, with whole-class activities?
3. What are the extensions of student dialogue when using different dialogue teaching strategies in science education?

4 RESEARCH IMPLEMENTATION

4.1 Research Context

Nowadays, most teaching theories are abstract and generalized, as Guba (1990, p.90) stated, current concepts and teacher training do not correspond to what is needed in practice, most of them are difficult to apply in practice, and teachers lack the necessary support. As a result, I was wondering to find out the challenges that teachers are facing in authentic teaching scenarios.

In 1978, China's transition from a planned economy to a market economy represented a shift from a central government-only policy to one where more individuals and enterprises were considered to be part of the policy making process (Miller, 2018, pp.165-179). The emergence of a market economy has led to a diversification of subjects, the government has delegated to each region the authority to develop its own educational documents in accordance with the national educational framework. Schools develop their own unique curricula based on the educational documents developed by the regional government, and teachers are required to follow the school's curricula in their teaching activities (Mok, 2013).

ECE education in China is divided into five main areas: health, language, social, science and art. (Ministry of Education of the People's Republic of China, 2012). This national document covers the developmental levels of children aged 3-6 years under the five domains of the ECE. In terms of science activities, which are subdivided into two themes: mathematical learning and scientific exploration. The ultimate aim of both types of science activity is to be able to apply them to real life and to solve practical problems. It is also mentioned in the document that science education is not only about developing children's scientific attitudes and learning habits, but also about the development of relevant competences in the process of practice. These competences are transferable.

4.2 Research Participants

I chose three female teachers who have bachelor's degrees and had been trained in science education at university. Two of the teachers graduated from the same university as me, and one of the female teachers worked in the same kindergarten as me. So I contacted each of the three teachers by email and found out that their kindergartens used the thematic curriculum model in which art, language, science, health and social were integrated into the corresponding thematic lessons.

4.3 Action Research and Data Collection

To get a more realistic picture of the pattern of science activity under the ECE in China, I adopted action research as my methodological approach and thematic analysis as my data analysis.

Depending on the role of the researcher and participant, there are two types of Action Research: Practical Action Research (PAR) and Participatory Action Research (PAR) (Altrichter et al., 2002).

Practical Action Research is typically a series of activities and workshops led by researchers that focus on more detailed, specific, domain- and situation-specific data on issues. In participatory action research, however, there is no clear distinction between the researcher and the research subject; they all participate in the research discussion together and are treated equally, thus the term democratic research. This democratic research, in other words, is problem-oriented, combining the theoretical knowledge and experience of the researcher and the practical knowledge of the participants in a collaborative way. In this collaborative research model, the participant and researcher form a cycle of planning-practice-reflection-planning, in which the problem orientation is in fact a mutual awareness and constant adjustment in the context of the complexity of the local community's surroundings and facilitating transformation. (Tracy, 2019, pp.56-58). This model of democratic research breaks with the researcher-driven

model and changes the role and relationship between researcher and participant. In this egalitarian model, participants are better able to recognize issues that they are not aware of daily and to make changes.

Therefore, in this study, four steps were taken. The first step was to collect weekly activity plans from each classroom for the previous weeks. The second was for each teacher to help me record the audio of the pre-intervention science activity. The third session involved me and the teachers discussing the definition of dialogue coding. The fourth session was the reflection session.

Due to the epidemic situation in China, this study was conducted online. Data were collected from September to October for the 3–4-year-old class and from October to December for the 4–5-year-old and 5-6-year-old classes.

These three teachers were now teaching children aged 3-4, 4-5, and 5-6. The study involved three classes of three teachers and a total of 94 children. There were 30 children aged 3-4 years; 25 children aged 4-5 years; 39 children aged 5-6 years in total. All of the science activities are conducted as whole class activities. In the 3–4-year-old class, however, for the 'Leaves' science activity, the teacher divided the children into two groups of 15 children for the leaf observation session. During the 'rainbow candy' experiment in the 4–5-year-old class, the teacher divided the children into groups of five, each with five children, to observe the changes in the candy and the children debated which cuisine was the most popular during the 'local food' activity. The four sessions in the 3–4-year-old class lasted 66 minutes, the four sessions in the 4–5-year-old class lasted 80 minutes and the four sessions in the 5–6-year-old class lasted 128 minutes. The three classes have a total of 12 activities and 274 minutes.

4.4 Data Analysis

With an attempt to be able to transcribe the classroom activities into textual patterns, the teacher's conversations in whole class activities were coded as T, the children's conversations were coded as S (whole), and the children's

conversations were coded as S1, S2, S3..., making it easier to identify the teacher's conversations with the children in the classroom without revealing the children's personal information.

4.4.1 Weekly Activity Plans And Editing

I asked each of the classroom teachers for their weekly activity plans, through which I was able to get a general idea of the kindergarten's curriculum model and what the children's previous relevant experiences had been. The weekly plan showed that the 3-4- and 4–5-year-old classes were theme-based curriculum, while the 4–5-year-old class did not have a specific curriculum model but had specific textbook for activities. However, the curriculum activities in all three classes were split up into distinct subject activities under the same theme.

To see what the science activities looked like in each of the three classes, I asked the classroom teachers to record the science activities under the corresponding themes. In the pre-intervention science activities, the 3–4-year-old class had the theme of falling leaves; the 4–5-year-old class had the theme of colors; and the 5–6-year-old class chose the theme of teeth based on the textbook.

4.4.2 Activity Intervention

Before the activity intervention, I utilized online meeting software to elucidate the definition of dialogue pedagogy and engage in a discourse concerning the definition of each dialogue pedagogy and the specific content categorized under its corresponding category with three teachers. The discussion enabled us to establish a common understanding of the definitions of the dialogue categories. As a result, the teachers were able to implement various dialogue teaching methods based on the developmental level of their students and the goals of the activities.

The three classroom teachers and I decided to further divide the Hennessy et al.'s (2016) dialogue pedagogy into three different categories, taking into account the different developmental levels of the children at different ages. The first classification of the dialogic approach included: Build on idea (B), Invite

elaboration or reasoning (I), Express or invite ideas (E) and Make reasoning explicit (R). We had combined E with I, because the dialogue pedagogy of E had the same meaning as the categories in I. In this classification, the teacher inviting and guiding the children in a way that enabled them to elaborate and reason with the ideas of others, based on their own position. And children's thinking might extended beyond the classroom as they sought further evidence from both inside and outside the learning environment to articulate one or more possibilities.

Based on the first classification, the second classification included the following pedagogies: Connecting (C), Positioning and Coordinating (P), and Guide direction of dialogue or activity (G). The first pedagogical approach (C) expanded in time and space, with the teacher and learner bringing past and present experiences into the present and thinking about the future direction of activities in the context of different activities within the classroom and outside the school environment. Once one's own position was clear, the second pedagogy (P) referred to the ability to integrate and link diverse perspectives. In contrast to the first category, this pedagogy involved the development and change of the subject's awareness of the role of self and others, where the interaction between the subject increased the challenge of the position of others and attempted to propose solutions and translate ideas into action. The third pedagogical approach (G) combined the first two approaches but is more directed and guided, with the teacher providing timely feedback during the activity and introducing authoritative perspectives to facilitate the construction of knowledge in the dialogue, as well as supporting further discussion of the specific activity by assessing the child's current level of development and the direction of development before the classroom activity, and generating new directions for the activity.

The last classification of dialogue pedagogy included: Reflect on dialogue or activity (RD) addressed dialogue skills and metacognition. Metacognition

encompassed more than just cognitive and emotional processes, as it also involved considering learning from various perspectives during dialogues, which helped individuals gain a deeper understanding of their own role and the roles of others. For the cognitive development of children in science activities, we used the 3-6 years learning and development guidelines as a reference (Ministry of Education of the People's Republic of China, 2012).

According to the Learning and Development Guideline for Child Aged 3-6, for science activity, children in 3-4-year-old class were mainly interested in their own experiences and perceptions in science activities, they were able to look closely at things that interest them and discovered their distinctive features. In the 4-5-year-old class, children in this age group entered a stage of hands-on exploration based on their own interests and were able to observe things and made initial comparisons to discover similarities and differences. They were no longer limited to superficial discoveries of phenomena or things around them but were further able to discover how things change and how these changes affected things around them, which was the basis for dialectical thinking. In contrast to 3-4- and 4–5-year-olds, 5-6 years old children needed to be able to describe the characteristics of different kinds of objects and changes before and after through observation, analysis, and comparison, and to develop an initial understanding of the connections between things through perception and investigation. They were also able to plan and carry out investigations with the help of adults and to use a variety of symbols to record and verify their guesses (Ministry of Education of the People's Republic of China, 2012).

Therefore, after discussion, the classroom teachers in 3-4 years old and I have divided the thematic lesson on leaves into the 'Life Science' category of science, which has six sub-themes: physical characteristics of organisms, basic needs of organisms, simple behaviors, life cycles, change and diversity and interrelationships between organisms and the environment. Taking into account

the children's prior experiences, the classroom teacher and I focused on the physical characteristics of living things and the sub-themes of change and diversity to deepen the topic of falling leaves in the post-intervention program. The physical characteristics of organisms included the color, shape, structure, and different components of plants and animals, which were easy to observe. Children could classify organisms in their way, and the teacher allowed them to describe and observe the diversity of organisms through further questioning and discussion.

The class teacher chose the 'Connect' approach in all post-intervention activities, which focused on enabling children to bring their own past experiences into the curriculum activities and, to a certain extent, invites children to make inquiries and investigations outside the curriculum. In the two sessions of the leaf theme, the class teacher first picked up some leaves from the kindergarten and brought them back to the classroom and provided magnifying glasses for the children to observe in groups for five minutes and also asked parents to take their children to collect leaves from their homes or the park at the weekend and brought them back to the classroom for sharing and discussion, but only three children brought leaves to the class. In the sport theme, the teacher used sports-related picture books as well as talked to them about the movements they were familiar with and the corresponding postures.

The class teacher in 4-5-year-old class decided to use the "Build on ideas" approach to help children learn to listen to others and to draw from and integrate the ideas of others to form their own ideas, which was not only a learning process in which children actively learn and develop a unique understanding of knowledge, but also promoted the integration and distillation of related ideas. The teacher also used the 'Invite ideas' approach as an extension of building on ideas, which required the teacher to guide the students in order to support their development. While the third and fourth lessons followed the school's theme of

the month, with a theme related to local food. As the topic involved knowledge from outside the school and as there are many different types of local food, it was not possible to discuss all the foods in the classroom activity, so the teacher replaced the ‘Invite ideas’ with ‘Connect’.

In the rainbow candy theme, the teacher shifted the focus of the teaching objective from explaining to the children how the water dissolved the rainbow candy to allowing them to observe the changes in the water and letting them choose their own experiment materials and designed their experiment procedures. Based on the shift in teaching objective, the teacher provided the children with the experiment materials in the form of pictures without telling them the steps of the experiment. When describing the experimental steps, the children described their thoughts in a complete sentence as well as predicted the process of the experiment by following the teacher's verbal instructions " to put... first... , then put...".

For the local food theme, the teacher handed out a questionnaire to each parent before the activity started, which included information about the places they had visited and the local food they had eaten. The teacher also provided an option sheet with the corresponding food items so that the children could check off the group's favorite food items. Teacher also gave more verbal clues such as appearance, taste and shape so that the children can explain their choice of food from the verbal clues provided by the teacher.

From the perspective of student, the class teacher in 5-6 years old adopted 'Make reasoning explicit' strategy to enable children to transfer knowledge from the external environment to bring it into the classroom and to further develop skills such as listening to others and reasoning, guessing, etc. From the perspective of teacher, 'Positioning and coordination' strategy was adopted, where the teacher synthesized and distilled multiple views and ideas, but also acted as a scaffold to help children compare and contrast similar and different

points of view, challenging children's views at appropriate times, giving reasons for agreeing or disagreeing to stimulate further discussion, thus facilitating negotiation and consensus. Because the third and fourth activities were restricted by the school, the teacher had to select two of the lessons with the materials provided by the school. Thus, the teacher replaced 'Making reasoning explicit' with 'Connecting '. In addition to combining children's existing experiences with current classroom activities, different types of activities were integrated, and attempts were made to extend the curriculum activities outside of school and to make connections.

Under the theme of teeth as well as the theme of maps and recognizing geometric shapes, teachers provided a variety of materials including models of teeth, geometric models, and road maps.

4.4.3 Reflection Session

The reflection section started with teachers and me discussing the objectives of the activity. By considering the objectives, we were able to determine which aspects of the activity were appropriate for the developmental stage of the students in the class. The next step was evaluating the process, which involved assessing whether the teacher expected the activity to go smoothly and identifying which parts of the activity were unpredictable or challenging.

In the 3–4-year-old class, the teacher mentioned that as she had taught 5–6-year-olds the previous year, the focus of the pre-intervention activities was on enabling the children to sort leaves. However, during the activity it was found that the children were only able to respond simply to the pictures provided by the teacher. The post-intervention activities therefore provided a lot of real materials, and the children had more responses, and their non-verbal expressions were more varied in relation to the themes that related to their daily lives.

In the 4–5-year-old class, the teacher found that in the more hands-on science activities, when she allowed the children to experiment in a variety of ways, the children began to use their own ideas in their conversations and were able to add

or replace materials on their own. However, in the theme of local food, which was arranged by the school and many of the children's parents were moving from other cities. Therefore, most of the children were not familiar with the local food, so the teacher had to provide as many prompts as possible for the children to discuss.

Also due to the time constraints of the classroom activity, the session of voting for the most popular food had less time for children to discuss it, many children only answered with their favorite food. In future activities, teachers may consider placing these voting activities in activities area in the classroom, which would allow more time for children to discuss on their own or with their peers.

In the 5–6-year-old class, the teacher noticed during discussions that the children were weak in listening to others' ideas, so she added the objective of listening to others' ideas to the post-intervention activities. By using language instruction, the teacher felt that the children were able to form more comprehensive responses in the post-intervention activities, considering both their own experiences outside the classroom and the responses of others. At the same time, the students also developed additional skills like critical thinking, making assumptions about things, and categorizing what others have said. However, teachers didn’t have any better ideas on how to actively involve families in classroom activities.

4.5 Data Analysis

Thematic analysis is one of the research methods of qualitative research and it is not restricted to a fixed research paradigm. Thematic analysis embodies constructivism, as it is not only a description of the data, but also involves the researcher in the process of coding selection and the elaboration of themes through coding. The processes of selecting codes and forming specific themes from them correspond to deductive and inductive coding frameworks respectively (Kiger & Varpio, 2020).

Deductive methods use pre-existing theories and the interests of other researchers to generate themes. The data collected under these themes allows for shared, as well as surface-level, interpretations based on pre-existing theories. While an inductive approach requires the researcher to code data themes according to social context and the context of the text, previous theoretical research can also help the researcher to code the data as they are analyzed, and through continuous categorization and integration eventually form multiple sub-themes, which will eventually form a global theme. These sub-themes and the global theme are independent, and the texts, sub-themes and global themes are interconnectivity, revealing the overall meaning of the content in the context of the dialogue, as well as a wealth of examples to illustrate the themes. (Kiger & Varpio, 2020).

As the traditional dialogue in formal teaching context has two functions: The first function is for the students to answer the teacher's pre-determined answers and teachers provide feedback, and the second function is for the teacher and students to generate new knowledge through joint construction, forming a meaningful dialogue (Molinari et al., 2013). In the process of collecting data, I discovered that before using the dialogue pedagogy in the science activities, the teachers applied questions with pre-determined answers at the start of the activity and there were fixed patterns of teacher-child interaction in the whole-class activities, which is similar to the first function of dialogue. As a result, in my study, I referred to the structure of Initiation-Response-Evaluation (IRE) (Bignell, 2019) and combined it with Hennessy et al.'s (2016) coding framework. As mentioned earlier in the second function of traditional dialogue, dialogue in the IRE model was not haphazard, but had a sequence and a meaningful dialogue through co-construction of knowledge. Thus, in the response phase, knowledge was co-constructed through three talk structures: the turn-taking (and turn-

creation) system; the adjacency pair and the repair (Atwood et al., 2010), resulting in a meaningful dialogue.

Therefore, in my study, deductive coding was applied to the research question one and two. Research question one pertains to question forms and functions of the teacher, while research question two pertains to the talk structures between teachers and students before and after the teacher employed the dialogue teaching strategy. The analysis of question function and form of the teacher helped me to understand the current patterns of interaction between teachers and students in real teaching situations. The analysis of the structure of the talk structure revealed the changing roles of the teacher-student dialogue and the ways in which the two subjects, teacher and student, were influenced by the environment in which they engage in meaningful dialogue (Ceci, 2006). The definitions of the function and form of the teacher's question and the talk structure could be seen in see Appendix 1 and 2.

The inductive coding process was applied to the research question three, which refers to the extension and expansion of the child's dialogue after the teacher had employed the corresponding dialogue pedagogy strategies (Hennessy et al., 2016). This coding process was conducted during the response phase of the IRE pattern as well and was complemented by the teacher's reflection on the activities, which pertained to the evaluation component of the IRE pattern. The teacher's activities were divided into four sections: Objectives, Preparation, Process and Reflection. The activity process was divided into three parts: introduction, formal process, and end of activity, so in the inductive analysis I analyze the raw data according to these three parts. The raw data is in conjunction with the discourse in inquiry science classrooms model (Lewis et al., 2014).

4.6 Ethical Solutions

As there was only one teacher conducting the science and other activities in each session, the data was collected by means of audio recordings, which may have resulted in my not being able to observe the non-verbal information of the teachers and children more fully.

Another way of collecting data from the recordings is that I may not have been able to hear some of the children's responses clearly, so I needed to listen to the recordings several times and to record the ambiguous parts in text form, marking which parts of the recording were ambiguous and asking the teacher what the child's responses were at the time. The reflection from teachers was also very useful in helping me to understand the content of the activities, as it contained the teacher's reflections and summaries on the content of the course activities.

In accordance with the ethical considerations involved in the research community, I began the study by describing the topic, purpose, and content of the study in detail to three teachers who expressed interest in the topic and were willing to participate in the study after learning about it. I therefore sent the informed consent forms (University of Jyväskylä, 2022) to each of the three teachers before the study began. As the study focused on the impact of teaching strategies on teacher-child interaction in educational activities, the children in the classroom were also taken into account in the activities.

However, as the children were under 15 years of age, the activity was not carried out until the teacher had communicated with the class and the children had agreed to participate in the study. In this study, I anonymized the children's information and followed the principle of minimization by anonymizing important personal data and using generalized nouns to represent the other children's conversational data (Tuuli-Project, 2018). The child's name was replaced by the full name using an alias, the generalized noun “W” for group

activities to indicate the responses of the whole class and the generalized noun "G" for group activities to indicate the responses of the children in the group.

Participants were not physically or mentally harmed in this study, nor did the study cause harm to participants or their family members. Participants could suspend or withdraw from the study at any time during the study. Children had the right to freedom of expression, to choose, to transmit and express information and ideas on their own, and my classroom teachers and I always respected the autonomy of children to participate in the research and adopted the principle of voluntary participation. The research data was used for research purposes only and will not be used for other purposes. The data was destroyed immediately at the end of the study. All research data was used to assist me and the classroom teachers in the improvement of the program and therefore no information about the teachers or the children will be divulged.

5 RESULTS

The presentation of the research results was in line with the research questions. The first part of the result presented the function and form of the teacher's questions before and after implementing the dialogue pedagogy; the second part presented the talk structures between the teacher and the students before and after the dialogue pedagogy intervention; the third part presented the results of the extended dialogue among the students in the three classes before and after the intervention in the transcribed text.

5.1 Question Functions And Forms Used By The Teachers

The form and function of the teachers' questions were depicted in bar charts. The blue bars illustrated the distribution of questions before the intervention, while the other colored bars represented the distribution of questions in the post-intervention activities, indicating the changes that occurred. The discussion section provided further explanation for the reasons behind these changes, but the data from the post-intervention activities could be viewed as a whole.

5.1.1 Question functions used by the teachers

In the pre-intervention activities, the teachers in the 3-4- and 4–5-year-old classes primarily utilized factual elicitation. Additionally, the teachers in the 4–5-year-old class employed elaboration and reflection to a certain extent. Conversely, the teachers in the 5–6-year-old class predominantly employed elaboration and also employed classroom management and factual elicitation to some degree.

In the post-intervention activities, teachers in the 3–4-year-old class raised new questions and elaboration twice as much as in the pre-intervention period. Additionally, there were slight increases in classroom management, skills practice, and reflection, while the number of factual elicitation questions decreased.

In the 4-5 years old class, teachers continued to employ more questions with factual elicitation, with minor increases in relaunching the same question to different children, reflection, elaboration and asking new questions in sessions two and three, but a decrease in these four question types in session 4.

Similarly, teachers in the 5–6-year-old classroom primarily utilized factual elicitation questions, but there were significant increases in three types of questions: elaboration, relaunching the same question to different children, and inviting children to practice skills in session three, and a decrease in these types of questions in session four. There was a slight increase in the types of questions that prompted children to reflect and ask new questions.

Figure 1

Questions functions for teachers in 3-4-year-old class

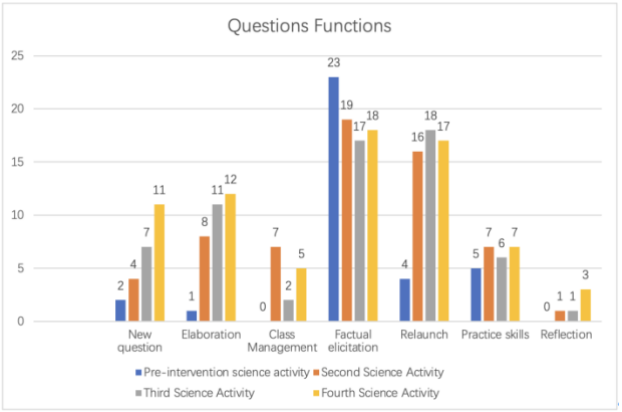


Figure 2

Question function for teachers in 4–5-year-old class

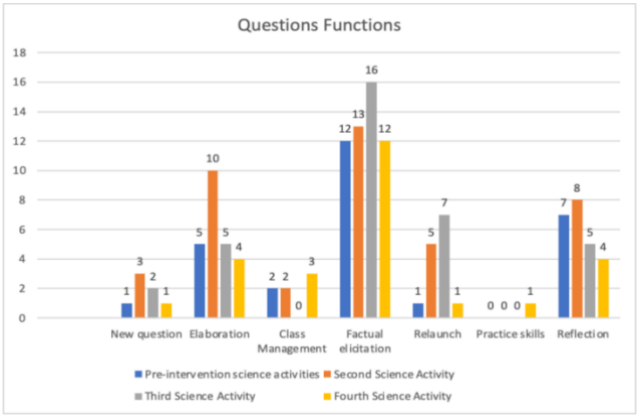
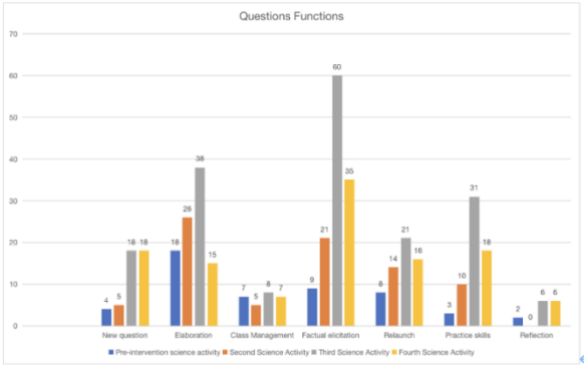


Figure 3

Question function for teachers in 5–6-year-old class



In the 3-4 years old classroom, the pre-intervention activity, teachers' questions were mainly factual elicitation, with a total of 23 occurrences, whereas in the post-intervention activity, although teachers still cited more factual information, there was a significant increase in the number of times teachers assigned the same question to different children, total of 22 and 31 respectively. There was also an upward trend in the number of post-intervention activities in which the teacher asked new questions and asked the child further questions about his or her ideas.

The number of sessions in which teachers invited children to practice relevant skills and reflect on them was low in both the pre- and post-intervention activities, but there was a small increase in skill practice in the post-intervention activities (see Figure 1).

In the 4-5 years old classroom, teachers' use of questions to elicit facts was the highest in the pre- and post-intervention classroom activities, while practice skills were the lowest in the four science activities.

Also, in the post-intervention activities the teacher increased the number of times inviting the children to elaborate their ideas, 19 times in total, and the number of times the teacher invited children to reflect on the learning process also increased somewhat, to 17. Similarly, teachers relaunched the same question to different children more times than in the pre-intervention activity, 13 times in total. In the second activity, the teacher invited the children to elaborate their thoughts and reflect on their learning process 10 times and 8 times respectively.

The number of times teachers asked new questions in the post-intervention activities increased compared to the pre-intervention activities, but the number of times they appeared in each of the three post-intervention activities was low.

Classroom management occurred similarly in the pre- and post-intervention activities, while the number of times teachers invited children to practice relevant skills through questions was minimal in the pre- and post-intervention activities (see Figure 2).

In the 5–6-year-old classroom, teachers invited children to elaborate most in the pre-intervention activities while teacher cited factual information most often in the post-intervention curriculum activities, a total of 116 times.

The number of times teacher invited children to elaborate on their ideas increased in the post-intervention sessions, with a total of 79; Teachers also asked more new questions, invited more children to express different ideas about the same content and developed skills related to the teaching objectives, with a total of 41, 51 and 58 in the post-intervention activities.

However, classroom management and invitations to reflect were less frequent in the pre- and each of the post-intervention activities. And all seven of the teacher's question functions reached their maximum in the third activity (see Figure 3).

5.1.2 Question forms used by the teachers

In the pre-intervention activities, the 3-4 years old and 4-5 years old classroom teachers used mostly closed questions. The 3-4 years old classroom teachers also used procedural questions related to classroom management and assigned questions to different children, while the 4-5 years old classroom teachers used a combination of authentic and process questions. The 5-6 years old classroom teachers primarily used process questions, with a smaller proportion of authentic, procedural questions related to classroom management and distributive questions, and fewer focused questions.

In the post-intervention activities, teachers in the 3-4- and 4–5-year-old classes used fewer closed-ended questions. In the 3–4-year-old classroom, teachers increased the number of questions assigned to different children and the use of authentic questions to ask further questions about the activities process. Similarly, teachers in the 4–5-year-old classroom increased the use of process and authentic questions, with both types of questions being used most frequently in session two and distributed questions most frequently in session three.

Figure 4

Question forms for teachers in 3-4-year-old class

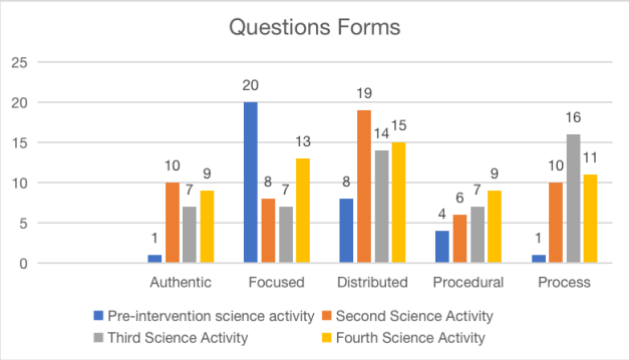


Figure 5

Question forms for teachers in 4–5-year-old class

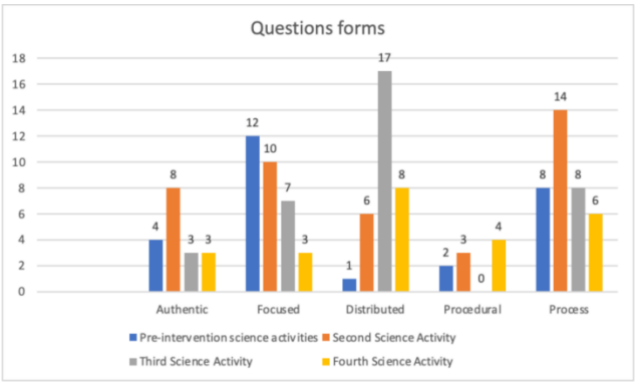
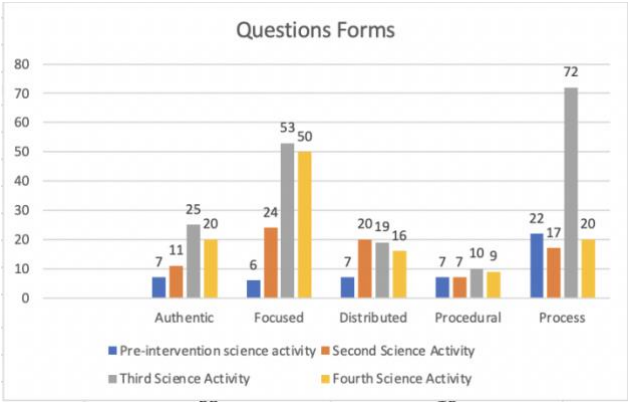


Figure 6

Question forms for teachers in 5-6-year-old class



In the 3-4 years old class, most of the pre-intervention activities consisted of teachers asking questions with only one answer, as many as 20 times. In the post-intervention activities, the teachers were more likely to assign the same question to different children, with a total of 48 occurrences, with the highest number of times being 19 in the second activity. Process questions were second in number to distributional questions, appearing 36 times in total, with the third course activity having the highest number of process questions at 16.

In the post-intervention activities, the number of teachers' authentic questions increased in the post-intervention activities to a total of 26, while focused questions appeared less frequently in all three post-intervention activities than in the pre-intervention activities. The number of questions related to classroom management was showing an upward trend for each activity before and after the intervention (see Figure 4).

The teacher in the 4-5-year-old pre-intervention activity used questions with only one answer, whereas the teacher in the after-intervention activity was more likely to engage students in conversation by assigning pre-determined questions to different children, with the highest number of occurrences in the third activity.

Authenticity and process questions were used most frequently by teachers in the second activity, 8 and 14 times respectively, but decreased in the third and fourth activities. As can be seen in the focused questions corresponding to the real questions, although the number of questions in which teachers used unique

answers decreased in the post-intervention activities, they still appeared more frequently in the post-intervention activities.

The number of procedural problems related to classroom management was relatively low in both the pre-intervention and post-intervention activities, with a total of 2 and 7 times respectively (see Figure 5).

In the 5–6-year-old pre-intervention activities, teachers invited children to describe their learning process more often, but in the post-intervention sessions questions with only one answer were asked most frequently, with a total of 127 occurrences, with the third and fourth activities having the highest number of focused questions, 53 and 50 respectively.

The authenticity and distribution questions showed a small increase in the number of post-intervention activities for the children, with a total of 56, 55. Process questions were only highest in the third post-intervention activity, at 72, and fewer in the second and fourth than in the pre-intervention.

Procedural issues related to the classroom were less frequent in the pre-intervention as well as in the post-intervention activities (see Figure 6).

5.2 Talk Structures Between Teachers And Students

If we only consider the changes in the structure of teacher-student talk in the pre-intervention and post-intervention activities, we could see that the number of all three talk structures increased in all post-intervention activities in the 3–4-year-old class. In the 4–5-year-old class only the repair type of talk showed an upward trend in the post-intervention activities, and also in turn-taking and adjacency, but in the fourth activity. In all the post-intervention activities with the 5- to 6-year-old class, the quantity of all three talk structures increased, with the third activity showing the most apparent rise.

However, there was a slight increase in the number of repair conversations between students and teachers in the 4–5-year-old class, as well as an increase in the number of teacher-adjacency talks in sessions 3 and 4 activities in the 5–6-

year-old class. Teacher-initiated talk still predominated in both the pre- and post-intervention activities in all three classes.

Figure 7

Talk structures in 3-4-year-old classroom

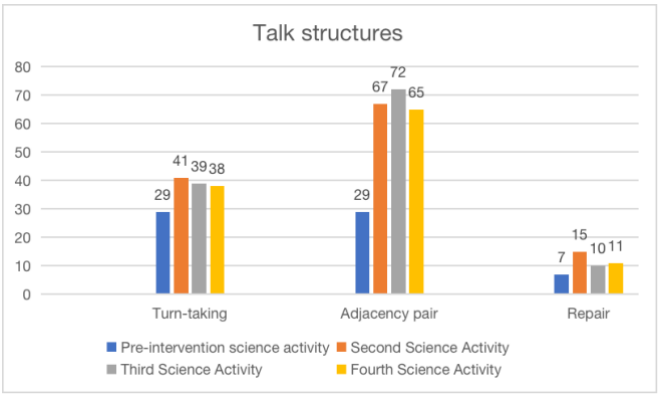


Figure 8

The talk structure corresponding to the teacher and students in the 3-4-year-old. classroom

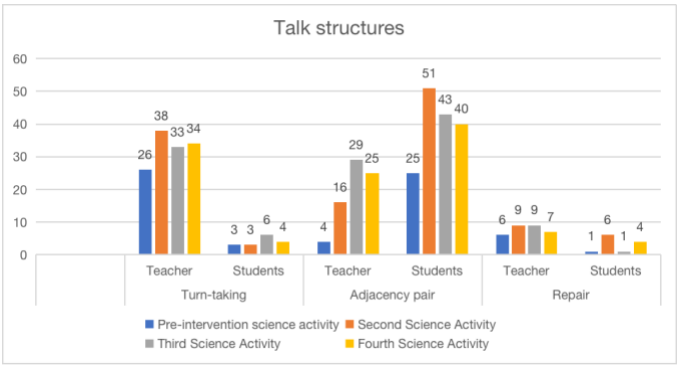


Figure 9

Talk structures in 4–5-year-old classroom

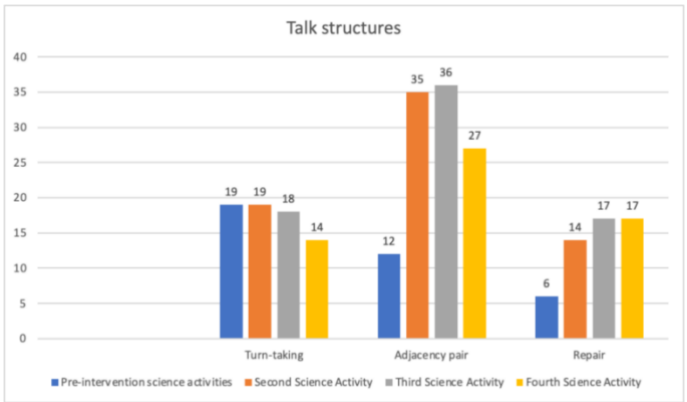


Figure 10

The talk structure corresponding to the teacher and students in the 4–5-year-old. classroom

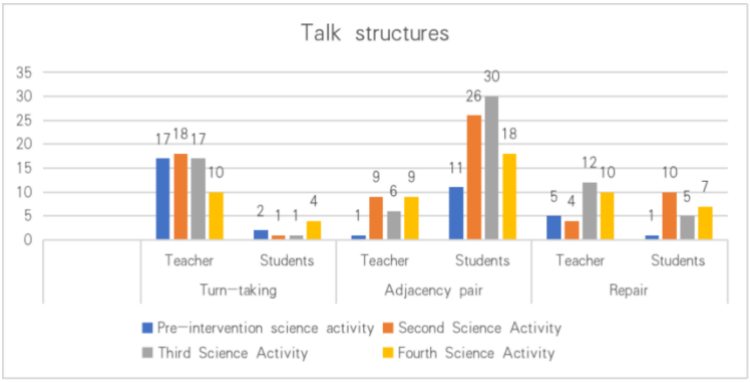


Figure 11

Talk structures in 5–6-year-old classroom

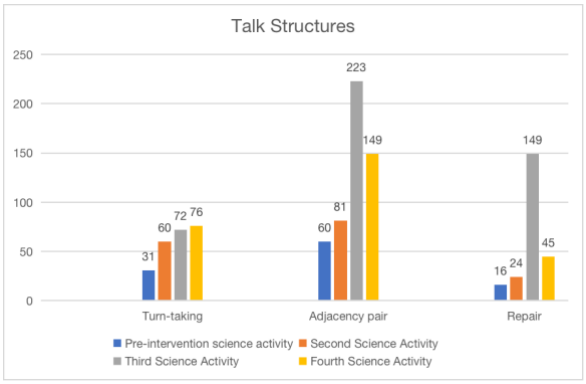
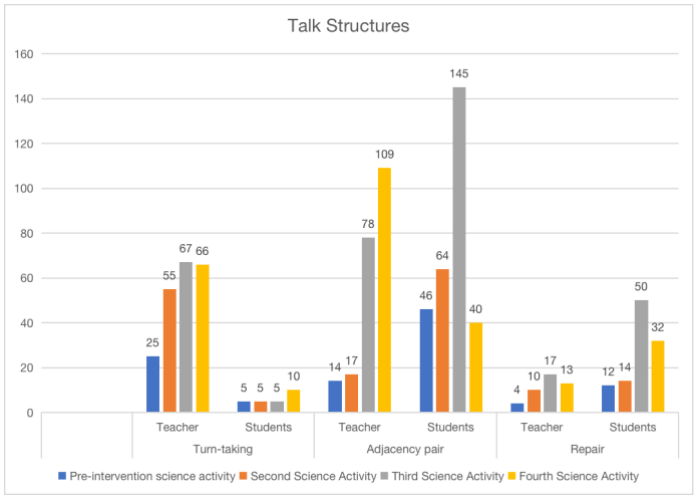


Figure 12

The talk structure corresponding to the teacher and students in 5–6-year-old. classroom



In the 3-4-year-old classroom, turn-taking and adjacency pairs were present in the same number of times in the pre-intervention activity, 29 times each. In the post-intervention activity, there were the highest number of adjacency pairs, with

204, followed by turn-taking, with 118. Repair, on the other hand, appeared less frequently in both the pre-intervention and post-intervention activities, appearing seven times in the pre-intervention activity and 15, 10 and 11 times in the three post-intervention course activities respectively.

Although the number of turn-taking and adjacency pairs was the same in the pre-intervention activity, the former was dominated by the teacher initiating a new topic, with the teacher initiating turn-taking 26 times and the students initiating the topic only 3 times, while the latter showed the opposite situation, with the students responding to the content of the previous conversation 25 times compared to the teacher's 4 times.

Similarly, in the post-intervention activity turn-taking was still dominated by teacher-initiated talk, with the corresponding numbers of teacher and student-initiated talk rounds being 105 and 13 respectively. Although there was a small decrease in the number of adjacency pairs between the three activities, the students' role in the activity was still dominated by responding to the content (see Figure 7 and Figure 8).

In the 4-5-year-old classroom, the turn-taking discourse structure dominated among four activities. The post-intervention activities were dominated by the adjacency pair type of talk, with a total of 78 sessions, while the repair talk also increased in the post-intervention sessions.

Although the teacher tried to reduce the initiation of the control wheel in the post-intervention activities, a small reduction in the teacher's turn-taking to 17 and 10 in the third and fourth activities, respectively, can be seen. The reduction in the teacher's turn-taking can be seen in the increase in the number of articulated conversations with the students, as can be seen from the graph that when the teacher's adjacency pair talk decreases, the number of students' adjacency pair talk increased, and vice versa.

The use of the repair talk structure by the teacher and students increased in the post-intervention science activities, but this did not represent a significant increase of the three talk structures (see Figure 9 and Figure 10).

In the 5–6-year-old class, the conversational structure of the adjacency pair was presented most frequently in the pre-intervention and post-intervention activities, with a total of 60 and 453 times respectively. The number of all three talk structures in the 5-6-year-old classroom tended to increase, with the third classroom activity being the highest in both types of talk structures, namely, adjacency pair and repair.

In the pre-intervention activity, turn-taking was dominated by the teacher, and the students' conversation types were mainly adjacency pair talk based on the teacher's or others' conversations. Although the number of teacher-turn-taking conversational structures also tended to increase in the post-intervention activities, the increase was more pronounced in the type of adjacency pair talk, especially in the third and fourth activities. However, in the fourth activity, the number of conversational structures of the students' adjacency pair did not increase with the increase of the teacher's adjacency pair talk, but on the contrary, it showed a decreasing trend.

The number of repair conversations in the pre-intervention activity was higher for students, 12, compared to 4 for teachers. In the post-intervention activity, although the number of teacher-repaired conversations increased, the overall number of student-repaired conversations was higher than that of the teacher, with a total of 96 (see Figure 11 and Figure 12).

5.3 Extension Of Student Dialogue Of Pre- intervention And After Intervention

In this part, inductive analysis of thematic analysis was utilized to see whether the content of students' conversations changed before and after the teacher applied the dialogue pedagogy (original text see Appendix 3). This contributed

to the modifications in the function and form of the teacher's questions, as well as the structure of the discourse in the post-intervention activities.

5.3.1 Inductive analysis in pre-intervention science activities

The theme for the 3-4-year-old class is Leaves, the theme for the 4-5-year-old class is Rainbow Candy; the theme for the 5-6-year-old class is Teeth.

The type of dialogue between teachers and students in all three classes showed a similar pattern: teachers asking questions and students answering the corresponding questions. For example, in the 3-4-year-old class, the teacher consistently emphasized questions about the color and shape of leaves for the children to answer, and the students' responses were largely brief. I have therefore categorized this model of teacher-student interaction as 'Initiation-Respond model', in which students gave short responses based on information previously mentioned or provided by the teacher.

However, in the 4–5-year-old classroom, teachers also used the interactive/authorative mode of communication to allow children to share their own experimental steps and to see children sharing different experimental steps with others in relation to their own experiences (micro time scale) in the activity. Thus, the second thematic code in the 4–5-year-old class 'sharing knowledge with others' was added, which meant that students shared their learning process in relation to their prior knowledge and experience. In contrast to the 4-5-year-old classroom, where teachers solely discuss abstract concepts, the family factor was incorporated in the children's responses when the teacher in the 5-6-year-old class also included the micro time scale and the interactive/authorative form of communication.

5.3.2 Inductive analysis in post-intervention activities

In the 3–4-year-old class, sessions two and three had the theme of leaf and session four had the theme of sports; in the 4-5 years old class, session two had the theme of rainbow candy and sessions three and four had the theme of local food; in the

5-6 years old class, session two had the theme of tooth protection, session three had the theme of map and session four had the theme of geometric shape recognition.

In the post-intervention activity of 3-4-year-old class, the teacher used an interactive/authoritative communication model to guide the children in answering the question 'what is different about leaves' and also worked with families to give the children a week (meso time scale) to collect leaves from their lives. As a result, the children were able to initiate a new topic of 'leaves have holes' based on their own observations, and they were able to relate their own experiences, such as imagining that leaves being eaten by caterpillars and calling ambulances to help the injured. These were consequently classified as "children bringing knowledge and experience from outside the classroom into the classroom".

Meanwhile, some of the children argued about the number of holes in the leaf, with each child giving a different number. Also, when the teacher described the dangers of the high jump, some children thought that the high jumper could grab the pole and thus be protected. It is clear that when the teacher translated abstract scientific terms into everyday language, the children began to initiate conversations with the teacher and generated new ideas based on the content of the conversation. And when the content of the science activity was derived from everyday life, children were likely to correct others. I had therefore coded this as 'the child initiates dialogue and interaction with others', either by correcting others or by generating new ideas based on their responses.

In the post-intervention activities of 4-5-year-old class, the child's responses could be seen to revolve around the teacher's questions, that was the initiation-response model. However, in this model the teacher used a different form of communication. When the teacher used interactive/authorative communication, the child increased the discussion of alternative symbols, for example, the

representation of food by color and its distinctive features (micro time scale). When the teacher uses the interactive/dialogue mode of communication, the child's discussion of the process of the activity and the changes in the phenomenon increased. For example, different children suggested different experimental steps and variations in the experimental steps using different materials. Thus, under the ‘initiation-response’ model coding theme, the sub-themes of 'increased discussion of alternative symbols' and 'further discussion of activity processes and phenomenal change' were added. The 'further discussion of activity processes and phenomenal changes' sub-theme pointed to content that students could make logical assumptions and description.

During the discussion, they contradicted the experimental phenomenon 'Why was it like a flood' and corrected the answers of others during the discussion. The theme coded from this content was therefore discussion and interaction with others, specifically pointing to the active correction of others to reconstruct meaning.

In all post-intervention activities in 5-6-year-old class, teachers used verbal prompts to encourage children to express more ideas, for example, "If someone else has already given this answer, there is no need to repeat it." to facilitate the child's ability to express more ideas. Furthermore, in addition to guiding the child to respect the ideas of others, the teacher didn’t dismiss the child's position when she heard that the child had a different one, but invited the child to elaborate further on his or her own ideas, and began to try to ask for further reasons based on the child's answers. With this verbal support (micro time scale), the child was able to receive emotional support, promoting a full explanation of the reasons behind his or her ideas and, and, ideally, motivating other students to join in the debate.

In the three post-intervention activities the teacher employed an interactive/authorative communication model to guide the students' responses,

so that the students remained in the initiation-response mode. However, the teacher provided the students with a variety of models of teeth and geometric shapes as well as a multimedia presentation of the road map and used an interactive/dialogue mode of communication to ask follow-up questions about the logic behind the thinking based on the students' responses. Thus, it was clear that the students' responses to questions about the position and shape of the teeth, as well as their use of scientific language about genes and growth processes and common knowledge about the characteristics of their own and their families' teeth, helped to demonstrate why human and animal teeth differ from one another. In actuality, this was a transformation of common knowledge into scientific knowledge. Under the theme of maps, the children discussed the names of the objects presented in the pictures.

It was worth noting that in the theme of teeth and in the theme of recognizing geometric shapes, when it came to making distinctions in knowledge, children began to challenge the views of others, for example, in the theme of teeth when one child suggested that human teeth were flat and animal teeth were pointed, but another child suggested that some animal teeth were also flat, thus making the discussion later on revolve around the theme of 'what causes teeth to be flat or pointed'; In the discussion of two-dimensional shapes and three-dimensional shapes, some children thought that two-dimensional shapes and three-dimensional shapes were the same, and some children suggested a new topic: some shapes have corners. enables children to provide a variety of answers and ideas.

In general, the initiation-response paradigm and the children' participatory interactions with others based on their responses were the two main topics in the 5–6-year-old class's post-intervention activities. Within the initiation-response model, there were two sub-themes: Students extended from multiple perspectives with teacher’s prompting and logically elaborated on others' ideas;

Students brought prior knowledge and knowledge from outside the classroom to current activities. The second theme corresponded to content where students challenged the views of others based on their existing experiences and might generate new content.

I grouped the three classes' pre-intervention and post-intervention theme codes. (See Table 1, Table 2 and Table 3)

Table 1

3-4 years old thematic codes in pre-and post-intervention science activities

Age groups	Themes and sub-themes	
3-4 years old		
Pre-intervention activity	Themes	Sub-themes
	Initiation-Respond model	Responded directly based on the information mentioned earlier by the teacher
Post-intervention activities	Initiation-Respond model	Responded based on actual observation
	Children brought experience from outside the classroom to the school	Recollection and discussion of experiences outside the classroom
	Proactive interaction and dialogue with others	Rephrased or proposed new ideas based on the responses of others

Table 2

4-5 years old thematic codes in pre-and post-intervention science activities

Activity	Themes	Sub-themes
Pre-intervention activity	Sharing knowledge with others	Students shared their learning process in relation to their prior knowledge and experience
	Initiation-Respond model	Responded directly based on the information mentioned earlier by the teacher
Post-intervention activities	Initiation-Respond model	Added discussion of alternative symbols
		A further description of the reasoning behind the process of phenomenal change
		Students focused on thinking about process phenomena and making logical assumptions and descriptions
	Interacted and discussed with others	Proactively correcting others to re-constructed meaning

Table 3

5-6 years old thematic codes in pre-and post-intervention science activities

Activity	Themes	Sub-themes
Pre-intervention activity	Initiation-Respond model	Responded directly based on the information mentioned earlier by the teacher
Post-intervention activities	Initiation-Respond model	Extended from multiple perspectives with teacher's promoting and logically elaborated on others' ideas.
		Students brought prior knowledge and knowledge from outside the classroom to current activities
	The child engaged in interactive dialogue with others based on others' ideas	Students challenged others in relation to their existing experiences and may generate new content

6 DISCUSSION

In this study, the ECE learning environment was defined as one in which three elements - physical, social, and psychological - were connected, with pedagogy at the center.

Therefore, I would combine with human development ecology, constructivist theory, and dialogic pedagogy theories to discuss the status of pedagogical and physical, psychological and social elements that made up the Chinese ECE learning environment and what elements of the future learning environment in ECE needed to be enhanced in order to constitute a high quality ECE learning environment.

6.1 Pedagogical Link The Physical And Psychological Learning Environment

The physical environment referred to the element of space that was most directly felt by students and teachers (IRIS, 2015). The data can be heard and seen in the classrooms with multimedia equipment during the data collection process in addition to the audio data, the lesson plans offered by the teachers, and the photographs of the after-school activities to support the teachers with both macroscopic and microscopic science activities. When it came to science activities that required experimentation, the resources offered were similarly varied.

The psychological dimension referred to the teacher's perception of the self and the role of the student. During the pre-intervention activities in 3-4-year-old class, the students simply responded to the pictures provided by the teacher and had difficulty remembering the types of leaves, most of them only remembering the colors of the leaves. Therefore, teacher switched from using only picture book stories to using real leaves to allow the children to observe and feel the differences in the materials of the leaves and the similarities and differences in the leaves, which also led to an increase in the number of times the teacher asked

new questions, invited the student to elaborate and allocated questions to different students in sessions two and three. The teacher also followed up the activity by asking the students to find out what the plants in the kindergarten looked like according to the size of the leaves. This extension of the classroom activity into the community was also used in the fourth session. Thus, in the session four, teacher employed an interactive/dialogue model to prompt the children to demonstrate various sports movements using different body movements.

Although the teacher still mainly used the interactive/authorative mode of communication, it could be seen that teacher was beginning to shift away from micro knowledge and toward macro knowledge and are using more open-ended questions and process-based questions about the activities, so that students were more actively interacting with their peers and the classroom teacher in relation to their own experiences outside the classroom. Teachers had also progressed from having a high degree of control over the subject matter of classroom activities to interacting with students based on their responses.

The students in 4-5-year-old class were not very good at listening to others, they were simply reacting to the information given by the teacher. During the sharing session, some students struggled to explain the process and steps of the experiment, and although they drew pictures, they couldn't explain the meaning of the symbols they used in their own experiments. Based on this situation, the teacher in the 4–5-year-old class shifted from a fixed step-by-step presentation on multimedia to a semi-open-ended presentation of the steps in section two of the rainbow candy experiment, which allowed the teacher to distribute the questions to more children and increased the dialogue of the students' adjacency talk.

Simultaneously, the teacher's increased reflection on the activity's process facilitated the student's beginning to think about their knowledge and experience, which was reflected in the question-and-answer format, in which the students

were able to further explain why the phenomenon occurred and made hypotheses and answered in a more logical and based on their own experience.

In 5–6-year-old class, some of the students in this class had more experience and knowledge but were less able to communicate with others interactively, and the teacher said that all the children in this class were less able to draw symbols for recording.

To encourage more discussion, in the session three and four, the teacher added the categorization objective. As a result, the teacher transitioned from being the primary initiator of the conversation to assuming the role of a scaffolder who probed students for further elaboration on the underlying logic and reasoning behind the conversation. This was reflected in the talk structure, as there was an uptick in the teacher's adjacency talk and an increase in the number of times students engaged in repair talk.

Although the topics of maps in section three and recognizing geometric shapes in section four were macroscopic science education, the teacher used multimedia and blocks that are accessible to students in the classroom as materials for the activity and did not limit the content of the materials to a single answer, so students were challenged and refuted the content of the conversation. This was a process of negotiation and co-construction of knowledge between macroscopic knowledge and microscopic knowledge.

6.2 Pedagogical Link The Social Learning Environment

In this section, social learning environment included not only family and community members, but also two learning spaces: informal and non-formal.

All three classes extended classroom activities beyond the classroom. For instance, the 3-4-year-old class teacher invited parents to go to the park with students to collect leaves, enabling them to observe the difference between leaves and understand that small leaves eventually grow into larger leaves. This extended the learning environment from the teacher to the kindergarten, as the

teacher and I collaborated to facilitate this experience. The 4-5-year-old class teacher sent questionnaires to parents, requesting that they take their children to experience local food culture in real-life situations. In the 5-6-year-old class, the teacher suggested that students and parents observe buildings in their surroundings and draw maps of their own. These activities encouraged the incorporation of real-life experiences into the learning process.

The curriculum activities in the three classes demonstrated that the science curriculum was most closely related to family members and that including family members created an informal learning environment to some extent, which could partially increase the diversity of the formal teaching and learning environment. However, community organizations hosting events outside of the school is uncommon, and although after-school activities are open to families, there is little recollection or sharing of prior extended activities in subsequent science sessions. The frequency of family participation in three class is also low. Additionally, limited time to develop lessons based on monthly themes in the kindergartens and weak cooperation between school family make it difficult to establish a community-based ecological learning environment in ECE in China currently.

6.3 Evaluation Of The Study

6.3.1 Reliability and Credibility

The data were analyzed deductively and inductively using thematic analysis. Deductive coding was applied to the question forms and functions of the teacher, and the talk structures between teachers and students before and after the teacher employed the dialogue teaching strategy. The function and form of each question was clearly defined, so the data transcribed into text could be classified and counted according to the definition.

The inductive coding process was applied to the extension and expansion of the child's dialogue after the teacher had used the corresponding dialogue pedagogy strategies. Before the intervention, I collected the teachers' lesson plans

for the several weeks preceding the science activity under the corresponding theme. I was able to use these lesson plans to get an idea of how the teachers would organize the activities based on the theme and to get an initial idea of the children's prior experience of the activities associated with the theme. The teacher also provided me with a lesson plan for the activity before the first session and I was able to understand the objectives of the activity and the teacher's expectations for the outcome of the activity. Once I deductively analyzed the data after transcribing the pre-intervention activities into text, presented the findings to the teacher, and we discussed which dialogue method would be best for addressing the presentation of the deductive data and the other issues during the activity while taking into consideration the objectives outlined in the teacher's lesson plan and the weekly plans associated with the theme.

For the post-intervention activities, I employed the Dialogue in the Inquiry Science Classroom model (Lewis et al., 2014) and the Dialogue Pedagogy (Hennessy et al., 2016), both theoretical frameworks that categorized and gave specific content to the categories from the teacher's perspective. Using these two theoretical models, I first coded the themes of the teacher's dialogue in the post-intervention activities, further coded the themes and subthemes of the children's post-intervention dialogue using a combination of transcribed text and the teacher's verbal and written reflective schedule, then removed the duplicate codes and categorized the others. The teacher also provided me with some of the children's activities and some of the science activities if they involved extension activities related to other areas of activity, and the teacher also gave me photos of the children's work in the extension activities.

The model of the two theoretical frameworks was therefore able to reduce the influence of subjectivity in the coding process, while the textual materials, photographs and verbal reflections provided by the teachers helped me to gain a more comprehensive understanding of how the activities were designed and

carried out, thus enabling me to code the content of the children's conversations with an understanding of the context of the curriculum, and increasing the credibility and reliability of the study.

6.3.2 Limitation

Due to the epidemic in China and the fact that the study involved adults under the age of 15, the data were collected in audio form. The audio lacked the non-verbal data of the teachers and students, which to some extent played an important role in the content of the conversations, especially as the younger children used non-verbal related behaviors to a large extent and also related to the emotional support mentioned earlier.

Also, due to the large number of students, it was not possible to record each child's discussion during the group work part of the science activity. Teachers had commented that the group discussions were a little more informative than the whole-class activities. Generally speaking, the study lacked dialogue between groups and individual students, two of the most important forms of teacher-student interaction in formal learning.

Although only three classroom science activities in China were chosen as a sample for this study, it was possible to apply the dialogic approach to other kindergartens to see whether it was applicable and, if so, whether the pattern of teacher-student interaction changed similarly or in a different way. Also, the effectiveness of dialogue teaching methods varies in different social and cultural contexts.

6.4 Conclusion

If we consider the three elements of the ECE - physical, psychological, and social environment - as spaces, these three spaces are separate but interrelated.

From a microsystem perspective, teachers extended the dialogue with children in Chinese ECE learning environments through four dimensions: changes in materials, multimodal approaches to support student development,

changes in communication patterns, and extensions to classroom activities (Ceci,2006). Within the four levels of change, in terms of individual development, 3-4 years old children began to attempt to rephrase others' ideas based on the content of their conversations, or to come up with new ideas; 4-5 year old children were also able to elaborate further on the process of the activity phenomenon and to make assumptions and inferences within the initiation-response model of dialogue; 5-6 year old children were able to have conversations from multiple perspectives, which is one of the key features of meaningful dialogue, and were able to think about things from various perspectives.

Meaningful inter-subjective interaction under different microsystems facilitated the formation of the exosystem. The inductive results suggest that as more subjects were introduced into the dialogue space, the content of the dialogue became more diverse and complex. In the 3-4- and 4–5-year-old classes, teachers expanded the dialogue space to include the community and family. This approach enabled children to bring their experiences from outside the classroom into the classroom, which in turn allowed them to generate more diverse ideas and positions, thus utilizing the microscopic time scales. Moreover, children were able to actively negotiate and co-construct meanings with their peers, which is a crucial aspect of social knowledge construction (Jonassen, 1994). The exosystem can also indirectly influence the interactions of individuals within the microsystem. For instance, in the 5–6-year-old class, the teacher did not extend the activities of the classroom to the community or the family, but the children brought their knowledge from home into the classroom, which allowed them to develop different perspectives.

Between the interactions of the microsystem and the exosystem, the mesosystem and chronosystem also influence the micro and exosystem. The mesosystem refers to the interconnections and relationships between

microsystems (Ceci, 2006), while the chronosystem refers to the influence of different time periods (past, present, and future) on the individual, similar to the concept of chronotope in dialogue theory (Erstad & Sefton-Green, 2013). During the reflection process of the action research, some teachers mention their reluctance to extend classroom activities to the home because it would disrupt their planned weekly activities. While some teachers are willing to extend classroom activities to the home, but they would simplify the tasks so that parents would not need to spend extra time completing them. This reflects the role of the mesosystem, where the level of involvement between parents and children in classroom activities indirectly influences the interaction between parents and teachers. On the other hand, it also reflects to some extent the macrosystem of ECE in China, which encompass the cultural, educational system, political etc. As could be seen from the results section of this study, the science activities carried out by teachers are not only limited by the school curriculum, but also by the amount of time given to them in the school. This meant that although teachers have the autonomy to develop the themes of the curriculum, they do not have much autonomy in terms of the content of the themes and the timing of the activities. Furthermore, most science activities in the three classes involved in the study are more oriented towards selecting macro science activities to be transformed into micro science activities. The top-down nature of the current science curriculum in ECE in China is comparable to the hierarchical power structures in its classrooms, which is inconsistent with the policy document's (Ministry of Education of the People's Republic of China, 2012) stated developmental objectives for science education in ECE, according to which science education should be practical and applicable to daily life and at the same time, children need to develop transferable skills. According to Osborne (2007), these transferrable abilities should be contextualized, and daily information and scientific knowledge should be interchangeable in macro- and micro-science

education, meaning that everyday knowledge could be conceptualized, and scientific knowledge could be made concrete.

Overall, the ECE learning environment in China have a complex interaction between the microsystem, mesosystem, exosystem, and macrosystem. On the one hand, teachers have some autonomy to design activities that align with children's interests, which could promote positive interactions in the microsystem. However, due to policies, school culture, and parental involvement, there may be limited interaction between teachers and families/community, which could affect the mesosystem and exosystem. Also, the macrosystems may vary from region to region, influencing the microsystem, mesosystem, exosystem to some extent.

Future research on high-quality ECE learning environments could be further developed by drawing on the four systems of human development ecology and the three types of learning environments: informal, non-formal and formal. Since macro systems are unique in different cultural contexts, we need to think about the relationship between macro knowledge and micro knowledge in ECE, given the difficulty of changing them. Both types of knowledge are present not only in scientific activities but also in other curricular activities. The way educators think about the relationship between these two types of knowledge affects the dynamic development of the four elements of the formal learning environment in ECE: social, psychological, physical, and pedagogical.

In summary, teachers are influenced to a certain extent by the policies and culture of the school and society. Although different types of knowledge are involved in science activities, teachers make a conscious shift in the application of dialogue pedagogy and communication from a single communication style (non-interactive/authoritative) to to a more varied and open communication style including interactive/dialogue, non-interactive/dialogue, and interactive/authoritative. Changes in communication and pedagogy have

extended the learning space beyond the school. However, as the learning environment becomes more complex, there is a lack of participation and dialogue between more subjects.

Therefore, in future research, it is important to understand if the four elements of the high-quality learning environment in ECE could develop dynamically in a formal teaching environment? Is it possible that, in addition to the inclusion of subjects from formal education institutions, they may have an impact on the construction of knowledge in non-formal educational environments? And what impact does it have on the learning environment when multiple subjects join the conversation?

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APPENDICES

Appendix 1 The definitions and examples for questions forms and functions

Categories	Subcategories	Description	Examples
Form	**Focused**	**Teacher asks a question that has only one possible and correct answer. Students' responses were typically brief.**	T:Have you ever had rainbow candies? S1:I have eaten S2:I have eaten too.
	Authentic	**Teacher asks an open question, which has not a pre-determined or prescribed answer.**	T :So what can we do if we want to protect our teeth? S1:Brush our teeth S2:Brushing our teeth every day, and eating *less sugar*. S3:Drink plenty of *plain water, as it washes down the crumbs (the remains of food)*
	Distributed	**Teacher assigns questions for students to answer**	T: I seem to have heard the answer a little bit. But I can't hear the answer very clearly. *Shushi(student's name)*, you answer.
	Procedural	**Questions relate to classroom organization and management (e.g. discipline issues)**	T:Are you ready? Are you sitting upright?
	Process	**Invite children to explain their understanding of learning process or explain their thinking**	T: Okay, tell us what you see that is different?

Categories	Subcategories	Description	Examples
Function	**New question**	**The teacher makes a question that is different from the previous content and themes**	T:As you can see, after eating lots of chocolate and sweets the teeth ended up broken or were? S:Pulled/replaced with dentures/golden teeth, I see a tooth at the bottom T:So what can we do if we want to *protect our real teeth*?
	Elaboration	**Teachers allow students to deepen or further elaborate on previous or current ideas**	S1:Dentures. S1:This is what my mum told me. T:*What do dentures mean?* S:It's fake teeth/toy teeth.
	Class Management	**Issues related to management of behaviors or tasks**	T: I want to see which child heard what she said. Why don't you listen to what people say?
	Factual elicitation	**Giving certain clues and recalling of fact and information**	T:I would like to ask the child who raises his or her hand to come up and say what colour the rainbow candy is?
	Relaunch	**Teachers ask different children about the same content**	T: What is the difference between these two leaves? S1:It is not the same colour T :I want to invite S2, what do you think is different about these two leaves? S2:Different sizes
	Practice and develop skills	**Invite children to rehearse, repeat or practise a strategy or grasp of understanding(e.g:Understanding and learning of words and phrases; Asking questions is about developing some skills,such as vocabulary,thinking skills, etc.)**	T: You have to say it (referring to the experimental steps) in full
	Reflection	**Invite children to think about how they learn and the strategies they use**	T:I'll start by asking you, child S1, to explain the steps of your experiment.

Appendix 2 The definitions and examples for talk structures

Talk Structures	Definition	Examples
Turn-taking	1.Involves a link to the preceding content; 2.A rotation or selection of the current content; 3.And a continuation of the subsequent content.	1.Speaker-led: T: Well, apart from the color, what else is different? T: We can feel the veins of which leaf is more solid? T: Then I'll ask the children to come up and touch it to see which leaf is harder and which is softer. 2. The listener becomes the speaker: T: This one (leaf) is yellow, this one is green, what else is different? S1: with a hole S: This leaf has holes S: There are 3 of them
Adjacency pair	1.Adjacency pair is not sufficient for the speaker and interlocutor to engage in multiple conversations. 2. Three characteristics: It consists of two discourses; the discourses are adjacent; the discourse is produced by different speakers	T: What does it look like? S1: Skinny T: What about this one? S2: Long S3: Long and skinny S4: Fat
Repair	1. In order to give meaning to the responses in the interaction, participators repair problematic turns or adjacency pair in the conversational interaction to re-establish a common understanding. 2.Speaker: rectify or supplementary herself or himself 3.Listener: active, assisting, and passive.	S1: It is if your teeth are hurt, that meat stuck in your teeth inside uncomfortable, cannot be forced to pick, forced to pick will be the teeth off, inside will bleed. T: What does meat mean? S2: Meat that has been eaten (Listener active repair) S1: The meat that has been eaten is stuck inside (Speaker supplementary herself)

Appendix 3 Original text for inductive analysis

The numbers (1), (2) indicate the different parts of the same activity.

1. Pre-intervention activities in 3-4-year-old classroom

(1) T: Today's story started with a little rabbit, who lived in the forest. He/She walked and walked, he wanted to pick up mushrooms in the forest, but what was on the ground?

S: Leaves

T: What was the color of the leaves of the ginkgo/ maple/ pine tree?

S1:Green

S2:yellow

S3:orange

S4:Red

T: We had seen many kinds of trees today, did they have the same colour leaves?

S: No, they are different

(2) T: Let's get to know more trees today, so that you could find mothers for the leaves later. Let's look at this tall, big tree called the Little Poplar. Let's look at the leaves of the poplar tree, which have their own characteristics.

S:Love heart

T:Great,it looks chubby and like a heart and a big apple,it looks chubby when it grows,and it's coloured?

S:Green

T:Then let's get to know the willow tree again.

S:A willow tree is coloured

T:What do the leaves of a willow tree look like?

S:It is like a tip

T: What colour is it?

(3) T: Let's help the leaves to find their mothers today, and I'll see who is the fastest. Let's remember what kind of tree is the one that looks like a needle?

T: A pine tree [because the child doesn't remember]

T: What kind of tree is the long, thin one?

S: Tall

T: A willow tree

(4) T: Now I'm going to show you a picture of a tree, will you help it find its children?

2 Pre-intervention activities in 4-5-year-old classroom

(1) T: Have you ever eaten rainbow candy?

S: I have eaten/I have eaten

T: I would like the child who raises their hand to tell me what colour rainbow candy is?

S1: Rainbow candies are coloured

S2:Pink

S3:Red and blue

(2) T: So let's see what fun and interesting things will happen to this rainbow candy in the teacher's hands?

T: So let's see what fun and interesting things will happen to this rainbow candy in the teacher's hands?

S: Change colour

T:The experiment we are going to do today is rainbow candy, so what is the first thing we need?

S: Rainbow candy

T: And then what?

T:A plate [because students didn't answer]

T: And then the third?

S: Water!

S: Cups

T: Then the children can work in groups to experiment and see what interesting

changes happen between them.

S1:How to play to get the changes

T: How do you play, as S2 has just said, there are several steps, what is the first step?

S3: Put the rainbow candy on the plate

T: Right, then step two?

S4: Form a circle

T: Yes you can form a circle or a triangle, then step 3?

S5:Pour water

(3) T:Will S1 please tell us how you experimented? Let me hold it for you.

S1: We put the red ones in first, then the yellow ones and the orange ones, then we poured water and it worked!

T: Then I would like to ask you whether you used cold or hot water?

S: Cold water, all of it was cold

T:Do you know why this happened?

S:It changes color

T: Because the rainbow candy has a layer of pigment that has a color, and when it melts with the water, the pigment will spread to smaller areas around it, and then slowly the children will observe that the colors will come out, just like a rainbow. So that's it for this experiment, you can go home and do it with your mum and dad and you can try it with other candies to see if it changes in the same way.

3. Pre-intervention activities in 5-6-year-old classroom

(1) T: OK, I had a question, what did you just see in the video?

S1: I saw the guy on top of the video eating candy and his teeth were rotten

T: What did Liu say he saw?

S2: Eating too much candy, his teeth were rotten

T: What did the other children see?

S3: They saw the tooth on the TV eating all the time and when it was about to finish the lollipop tooth next to it turned into a shiny gold tooth

(2) T: What else was different? Listened carefully to what I say, if the previous child has said it you should not say it again, what did you see that was different?

S3: The last tooth was broken on the head

S3: He had a broken tooth, he got a mechanical tooth straight away, and then he had to brush his teeth, the golden tooth

T: He had to start brushing his teeth after he had replaced the gold tooth, right?

S: First change the teeth, then brush them

T: OK, tell us what you see that was different?

S4: I just saw a tooth fall out

T: Wait a minute, which tooth had fallen out?

S5:The tooth in the middle had fallen out

T: Does anyone think it wasn't the middle tooth that fell out?

S6:It's been pulled out

S7: Replaced with dentures

(3) T: I heard S7 say a word

S7: Dentures, that's what my mum told me

T: What did dentures mean?

S: It meant fake teeth

T: And what were real teeth?

S: They were our own

T: They were our own teeth

S: The deciduous teeth

4. post-intervention activities in 3-4-year-old classroom

(1) S1: There was a little bit without waves, our group had no waves

T: You could tell the children what was different about them?

S2: This one was different, this one had a different color.

T: Oh you mean they were different in color, right?

S2: This was yellow and this is green

T: S3, which two leaves were you observing?

[S3 points out]

T: What was different about these two leaves?

S3: It was bigger and it was smaller

T: Well, these two leaves are different in size

(2) T: Today I wanted these three children who picked up the leaves in the park with their parents on Saturday and Sunday to shared.

S1: I picked them up last night from the ground floor

T: OK, I would ask S2 to tell us about the leaves you found. You could tell us who you picked it up with. Where did you pick up the leaves?

S2: My dad and I picked them up together

T: Where did your dad and you pick them up?

S2:Downstairs on the ground floor

S3:I picked them from the playground

S4:I picked them in the yard

T: And did you know what kind of leaves these were?

S5:Yellow leaves

T: Oh, they were all yellow leaves, what color leaves did S5 pick?

S: Green

S: There were holes

T: Very good observation. Did you see any holes in this leaf?

S6: No

T: This leaf had a hole.

S6: The caterpillar ate it

T: Oh yes, maybe a caterpillar ate a hole out of it, it looks like this leaf was hurt and eaten by a caterpillar, this leaf was healthy because there was no caterpillar

hole. It was different here, that was good. Then I would ask the children to come up and touch it to see which leaf was hard and which was soft

S7: This one was hard and this one was soft

S : Teacher, it had a hole here too.

T: Yes, it was obvious, so let's try to find the difference one last time. Okay, you chose two leaves for me, this one had just been searched. Now what was different about these two leaves?

S: This leaf had holes

S: There were 3 of them

S: There were holes in this one

T: How many holes were there?

S:4

T: Okay, let's counted them together, there was a little one here [teacher and children count the holes on the leaf together]

T: Wow! There were 7 holes on this leaf, and the worms have eaten a lot of it.

(3) T: This man used a pole to run all the way over the high railings

S1: So would he fall down?

T: There was a very soft mat underneath to catch him, and he won't feel any pain when he falls on the mat

T: This sport is a little bit dangerous, only trained people can do this sport

S: Only adults could do this

T: Even adults like teachers couldn’t do it because I didn't learn how to jump high when I was a child and I can't protect myself, so when I jump high I get hurt, so this sport is a bit dangerous

S: We had to call an ambulance

S3: There was a pole to catch him, and then he holds on to it

T: No, he had to jump over the railing, he can't touch the railing, if he touches the railing he loses, he couldn’t win the race.

5. post-intervention activities in 4-5-year-old classroom

(1) T: What did you use for dry steaming?

S1: Yellow

S2: Used the peel instead

S3: Used that tart paper for the tart

S4: Used egg instead

(2) T: Here were some pictures of the experiment steps, but this step did not tell you how to do it, you needed to think about it, what did you think you should put first and then what?

S1: Put the rainbow candy in first

S2: Put the water in first

S3: Took another plate

T: Did the other groups of children do the experiment differently?

S4: Put the sugar snap peas in first, then got a plate, then poured the water

S5: Poured the water in and then the rainbow candy would change color, then the other children could look at the rainbow candy

S6: Put the rainbow candy in first, then took a plate, put the rainbow candy in a big circle, poured some water in and stir it up, then looked at it again after a while and saw if it turned red like this?

T: And what happened when you poured the water in?

S7:I found it a bit unattractive and a bit dirty

S8:It disappeared

T: Why did it look like something dirty?

S9:Because it was a big one, but then it became a small one

T: Oh you meant it was colored and then its colors dissolved together and it was a bit like?

S9:Dirty

T: Why did it disappear?

S10:Because it disappeared when you put it in water

S11:Because there was water

S12: When we did the experiment just now, we put him in the flood afterwards

S13: Did you see that it's a bit like a flood?

T: Why was it like a flood?

S14: Because it looked like a flood

S15: No, it was a flood because we poured water from here into it.

(3) T: Why did your group tick a lot of boxes on the egg tarts?

S1: Because all four of us liked it, it had this in it, it was delicious

T: This was an egg wash, so what was the different?

S2: I found that some of the tarts were colored, and some were black, and the shape was half round

S3: Round

S2: There was also an egg liquid inside and a skin around it

6. post-intervention activities in 5-6-year-old classroom

T: So what were the characteristics of human teeth?

S1:I had a tooth that looks like a tiger

S2:Because human teeth were a bit pointy underneath

T:S2 mentioned a spot where there are four little tips under the end of the tooth.

S3: The top part of his was square

T: He said that apart from the cusp, the top part was square.

S4: The tooth was a bit like a chopped off section of a tree (pointing to the stump)

S3:Each animal grew different teeth as it grows

S5: Because Human teeth were small and other animals had no teeth, so they had to use sharp teeth

S6: Then why did some animals have flat teeth? For example, the squirrel.

S3: Because they must eat something, each of their teeth would be different

T: Very good, go on, why?

S2: Because tigers must eat meat

S6: Because the tiger had to ate meat, so its teeth are very sharp, other animals ate vegetarian food

T: Did anyone know why these little animals (referring to the squirrel and rabbit mentioned earlier) have different shapes of teeth?

S7: It was a feature they were born with

S8: I thought it was because of their genes

T: You were saying the same thing as S7, but you were using it in a more professional way. You had thought about it carefully, but I wanted to hear a different idea

S9: The process of growth

S10: It was that humans have pointy teeth too

S11: because I found out that my dad and I both have pointy teeth, my dad has 3 pointy teeth and I have four

(2) T: S1, what did that tooth stand for?

S1: To brush your teeth first

T: To brush your teeth, what was you thought about the name of that shop?

S2: Tooth extraction shop

S3: Dental clinic

T: It could be a dental clinic or a place that pulls teeth

S4: I think it was a bit like a house, where a child had to go to bed, so he had to brush his teeth.

(3) T: What did you think this letter is trying to tell us after you see it?

S1: The letter was missing

T: Yes, there were no words, was this a letter?

S2: Only Sunday

(4)T: Now please go back to the shapes we knew, all of you saw the blocks, so what was it?

S1:Rectangle

T: Two-dimensional rectangle or three-dimensional rectangle?

S2: Two-dimensional rectangular

S3:Both were the same

T: Okay, then please looked at these blocks and the shapes you saw on the projector, how were they the same?

S4: This side had an oval shape and this side did not have an oval shape

T: He thought it was an oval instead of a square circle, it was not a regular circle, is it?

T: Then let's change it to a square circle. Now what?

S5: It was a bit wrong

T: What was wrong? If you can tell us what you thought, please.

S5:It was that this one was long and this one was round

T:OK, what was different then?

S6:It was that rectangles and squares have corners and circles didn't.

S7:Three-dimensional rectangles and squares with angles, circles without

T: What was angles? I would get you a pen later. Could you circle the angle?

T: What shapes had edges and angles? Thought about which shapes had edges and angles?

S8: The square and the Three-dimensional rectangle

T: Did you have other thoughts?

S9:Triangles had angles

S: Also trapezoids

S: Pentagram

S: Hexagram

T:OK, what shapes didn't have corners?

S: Circle

Appendix 4 Eight clusters of dialogue pedagogy

Cluster code	Cluster name	Description
I	**Invite elaboration or reasoning**	Invite others to: 1. respond critically to ideas, perspectives, problems, situations or artefacts through explanation, justification, argumentation, analogy, categorisation, making distinctions, use of evidence 2. explore possibilities, predict, speculate, hypothesise, extrapolate 3. elaborate, reformulate, extend/add to or build on own or other's contributions/ideas/theories 4. evaluate or (dis)agree with another's contribution/idea/theory In 1 and 2 above, turns coded **I** should be **explicitly** asking for reasoning, typically through key words such as 'why?', 'how?', 'what caused...?', or speculation/prediction through conditional phrases such as 'what would/could/might happen if...?' Includes inviting to explain or speculate based on **one's own or other's ideas**. In 3 and 4 above, invitations should make explicit reference to prior contributions. If not immediately prior, use **C** also as appropriate. When asking for reasoning or elaboration later on, for example within an upcoming activity, use C instead. Excludes: asking for simple repetition of contributions.
R	**Make reasoning explicit**	Make reasoning explicit through 1. explanation, justification, argumentation (providing an argument or a counter-argument), analogy, categorisation, making distinctions, use of evidence or 2. exploration of possibilities, prediction, speculation, hypothesising, extrapolation Turns coded **R** should indicate a **clear attempt** at reasoning, typically (but not necessarily or sufficiently) through key words such as 'because', 'so', 'therefore', 'thus,' 'in order to', 'if...then', 'not...unless', 'it's like...', 'imagine if...'. The attempt need not be 'successful' - that is, reasoning need not be judged good in order to be coded. It should be remembered that when engaging in reasoning speakers will often be tentative and less than clear in their expression. Includes explaining or speculating based on **one's own or other's ideas**. Turns coded **R** need not relate directly to a previous comment, as reasoning may stand alone as a dialogic feature. Where they do relate, additional clusters can be coded as appropriate. A **counter-argument** (proposition + reason) or argument with expressed (dis)agreement can be coded **R and P**.
B	**Build on ideas**	Make a relevant contribution to the dialogue by **building on, adding to, reformulating or clarifying one's own or other's contributions** Includes: judging ideas to be similar or different to each other without evaluating them, and without giving reasons. If reasons are given, use **R** instead. When referring to comments, ideas or resources from outside the immediate dialogue either in time, place or person, use **C** instead. Excludes: repetition of one's own or other ideas; contributions should add something either in terms of content or in the way ideas are expressed.
E	**Express or invite ideas**	1. Invite others to express opinions, ideas, beliefs, perspectives or give examples without specific reference to prior contributions, ideas or artefacts. Includes open, general questions that do not name ideas or participants, but not closed questions that seek yes/no answers 2. Make a relevant contribution not covered in 'Build on ideas' or other categories. Can include short unelaborated responses to closed questions; contributions that feed back from, but do not add to, prior group work; ideas offered in addition to others that are not linked.

		Utterances are coded E when they are judged relevant to the dialogue but not explicitly linked to previous contributions. The response to the participant's utterance should not be used retrospectively to infer the intent of his/her contribution. Utterances under 1 above should appear to invite relevant contributions without the explicit suggestion that respondents should build on what has been said before - even if this is implied in context. For example, "what do you think?". If direct mention is made of prior contributions, ideas or contexts, use IR or C as appropriate. Utterances under 2 above should appear to contribute a new and relevant idea or example without an explicit link to a prior contribution or context. Where clearly and explicitly building on, responding to or evaluating previous contributions, use B R, C or P.
P	**Positioning and coordination of ideas**	Take a position/ stance in the dialogue by: 1. evaluating different ideas/ perspectives/ arguments by comparing/contrasting/critiquing them 2. offering an opinion on the value or lack of value of an idea/ position/ argument/ artefact in relation to the task at hand 3. explicitly acknowledging a shift of position 4. challenging other's argument, belief or assumption 5. stating agreement/ disagreement /partial (dis)agreement with others 6. proposing to resolve differences /agree a solution 7. synthesising or bringing together ideas or generalising Excludes: expressing agreement with one position or idea when no contrasting ones have been offered. Includes: agreeing with one position or idea **after a different one has been mentioned**, even if the disagreement with that different position is implicit; **however**, simply saying 'I agree' is not enough in this case - the particular position or speaker must be identified (e.g. I agree with Simon).

		This code excludes identifying similarity or difference between ideas without judging their value - in this case, use **R** instead if a reasoned distinction is made; if not, use **B** instead.
C	**Connect**	Make **explicit** links to ideas / positions / arguments / artefacts / prior contributions or knowledge **beyond the immediate dialogue** that: 1. refer back to earlier contributions within the group (not immediately preceding) 2. make trajectories of learning explicit, including refer forward to an activity or contributions to be requested. 3. refer to wider contexts: present, past or future, beyond the classroom or to prior knowledge and experiences If the idea/ position/ argument/ artefact referred to has very recently been mentioned, use **B** instead. If it has to be explicitly retrieved/ recalled, use **C**.
G	**Guide direction of dialogue or activity**	Take responsibility for shaping and directing dialogue or activity by: 1. encouraging student-student dialogue (includes whole class contexts; excludes simply setting group work without an explicit dialogic element) 2. explicitly inviting or proposing thinking time 3. proposing possible courses of action or inquiry Or through scaffolding strategies such as: 4. feeding in / highlighting salient ideas 5. introducing an authoritative perspective as part of the dialogue in response to participants' level of understanding 6. providing informative feedback on which the recipient can build 7. guiding or focusing the dialogue in a desired direction or towards key aspects of an activity (excludes simply reading out a task / question / text) If a proposal for possible courses of action or inquiry extends beyond the lesson, use **C** instead.

RD	**Reflect on dialogue or activity**	Explicit self or group evaluation or metacognitive reflection on purposes/ processes/ value/ outcome of learning or activity, also including: 1. engaging in talk about talk / protocol for dialogue 2. an **invitation** to engage in any of the above

Appendix 5 Teacher Reflection Form of T-SEDA

Activities:

1.Motivation for inquiry

2. Focus and themes of inquiry

3. Current conversational status and relevant prior learning experiences

4. Expected / desired outcome?

5. What aspect of the dialogue would you like to focus your inquiry on?

Assessment:

1.Results of the inquiry:

current findings (general findings, unpredicted findings);

answers generated from the inquiry questions;

what changes have you observed in the child?

2.Self-evaluation in the process:

What parts of the practice went well? What are the reasons?

Have you encountered any challenges or shortcomings in conducting classroom investigations?

Plan for next session:

1.Which dialogue teaching strategy do you want to use?

2.Do you intend to continue with your current topic of enquiry or change it?

3.How can you improve your next classroom activity based on the dialogue strategies you have chosen?

Appendix 6 Discourse in Inquiry Science Classrooms (DiISC)

Discourse in Inquiry Science Classrooms (DiISC)

(I) Inquiry Scale

1. Teacher creates an environment that supports inquiry	**2. Teacher engages students in asking scientific questions for the purpose of investigation (hands-on or other means)**
Teacher provides students with: a) guidelines and time for (hands-on) exploration b) tools and techniques for analysis of data c) opportunities to elaborate on conceptual understanding	Teacher provides students opportunities to: a) formulate questions about the natural world b) present explanations for questions c) distinguish between scientific and non-scientific questions
3. Opportunities for students to design and plan exploration of the natural world individually or in groups	**4. Opportunities for early stages of scientific exploration: making observations, recording data, and constructing logical representations (e.g., graphs)**
Teacher provides opportunities and guidance to: a) plan and conduct scientific investigations individually b) plan and conduct scientific investigations in groups c) justify procedures before carrying out investigations	Teacher provides opportunities to: a) make observations through doing the activity b) record and use data c) record and represent data in logical forms that show patterns and/or connections
5. Opportunities for later stages of scientific exploration: explaining phenomena via claims and evidence, making predictions, and/or building models	**6. Generating scientific arguments and constructing critical discourse about limits and sources of error**
Teacher provides students opportunities to: a) make claims, provide evidence, and develop explanations b) revise explanations and models using data and logic c) make predictions and build models	Teacher provides students opportunities to: a) think of other ways to interpret data using scientific knowledge and logic to generate scientific arguments b) identify limits and exceptions of interpretations of data c) discuss the effects of error on results and suggest ways to reduce error in collecting data

(OD) Oral Discourse Scale

7. Teacher promotes discourse through questioning	8. Teacher promotes peer-to-peer discussion
Teacher asks questions: a) that require analysis and comparison b) that are divergent and have multiple possible answers c) to redirect for more information, to evaluate answers, and to uncover students' reasoning	Teacher: a) provides opportunities for small group discussion and negotiation of meaning with specific questions or tasks b) monitors student participation in groups c) facilitates large group discussion among students or student presentation
9. Teacher (or instruction) bridges everyday experiences and scientific discourse	**10. Teacher models scientific discourse and vocabulary**
Teacher: a) is sensitive to gender issues of discourse (using topics of interest to all students) b) connects everyday (e.g., pop culture) and scientific discourse c) distinguishes between everyday meaning of words and their scientific meanings	Teacher models how to: a) use scientific terminology b) use logical connectives in explanations (why-because) c) argue from evidence, compare, and analyze
11. Teacher engages students in discussion that emphasizes the nature of science	
Teacher provides students with opportunities to: a) discuss that science is tentative and fallible b) discuss results and methods (replication of experiments) with skepticism and openness c) engage in public sharing of knowledge (incorporating NOS)	

(W) Writing Scale

12. Formal writing in a genre that reflects the nature of science	13. Engaging students in <u>prewriting</u> associated with science concepts
Teacher provides students with opportunities to: a) write for different audiences and purposes b) use expository, reflective, and expressive formats (e.g., newspaper article, poster, a lab report / scientific investigation report) c) emphasize the nature of science	Teacher provides opportunities for students to: a) use brainstorming strategies and/or create concept maps b) develop questions and outlines c) take notes and/or use scientific terminology or symbols during scientific inquiry investigations
14. Engaging students in recursive writing processes using rubrics to review and revise	**15. Engaging students in writing to acquire the language patterns and vocabulary to communicate scientific ideas**
Teacher provides time and opportunities for students to: a) review and revise through multiple drafts b) engage in peer-to-peer editing c) use rubrics that guide revision * Homework does not qualify here.	Teacher provides opportunities for students to use: a) scientific terminology and/or symbols or equations b) language patterns of science c) structural patterns of scientific writing (e.g., claims-evidence)
16. Teacher provides direct instruction in writing content, forms, and processes	**17. Engaging students in using science notebooks as a learning tool**
Teacher: a) provides instruction about the nature of scientific writing b) provides templates for each genre (lab report, brochure) c) explains function and appropriate time to use genres	Teacher provides instruction in how, or opportunities, to: a) use notebooks as a learning tool b) organize science notebooks c) record data, reflections, and/or handouts

(ALD) Academic Language Development Scale

18. Providing students opportunities to acquire vocabulary	**19. Teacher uses clear instruction throughout lesson by modeling expectations**
Teacher provides opportunities for: a) reviewing and repetition of vocabulary and tasks b) building academic language from the vernacular c) interpreting words from contextual clues	Teacher: a) varies speech and enunciates clearly b) explicitly defines content and language objectives of the lesson c) gives simplified directions
20. Using visual aids and gestures to communicate with students	**21. Building lesson on students' language *(vernacular or non-English)* OR culture**
Teacher: a) uses visual imagery, organizers (e.g., thematic boards, word wall displays, concept maps) b) employs gestures c) uses manipulatives for abstract and concrete concepts	Teacher incorporates into instruction: a) culturally-relevant examples (family, pop culture, ethnic traditions) b) native language when appropriate c) cultural artifacts (*anything human-made*) and community resources (*eating rice & beans, force on tortilla press, force on toes of a ballerina*)
22. Teacher addresses multiple levels of academic language proficiency *(differentiated instruction and/or assessment)*	**23. Provides direct instruction for using academic learning strategies**
Teacher: a) provides activities of varying academic linguistic demands b) uses assessments that match academic language proficiency c) adjusts pedagogy to the language proficiency	Teacher provides instruction in: a) summarizing b) organizing information for understanding (taking notes, data organization, mnemonics) c) making inferences from data (evidence supported)
24. Teacher provides instruction for interactions among students	**25. Uses supplemental resource material *(Note: lesson could be done without these)***
Teacher provides instruction in: a) how the groups will be organized and function (defines roles, collaborative structure, social norms of behavior in a group, inclusive interactions) b) using collaborative inquiry skills (how to paraphrase and ask questions for clarification) c) structures of accountability (academic and socially as a group)	Teacher: a) provides supplemental materials (e.g., trade books) b) provides access to reference materials (e.g., bilingual dictionary) c) uses technology to support language development (e.g., Internet)

(LP) Learning Principles Scale

26. Accessing students' prior knowledge	**27. Teacher modifies instruction based on students' prior knowledge**
Teacher provides students opportunities to: a) access their prior knowledge b) compare prior knowledge with normative ideas in science c) reflect and/discuss initial ideas and conceptions Note: Accessing prior knowledge means determining what students know before teaching the unit, oral or written.	Teacher: a) identifies alternative conceptions b) revises instruction based on students' understanding c) uses conceptual change strategies
28. Teacher and/or students situate factual knowledge (experiences, ideas, data, and explanations to past lessons and/or real-world experiences) within a conceptual framework *(fact to concept relationship)*	**29. Teacher provides opportunities for students to review key concepts *(focus on the review, not the discourse)***
Teacher provides opportunities to: a) link facts and experiences to promote patterned reasoning b) assimilating new information into existing frameworks of past lessons and real-world experiences c) place factual knowledge in a conceptual framework	Teacher provides opportunities for conceptual understanding: a) through multiple and rich representations b) by linking formal science to ideas beyond the classroom c) by reviewing key concepts
30. Teaching with embedded metacognition for students to elaborate and summarize their understandings	**31. Teaching self-monitoring for understanding *(focus on direct instruction of strategies)***
Teacher: a) models thinking in analysis of tasks or learning b) provides advanced organizers and/or develops graphic tools c) provides opportunities for students to elaborate and summarize	Teacher directly instructs students how to: a) reflect on their understanding, abilities, and affective states b) evaluate their own progress and quality of completed tasks c) identify what they have and have not been learned
32. Teacher provides students opportunities to develop awareness of their own learning strengths and challenges	**33. Promoting executive control of learning *(student choice about what and how they learn)***
Teacher provides opportunities for students to: a) self-assess effectiveness of their learning approaches b) understand unique learning approaches c) set the intensity or the speed of work	Teacher provides opportunities for students to: a) make choices and decisions about what and how to learn b) recognize that learning is under their control c) organize and sequence their own activities
34. Teacher establishes or reminds students of community norms for discourse	**35. Communicating lesson expectations with guidelines *(oral or written)*, or rubrics, or exemplars**
Teacher: a) negotiates, or reminds students of, guidelines for respecting each other's ideas b) establishes clear rules and expectations for discourse to promote everyone's participation c) provides opportunities for internalizing norms	Teacher: a) uses rubrics to inform students of performance expectations b) provides exemplars of student work c) provides easy to follow guidelines
36. Teacher uses feedback strategies that have an academic focus *(NOT just praise; "be more specific")*	
Teacher: a) uses both oral and/or written feedback b) give timely feedback c) encourages student self-reflection	