

Creating Collective Scientific Consciousness: A Cultural-Historical Study of Early Learning about Earth and Space in the Context of Family Imaginary Play

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Abstract

Based on a cultural-historical perspective, where play is conceptualized as the creation of an imaginary situation, this study seeks to examine how scientific learning is fostered through collectively created imaginary situations during everyday family practices. This study forms part of a broader study, and in this paper the focus is on a three-year-old child and his family from Mainland China. A theoretical discussion of data collected reveals that a collectively created imaginary situation provides the conditions for a child's exploration of scientific phenomenon not directly observable (e.g. Earth rotation and revolution). A form of collectively supported scientific consciousness was realized through discussions, imagining and re-imagining of everyday objects as scientific phenomenon. Scientific laws, as the rules of the scientific play being enacted by the family, enabled the child to be both imagining and viscerally experiencing which cannot be seen. The findings contribute to understanding how families create playful conditions that support scientific learning in the early childhood period.

Keywords: play, imaginary situation, family, scientific consciousness

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Over the past 30 years a vast body of research has accumulated on conceptual change (e.g. Herakleioti & Pantidos 2015; Kermani & Aldemir 2015; Tytler & Peterson, 2003). In line with constructivist theory (e.g. Taber, 2015), much of this research has focused on what a child thinks in relation to certain concepts (e.g. Blown & Bryce, 2006; Saçkes, Flevares, & Trundle, 2010; Tytler & Peterson, 2004). For instance, we know a great deal about children's thinking of the Earth (e.g. Bryce & Blown, 2013; Saçkes, Flevares, & Trundle, 2010; Tytler, 2000), space (e.g. Blown & Bryce, 2006; Kallery, 2011; Lelliott & Rollnick, 2010) and astronomy (e.g. Kallery, 2011; Plummer, Wasko, & Slagle, 2011). Much of this research has provided insights into the nature of children's thinking, usually in the context of interviews about incidents (e.g. Bryce & Blown, 2013; Plummer et al., 2011), or in classrooms where the focus is on concept learning (e.g. Rahayu & Tytler, 1999; Tytler, 2000), and where what children say was documented. From within this constructivist framework, this body of work resulted in knowing that children have a myriad of ideas that were found difficult to change once formed (e.g. Lelliott & Rollnick, 2010).

Over the past ten years more attention has been directed to socio-scientific thinking, where the context for thinking and learning science has been included in the research designs (e.g. Sadler, 2004; Siry & Kremer, 2011). Here the focus has been on not just the identification of children's thinking, but also finding a range of effective ways to enhance learning in the context of real world problems. Not only have researchers examined more than just what ideas children have about a particular scientific phenomenon, but they have also looked at the range of situations in which thinking occurs. Here a broad range of approaches to teaching scientific concepts for improved outcomes for children has been noted (e.g. Herakleioti & Pantidos, 2015; Kermani & Aldemir, 2015; Kirch, 2007). In addition, teachers' attitudes to scientific concepts, their competence in teaching, and careers aspirations of children/students have also been studied (e.g. Garbett, 2007).

The contexts for researching the scientific learning have predominately centred on formal settings, with notable exceptions being about learning in museums, zoos, science and technology centres, gardens, and the like (e.g. Zhai, 2012). What has been missing from this vast body of research has been a comprehensive study of how very young children learn scientific concepts in informal settings, such as playgroups, kindergartens (Siry & Kremer, 2011), and family homes (Sikder & Fleer, in Press). In some of these

contexts partnership models between specialized academics (e.g. science experts) and early childhood educators have featured (Howitt et al., 2012). These studies have moved beyond constructivist traditions and have framed their research using other theories, such as sociocultural theory or cultural-historical theory. What is common to these latter studies of informal settings, is the predominance of play. Yet, little research has been directed to the learning nature of play for scientific concept formation.

This paper draws upon the cultural-historical concepts of play and development as conceptualized by Vygotsky (1966, 2004, 2005) in order to examine scientific learning through play when a child's explorations of scientific concepts are considered during his or her everyday family play practices. The analyses focus on parent-child playful interactions and their relations to the child's process of scientific concept learning. Our analysis is premised on the view that a cultural-historical theorization of play is the basis for understanding a child's scientific explorations as supported by, and simultaneously contributing to, the collective mind created through the shared imaginary situation. This paper offers deeper understandings of early scientific learning in play through a study framed to capture the dialectical relations between collectives and individuals and between imagination and reality within everyday family play practices.

In order to examine how a child's thinking moves towards a collective scientific understanding during family play, where scientific thinking changes to that of a collective scientific consciousness, we have used the concept of collective play (Fleer, 2010, 2013). Our theorization focuses on collective and individual imagining in scientific phenomena and the dual thinking achieved as a child simultaneously moves inside and outside of the play situation (Kravtsov & Kravtsova, 2010; Bretherton, 1984). Our study explores the child's intentions, actions and perceived consciousness of certain scientific phenomenon as it is jointly performed and demonstrated in the family through playful moments.

We begin this paper with a discussion of the key cultural-historical concepts about play, learning and development, in the context of scientific exploration and family play. This is followed by a theoretical analysis of the collective environment created during family play where a form of collective scientific consciousness is possible to be built and which may change the nature of individual conceptual thinking. The analysis is based on a case study of a child's everyday family play practices. Specifically, this paper is designed to answer

the following question:

How is a collective scientific consciousness achieved between the child and the parents through family play practices?

A Cultural-Historical Understanding of the Dialectic between Collective Imagining and Individual Imagining

In drawing upon cultural-historical theory, the creation of an imaginary situation in play can be viewed as a dynamic and dialectical interplay between individual and collective imagining (Fler, 2010). It is argued that creativity and imagination is in the process of the movement between collective and individual imagining. In play a child is both individually acting something, whilst at the same time he/she also tries to explore and understand the roles and rules that have been culturally and historically created (Fler, 2010, 2013). That is, the child is forming his/her own imaginary situation, and generally, he/she is also positioned in the collectively constructed conceptions of what is being played, such as the rules and roles observed in everyday life. In other words, a child's individual imagining was formed and developed as he or she continually thinks through the collective imagining around certain concepts. If we consider the play setting, when children (or sometimes adults) engage together in a shared imaginary situation, they are not only individually imagining, but they are also within a collective form of imagining (Fler, 2013). From this point, we focus more on the collective community of players where they are able to regulate their individual imagining so as to build up the common understanding of the shared imaginary situation.

The contradiction between the individual and collective creates the possibility for movement that we were interested to examine within everyday play settings. In play, it is thought that children and adults are able to work together within a shared imaginary situation where the scientific rules may be introduced, and simultaneously, be collectively role-played, discussed and understood. Thus, it is important to know more about the collectively created imaginary situation under adult support. In this context, based on Fler (2010), we may find out how the conceptual rules that have developed over time were

embedded through collective imagining, as well as how the child's individual imagining was also taken into account. In considering the development of imagination in a dialectical way, adults play an important role in supporting the movement between the collective and individual imagining. Specifically, they may foster "the disassociation and reassociation process involved in the imaginative act and the crystallization process of imagination into a material form" (Fleer, 2010, p.143).

However, traditionally, play has been deemed the sole activity of children in many early childhood settings, and the educators usually do not have a role in children's play (e.g. Bruce, 2005; Dockett, 1999; Kennedy & Barblett, 2010; Moyles, 2005). Play when theoretically interpreted as the dialectic between individual and collective imagining gives new conceptualization of it so as to help understanding the collective formation of play with adults' supports. It is of significance to note that in family play, parents may introduce collective knowledge, and in this particular study that might be science concepts. Further, based on their past scientific experiences, what matters here is their interactions with the child and their mediated role in connecting science knowledge with a child's imagining.

In our study, early childhood children's collective play in contexts where scientific concepts are not directly observable, such as the Earth's rotation around the Sun, was seen to be particularly important. It is pedagogically significant to identify the conscious moment of tension or contradiction in play, which may lead to a scientific consciousness for the individual who might never have easily noticed or read the context through scientific lenses. It is important to note that the term "consciousness" mentioned here needs to be understood from a cultural-historical perspective. Different from our traditional illustrations of consciousness, "consciousness is not only born in existence and not only reflects and therefore embodies it - to be sure, in a reflected or distorted light - but also creates it" (Zinchenko, 2009, p.46). That is, consciousness cannot be simply conceptualized as a reflection, it is the individual creative process, where the active individual's engagement (e.g., real motives and interests) is evident. Children have their needs to understand and gradually generalize certain concepts, and this is meaningful to be taken seriously during everyday family play practices. It is through examining the dialectic of collective and individual imagining in family play that we believe better understandings of the child's process of scientific consciousness through play can be found.

A Cultural-Historical Understanding of the Dialectic between Imagination and Reality Existing in Play

It has been demonstrated that in play children simultaneously move between the collective and individual, the concrete and abstract, the imagined and real experiences, as well as the imaginary situation and reality (Fler, 2013). Anchored in Vygotsky's (1966) definition of play, children can reach a new state of development that they cannot meet in real life, because they place themselves into an imaginary situation in play. Vygotsky (2004) has argued that a child's play is not simply a copy of their real experiences, but a creative process of engaging in what has already been experienced, and this will result in the creation of a new reality where the child can find and fulfill his or her needs and desires.

When children are in an imaginary situation playing, they engage in the fields of imagination and reality simultaneously. The essence of play is the creation of an imaginary situation where the visible objects and actions are imbued with new meaning and a new sense of the situation is created. For instance, when a child sees a stick (visual field) he can give new meaning to the object (hobby horse), and create a new sense of the situation (riding a horse). There exist two motivational dimensions in play – objective field and sense field (Elkonin, 1999). "Sense invests the object, and the object acquires sense" (Hakkarainen & Veresov, 1999, p.9). When meaning begins to dominate the concreteness in play (rather than just exploring the object – objective field), we can see the divergence between the field of meaning and the field of what is seen (Vygotsky, 1966). That is, the child is able to act differently to what s/he sees (riding a stick as though it were a horse).

However, as has been mentioned by Vygotsky (1987), a more profound penetration of reality demands that consciousness attains a freer relationship to the elements of that reality. For example, when a child is able to ride a horse, s/he is playing with the new meaning given to the stick, and through this moves away from reality. That is, the child can freely deal with meaning in the sense field exploring the rules and roles found in everyday life - i.e. what it means to be a horseman/horsewoman are possible to be explored. When the child tries to be the role of other people and performs its actions, s/he moves toward reality, by trying to show the relationships that are characterizing the real role that they are playing (Elkonin, 2005). The result is that "the processes through which the cognition of reality is

achieved become more complex and richer” (p. 349). Thus, imagination “can lead a person either toward or away from reality” (Vygotsky, 2004, p. 37).

The movement between imagination and reality is important in our research. In terms of the position of a child during play, as noted by longstanding play researchers, being inside and outside of an imaginary situation has been found to be intertwined (e.g., Bretherton, 1984; Giffin, 1983). “The two levels (out-of-frame metacommunication and within-frame acting) are logically distinct, in actual play the levels are often intertwined. Play-acts and utterances therefore tend to carry multiple levels of meaning, which can only be disentangled conceptually” (Bretherton, 1984, p. 24). Identifying these two levels in play is useful to differentiate children’s positions; however, in real play children usually take a dual role (Kravtsov & Kravtsova, 2010) when being the subject of play acting out a role and simultaneously taking up the objective position controlling the play. This is different from children’s natural everyday activity, because when taking a dual role in play, children become conscious of what they are being and/or performing. Fleer (2013) has argued that the dual role mentioned here not only refers to children’s dual positions in play, but also takes into account the dual role of objects/actions (visual and sense fields).

When children are provided with the conditions to experience dual positioning, substantially new forms of consciousness of reality may appear, reality that cannot be encountered through direct experience, such as the rotation of the Earth around the Sun. During collective family play, the parents and the child may experience the ‘dual role’ together. They may, jointly or in negotiation with each other, give new sense to the objects/actions in their play. They may not only behave in their roles but also discuss collectively the rules for playing out the roles. When understanding play from a cultural-historical perspective, we believe a better interpretation of the role of play in a child’s process of scientific concept formation can be established.

Research Design

The study seeks to use digital video technologies to capture the dynamics of a child’s scientific learning in his everyday family life, and the focus is on his social relations and

interactions to reveal the wholeness of this research situation. The cultural-historical research was designed based on Hedegaard's (2008) dialectical-interactive methodology. Depending upon this theoretical framework, research always implies the inclusion of the researchers in the specific settings the children's everyday activities take place, as well as their interactions with the researched persons in particular contexts (Hedegaard, 2008). Hedegaard highlights the researcher's role as a partner within the activity with the participants while examining children's everyday experiences, which means the researcher needs to be aware of their relations with the participants and the participants' perspective of the research process. In this way, it is possible to make the researcher think consciously about whether their descriptions or arguments could be reliable in reflecting the participants' everyday states of life.

In the study, the naturalistic observation as the main data collection strategy requires the researchers to enter into the activity settings in which family play takes place and to catch the perspectives from the families within play practices. We conceptualize ourselves as a part of the context in which the child's play activities are involved. This approach allows us to be inside of a child's everyday family life rather than to be a "fly on the wall" or to stand outside the research context to explore a child's everyday interactions with their parents during play.

Participants

The data was related to Yao's family, comprising Yao who is the single child in his family and his parents from a medium-sized city (Taiyuan) in Mainland China. The participant child was randomly recruited through a public childcare center in Taiyuan. Yao was 3.3 years old in Observation Period 1 and 4.2 years old in Observation Period 2. From age three, Yao attended the childcare center between 8am to 5pm five days a week. The mother (Shu) held a bachelor degree, and when employed she works for a language training school. The father (Li) received master degree. He is employed as a teacher for college of language in Taiyuan Normal University. Both parents have no background of early childhood education. They have not been trained in any parent school or research programs about parenting or family education in preschool years.

Data Gathering Approach

Data from Yao's family was gathered over two different research periods through video observations, videoed parent interviews, and photographs. Totally 18 family visits were conducted based on the parents' and child's convenience. Researchers videotaped the focus child during his participating in everyday family practices among weekdays (including morning and afternoon routings), as well as observing at weekend (when they were playing at home, reading together, or going to the nearby park). The filming was conducted using a roaming camera following the child as he or she engaged in family set activities. A second camera mounted on a tripod was fixed near the settings for daily activities. Two cameras provide the opportunities to capture close up and long shots of a child's everyday family practices. A disposable camera was left for the parents to videotape and/or photograph Yao's everyday family activities that they considered valuable. The study reported in this paper draws upon the data collected from the Yao's family, which included 21 hours' video observations over five visits with each visit lasting around 1.11 – 1.90 hours ($M=1.69$ h) and another eleven visits made after 10 months with each visit lasting around 0.45 – 2.08 hours ($M = 1.14$ h), as well as 3.06 hours ($M=1.53$ hours per observation period) of parent interviews when they were showed the video clips made through the family observations. Additionally, parents as the co-researchers in this study took 11.6 hours of videos (51 clips) about Yao's everyday family activities especially his play. These videos were taken in natural family context, focusing on the activities (esp. play) parents valued as importance for Yao's development. A total of 35.66 hours of video data resulted.

Data Organization and Interpretation

A research protocol was developed for analyzing the related video observations, interviews and photographs, where all the data were logged following the time order for each hour of visual data collected (see Figure 1). The visual data were then segmented through iMovie into concept learning episodes (e.g. counting blocks, recognizing materials, reading about Earth structure), imaginary play episodes (e.g. playing with a toy phone, rocket launching) and the episodes about imaginary exploration of scientific concepts (e.g.

Earth orbiting, Earth moving play).

Related history	3012015 Sat. Afternoon	Common sense	Related history	4012015 Going & Picking up	Common sense
	5.15pm Talking with parents about the activities for new year celebration Science centre; Concert			7.20 am Get up Yao did not want to go to the childcare center and discussed with Li. Li explained that he should go to work and earn money.	
Li said they helped Yao find the videos and then Yao usually watched by himself and modeled the launching process. Sometimes they watched the videos together with Yao and explained the concepts he asked.	5.18 Watching rocket launching Parents were talking with Yao about the processes of rocket launching, the concept of gravity and energy. Shu let Yao count down in English.	The science concepts were discussed and explained during watching the video. Yao created the imaginary play about rocket launching.	Li said he found that Yao usually had his imagination as a spaceman, and when he could understand this Yao could do more than what he normally did.	7.34 wear clothes Li told Yao that you are the spaceman, so that you should be quick. Then Li helped Yao quickly wear the clothes.	The imagination could help Yao take another role and behave like the new role, because he knew the meaning of the new role.
Shu said Li has told Yao the concepts about earth revolution and rotation during book reading. Yao was really interested with the process of the demonstrations about the concepts rather than reading through them.	5.30 Reading book (encyclopaedia) with parents Lands and ocean Revolution and rotation (parents let Yao do the demonstration using a ball.)	Yao was interested with the demonstration. That means he could use the imaginary situation to experience the abstract concepts. Parents were conscious about the concepts and tried to find the way to let Yao understand. Yao was motivated to play out what the parents explained.	Researcher found that Yao usually used his hands (finger) to do a rocket play. The forefinger could be the escaping tower and the hands (close and open) could be the fairing.	7.40 Washing face Yao used his hands to play as the fairing. The researcher asked him that you opened the fairing.	Yao imagined the image about the rocket every where.
Shu said Li and Yao used to play this game. Li said Yao really preferred to play with him about earth orbiting.	5.54 Earth-orbiting Li pretended to be the earth and Shu played as the moon. Yao acted as the rocket. Yao did earth-orbiting and then landed on moon.	Yao was enjoyed the imagination. He could not understand clearly the concept but could experience it through play. The parents was also participate in this play. The father played as the earth and the mother was played as the moon.		7.47 Preparing to go out Li said to Yao that you are the spaceman and should be quick. Then Li let Yao wear the space suit. Yao said he could not do this by himself. Li helped him wear the jacket.	Li used the collective imaginary situation about spaceman to let Yao quickly wear the jacket. Li explained to Yao the concept of space suit that the spaceman should wear the space suit.

Figure 1. Research protocol writing with common sense interpretation

These data were analyzed in relation to a child's family play and concept learning according to three main levels of interpretation (Hedegaard & Fleer, 2008): 1) Common sense interpretation: some striking parent-child interactions in relation to the imaginary play and scientific learning stood out (see Figure 1). 2) Situated interpretation: the analysis involved the examination of the clips created from commonsense interpretation for relevant family practices in order to find the conceptual patterns. 3) Thematic level: the analysis involved the rigorous examination of the interpretations across situated practices for finding the schemes of interpretation (as listed in Table 1) using specific concepts from a cultural-historical perspective.

Table 1. *Schema for analyzing a child's scientific learning during everyday family play practices*

Category	Analytical focuses
The relations between collective and individual imagining – the dialectical relations in everyday science learning	
a. Towards the contradictions between individual and collective imagining existing in everyday family play settings	Noting moments in play where a child's individual imagining appears to contradict parents' introduced collective imagining about certain science phenomenon
b. How is the regulation between individual and collective imagining possible to be achieved?	When parents' introduced science knowledge tends to link with child's readable imagining
c. Towards the movement between the individual and collective imagining	When child's individual imagining is in concert with the parents' introduced science knowledge
Scientific consciousness: The relations between imagination and reality – dialectical relations in collective family play	
a. Towards the dialectic between objective (visual) field and sense field	When child/parent takes an objective situation and forms a new meaning (e.g. a ball becomes a planet) What objects (if any) do the family change their meanings What actions are performed with new meanings by the child and parents
b. Towards the movement between imagination and reality	When child/parent takes different positions (being inside an imaginary situation to imagine with the new meanings created and being outside to work on the real meanings)
c. How is the child's consciousness of the reality supported?	When the child is able to experience more about the dual positioning during parents' play participation
Making conscious key scientific concepts in play – Collectively supported play	
a. How do parent-child playful interactions create the conditions for realizing collective consciousness?	What communicative process do the families use in play and do they get a common awareness
b. Towards the collective understanding around the scientific meaning	When the shared imaginary situation is continually built and the common understanding continues between the child and the parents

Findings

The study found that when parents entered into the imaginary play of their child, their child's imaginary play deepened and became more scientifically meaningful, supporting the learning of abstract concepts not directly observable in everyday life. To illustrate the findings of the overall study, detailed examples of family play practices taken from Observation Period 1 and Observation Period 2 are presented alongside of the results of the family interviews. We begin with a general description of Yao's everyday family activities to give a context for the examples that follow of the family play practices where scientific learning was being supported through imaginary play.

Everyday Activities and Family Pedagogical Practices for Learning Concepts

The main activities (including weekdays' and weekends' activities) observed during the two observation periods are summarised in Table 2. During each observation period sometimes, several contradictory activities occurred simultaneously. For instance, Yao was inclined to play in imaginary situations, such as pretending to use a mobile phone to have an imaginary conversation, rather than engaged in the learning activities planned and initiated by the mother, such as, painting, reading, counting blocks/bowls (Observation Period 1) or when pretending to launch a rocket rather than get dressed and prepared for preschool (Observation Period 2). A close analysis of all the moments of imaginary play in both observation periods and their respective contexts for play revealed that more imaginary play took place during the second observation period. Similarly, the families created more play conditions including the formation of imaginary situations for supporting Yao's science learning during the second observation (see Table 2).

In Observation Period 1, Yao frequently played with the real or pretend mobile phones. This was his preference, and the parents mentioned during the interviews that they did not consider these kinds of imaginary play meaningful, or considered orienting Yao's learning through these play activities. In fact, they rarely participated into Yao's phone play. For example, they stated that:

Table 2. *Yao's everyday family activities*

Observation period 1 (Winter holiday)	Duration/ Frequency	Observation period 2	Duration/ Frequency
Weekdays		Weekdays	
<i>Morning activities</i>		<i>Morning activities</i>	
Mother led painting	20mins/2	Raising out of bed	20mins/2
*Self-playing with real or pretend mobile phones	6mins/2	*Getting dressed (Sometimes Yao was called as the spaceman to quickly wear the clothes)	10mins/2
Playing with the camera (researcher's)	9mins/3	Finding the rocket (hand-made) or a part of it	11mins/3
Playing drum (recognizing the number of knocks)	7mins/1	*Playing with the imagined rocket or parts of it	15mins/3
Learning Chinese words (cards)	8mins/2	Walking to preschool	9mins/2
<i>Afternoon activities</i>		<i>Afternoon activities</i>	
*Self-playing with real or pretend mobile phones	31mins/10	Picking up from preschool	21mins/3
Bowling (recognizing the shape and counting the bowls)	8mins/3	Finding the rocket (model) or a part of it	32mins/4
*Playing blocks (building a long train and counting the blocks)	15mins/3	*Modelling rocket launching	57mins/9
Mother led painting	25mins/3	Watching the video programs of Shenzhou spacecraft	60mins/7
Reading books (geographic names, simple math, idiom, angry, love my mum, love my dad, I want to play...)	66mins/6		
Family exercises	25mins/2		
Playing with the camera (researcher's)	9mins/3		
Weekend		Weekend	
Cleaning the room with parents	17mins/2	Reading books (encyclopedia about land, ocean, Earth structure, earthquake, volcano, four seasons...)	77mins/10
Guessing game (e.g. the functions of electronic products)	23mins/4	Watching the videos about rocket launching with father	21mins/3
*Role-playing with parents (calling someone, thief and policemen...)	19mins/2	Making up the rocket model with parents	55mins/3
Watching cartoons with the father (Tom and Jack)	42mins/2	*Role-playing with parents (Earth rotation and revolution, Earth-orbiting, acceleration of the rocket, rocket launching...)	63mins/8
Reading books (simple math, four seasons)	35mins/4	*Modelling rocket launching	95mins/10
		Riding in the park (Yao called himself as the astronaut)	36mins/3

*Imaginary play

Yao had his imagination in his play...We usually teach him meaningful knowledge...We did not usually joint his play. Actually, we don't know how to imagine with him or to develop his imagination. We could choose a book to let him cognitively understand something. As for his development of imagination or imaginary play, we rarely paid attention to. We have not considered this. (Interview Shu) In contrast, many everyday activities Yao engaged in during the second observation period could be labelled as imaginary play or parents' joint role-play (such as family joint play of Earth-orbiting, Earth rotation and revolution). Yao's interest in the area of Earth and space was predominant in this observation period. Compared with the first observation period, the parents paid more attention to Yao's play interests (such as downloading the videos for modelling a rocket launching and assembling the launching tower and a rocket model) and participated in more imaginary play with Yao (see final column in Table 2). The findings indicated that the parents began to consider Yao's perspective (such as his self-imagining) and to arrange his everyday family practices in regard to what he was interested to do. This type of orientation has also been explained by the parents:

Researcher: How did the child get the relevant knowledge such as gravity and the electric power furnished by the solar panels?

Shu: We told him about that. He usually asked questions then we explained the answers to him. For example, he asked why people were floating up because of weightlessness.

...

Li: I chose to play with him and showed him some concepts through vivid demonstrations. We usually orient and persuade him rather than force him to follow our ideas...For children, adults have power. If we force him to do something he will be negatively influenced...I encouraged him to have his ideas and to be creative. (Interview Shu and Li)

The change in pedagogical practices of the parents is evident between these two observation periods. Correspondingly, the orientation of Yao in family activities moved from completing the parents' designed activities (e.g. reading, painting, counting, etc.) to formulating and developing his own expected activities collectively with his family. Yao's active engagement in imaginary play appeared to be a key dimension of the change in pedagogical practice of the family.

As shown in Table 2, during the first observation period, Yao's parents focused more on

his everyday reading (e.g. simple math, four seasons, idiom and so on) compared with giving attention to Yao's imaginary play, such as pretending to call someone on the phone. However, during the second observation period, even though the parents still paid attention to his reading in the context of relevant concepts (such as the science knowledge about the Earth), they began to take into account Yao's imaginary situations, such as supporting demonstrations of concepts shown in books. An example taken from the overall data set for the second observation period follows (see Figure 2):



Figure 2. Reading about the alternation of day and night through imaginable demonstration (E1)

Li asked Yao to read the encyclopedia regarding the alternation of day and night. Yao intended to pick up the hand-made rocket to play rocket launching. Then, Li initiated a new game and let Yao turn off the light. Yao was very excited. The father held the watermelon ball and let Yao sit with him on the tatamis. When the father asking, "Which side of this ball is bright?" Yao pointed at the bright side facing the light from the camera. When asked, "Which side is dark?" Yao pointed at the dark side. The father then faced the camera and said, "That is the sunlight". He explained that if Yao stood on the bright side it was day time, and the mother continued "You go to the childcare centre", but if standing on the dark side Yao needed to go to bed.

The duration of the activity and its frequency during the second observation period are shown in the final column of Table 2, where the parents' joint performances and demonstrations were noted as occurring more frequently. In each of these family activities, it was observed that Yao's interest focused mainly on the area of Earth and space. For example, the father explained that Yao was inclined to ask him to play rocket launching or Earth orbiting with him. The father also indicated that he was very happy to cooperate with Yao in his rocket play. The play theme of Earth-orbiting was firstly introduced by the father, and gradually became one of Yao's favorite play activities, which could be specifically shown in next example (see Figure 3).



Figure 3. Parents' participated play performance of Earth-orbiting (E2)

The father selected the Children's Encyclopedia from the shelf and read it with Yao and the mother. They discussed the structure of the Earth. Later, Yao suddenly climbed into the bed and let his father catch him. Yao acted as the rocket now and expected his father can play the Earth to attract him. Then the father was in his role and demanded the rocket (Yao) to do the Earth orbiting. Yao showed his active mood to play as a rocket. The mother then participated in this play and suggested "Please be aimed for me – the moon now". Yao held the father's hand and walked toward his mother. The mother asked "Will you make for a soft landing or a hard one?". Yao answered "I will do hard landing" ... The father at last pointed to the bed and

asked the rocket (Yao) to fire at the Mars (the bed) ...

An analysis of the data showed that during the second observation period that the parents' interactions with Yao in play situations were always positive and supportive of Yao's perspective. The parents preferred to use playful demonstrations that were considered easier for Yao in order to support his conceptual learning. As mentioned by the parents, this approach was useful for attracting Yao's attention, to let Yao be more active in his learning, and to focus more upon the concepts that he was interested in. As is shown in Example 3 below, Yao tended to test and explore more about the Earth rotation and revolution when he played with his parents collectively where he was supported by playful demonstrations by his parents. The play topic of the Earth's revolution has been explained and demonstrated by the father according to what he read with Yao through the children's encyclopedia. In the following example, the parents tried to let Yao know more about Earth rotation and revolution when a play setting was formed around this (see Figure 4).



Figure 4. Parents' initiated playful demonstration of Earth rotation and revolution (E3)

The father then asked Yao to show how does the Earth rotate on its axis and simultaneously revolve around the sun. The mother suggested, "We can use this watermelon ball as the Earth". The father said, "For example, dad is the sun. How does it make the rotation and

revolution?”. Yao was very excited and kept turning around his father. He explained that he was showing the Earth orbiting. They all laughed, and the mother repeated the new roles Yao and his father played in this performance. Yao needs to play out the moving Earth. The mother then circled around the father and at the same time she made the ball spin tilted to one side. Yao showed his interest to perform this action by himself, but he still could not simultaneously move like the Earth around the sun whilst turning himself around. Later, the father changed to use a cylindrical barrel to be the sun. He held the watermelon and made it rotate around itself and simultaneously move around the barrel. Yao was really eager to demonstrate this, for example, “Give me this (ball), dad...”. The parents kept showing the law of the Earth moving. The father explained at last “For example, dad will stand up and move around myself. That is the rotation on its axis”. Yao suddenly stood up and began to spin around himself...

The overall findings showed that Yao expressed more active explorations of certain concepts emotionally and cognitively during the second observation period when his parents collectively participated in the family play. This finding focuses directly on the pedagogical practice of the family, and this will be discussed further in the next section, where a more theoretical discussion of how families create the conditions for consciously considering scientific concepts in play is presented.

How Parents Create the Conditions for Collective Scientific Consciousness through Play

Vygotsky (1997) explains that mental functions are firstly constructed through a form of relations between people and then they are formed internally. Based on this cultural-historical perspective, collective activities can be explained as a necessary condition for constructing the social relations (Davydov, 2008). As has been noted by Hedegaard & Fler (2013), within a practice setting, a person is able to engage in his or her individual activity, which can be oriented towards the commonly accepted traditions and values of a collective community. During parent-child playful interactions in this study, it is possible to determine that the child’s individual imagining was oriented towards and sometimes combined with the parents’ formed or expected imagination about certain science

Table 3. *Data examples for Yao's scientific learning during everyday family play practices*

Category	Data example
The relations between collective and individual imagining – the dialectical relations in everyday science learning	
a. Towards the contradictions between individual and collective imagining existing in everyday family play settings	E3: Yao's self-imagining of doing earth-orbiting contradicted parents' expected imagination of Earth rotation and revolution.
b. How is the regulation between individual and collective imagining possible to be achieved?	E1: Li tended to specifically demonstrate the Earth rotation to let Yao imagine the alternation of day and night. E3: Parents tried different approaches (e.g. Shu made the ball spin and turned around Li simultaneously; Li let the ball spin and simultaneously move around the barrel) to help Yao form his imagination of Earth rotation and revolution.
c. Towards the movement between the individual and collective imagining	E2: Li captured Yao's imagining about a rocket taking away from the Earth and continued this imagination by introducing the performance of Earth-orbiting, and simultaneously Yao jointed with Li to do an imaginary play of Earth-orbiting.
Scientific consciousness: The relations between imagination and reality – dialectical relations in collective family play	
a. Towards the dialectic between objective field and sense field	E1/E3: Parents gave new meaning to a toy ball to make it act as the Earth. E2/E3: Many performing and demonstrating actions were used to represent new meanings such as Yao turning around Li for doing Earth-orbiting and Yao's self-turning as the Earth rotation.
b. Towards the movement between imagination and reality	E2/E3: Yao and his parents changed the meaning of the toy ball and their actions to perform Earth rotation and revolution, and simultaneously, they tried to exactly play out the scientific rules by sustained communication.
c. How is the child's consciousness of the reality supported?	E3: The parents helped Yao choose the substitute object (the toy ball) and gave it new meaning. Continually, they not only performed the Earth moving with Yao, but also supported it by making it visible.
Making conscious key scientific concepts in play – Collectively supported play	
a. How do parent-child sustained communication create the conditions for realizing collective consciousness?	E3: The parents continually communicated with Yao (such as negotiation, critical question, re-question, demonstration, re-demonstration) to let him reach the common understanding of earth rotation and revolution; simultaneously, Yao tested different ways to move like the earth.
b. Towards the shared sustained thinking around scientific meaning	E2/E3: The parents continually added new meanings (represented through new operations on the rocket and new actions made on the toy ball) with Yao during play.

knowledge. This was shown in the interactive process when the parents' introduced a collective imaginary situation that was connected with the child's individual imagining. Pedagogically, this reflected the parents' strategies in setting up collective family play and supporting the child's exploration of new science concepts. The dialectic between imagination and reality were also examined during collective family play, where the parents' play participation was observed as supporting the dual positioning (seen through the interweaved two worlds – imagination and reality). The findings revealed three elements considering Yao's science concept learning in family play (see Table 3), which are discussed in turn: The dialectical relations between collective and individual imagining, the dialectic between imagination and reality, and collectively supported consciousness of key scientific concepts through family play.

The relations between collective and individual imagining – the dialectical relations in everyday science learning. The findings indicated that Yao was socially supported in his process of understanding certain science concepts, as refracted through the collective creation of an imaginary situation between the parents and the child in their family play. There exists a conscious regulation in the plane of the collective subject, which is, in other words, embedded in the social form as an individual subject (Lektorskii, 1981). This is in line with the theorization of the dialectical relation between individual imagining and collective imagining, that is, the regulation and development of individual imagining as seen through the socially supported movements between individuals and collectives.

Figure 3 shows what Yao has initiated and how his parents extended it during their family play. Although Yao's own imagining was in conflict with the family's reading about Earth structure, the father captured Yao's play demand and reflected it by being the Earth. Then, he introduced the collective imagining about how a rocket was moving in the space, following the rule of the Earth-orbiting, so that their play was continually formed and developed. Later, the mother also played a role (the moon) and the complexity of this role play largely increased. It is clear that the father paid enough attention to Yao's individual imagining of being the rocket, and naturally, he also tried to connect it with the collective imagining of the rule for moving as a rocket. The findings also indicated that when the father suggested to play, Yao reformed his rocket play. That is, his self-imagining was in

the process of making changes because of the introduced collective imagining. The individual and collective imagining of scientific concepts was supported because the parents not only took into account what Yao was imagining but also directed it more towards a common activity, where a general scientific understanding could be built.

When play was initiated by the parents, as shown in Figure 4, Yao was at first still playing in the role as the rocket. It might be that Earth rotation and revolution was seen through Yao the same as a rocket orbiting the Earth. Yao's individual imagining greatly contradicted what the parents expected Yao to imagine and show. Through playful demonstration and re-demonstration, the parents were trying to create a shared sense field with Yao and to lead him towards a collective imagining, where the scientific rule of the moving Earth was being formulated. Yao seems find his imaginable point within the parents' introduced imaginary play and showed his willingness to engage in the play his parents initiated. Because of this he gradually formed his own imagining based on what his parents had introduced. When the play settings were constructed, the parents had already considered Yao's preferred imaginary play, which was always associated with Earth and space. A shared imaginary moment appears if both the parents and the child are able to find the common points to share their individual understandings.

The interactive relations between Yao and his parents were collectively built through the role play of the Earth moving. In this shared imagining, the Earth spins around itself during the ongoing revolving around the sun, and in reality, the parents' demonstration of the scientific phenomenon showed this concept to Yao. Simultaneously, Yao tried to socially relate to his parents, due to his new social position of being the Earth and showing the scientific rule of the moving Earth. Yao showed his eagerness to express his personal view of how to perform like the Earth, but this was undertaken as he subjectively connected to his parents' acts and ideas shown through this shared imaginary situation. Yao's individual science experience was largely extended and formed at a collective level where he was involved in the sustained interactions with his parents in play.

Scientific consciousness: the relations between imagination and reality – dialectical relations in collective family play. If we think of the science concept, we may ask how does a scientific consciousness appear in family collective play? In this study, it was

important to see how the parents' engagement in family collective play provides the conditions for a child's development in the form of a scientific consciousness. Based on a cultural-historical perspective of play, the dialectical relations between individual and collective imagining must be considered, and simultaneously the dialectical nature of imagination also needs to be taken into account (Fleer, 2013). In this conceptualization of play, it becomes possible to examine the collectively supported movement between the individual imagining and collective imagining around certain science knowledge that cannot be directly gained from real experiences. That is, for example, Yao is unlikely to have the opportunity to travel in a rocket and to see from this perspective the Earth's rotation and revolution. This perspective has to be imagined, and play supports this imagining.

Sense – object relations. Based on Vygotsky's (1966) conception of play, in an imaginary situation, a new sense of real life emerges for a child. What is important here is the collectively created sense field where new meanings are initiated and discussed collectively (see Table 3). There exists a collective meaning-making process through which new meanings are created, upgraded and continually developed following the progressing of the play plot. In this study, when the parents helped the child imbue the object (e.g. watermelon ball) and the actions (e.g. spin and circling) with new meanings, Yao changed his sense of the objective situation and became oriented towards a new sense field with his parents. We can see that the parents supported the departure of the child away from the objective reality of the ball to the imagining of the Earth.

What is noted here is that when engaging in a shared imaginary situation, the child is able to continually reach a common understanding of the meanings and to update his own sense of the situation with new meanings. For example, Yao turned himself into the Earth with the ball, and enjoyed the circling movement around his father, but his actions were continually formed and given a new meaning due to the development of the shared imagining between Yao and his parents. The essence here is the formulation of the shared sense field, where a freer relationship to the concrete objects is supported. This was found to be important in this study for realizing a more conscious understanding of the science reality being imagined and which the child could not easily achieve through direct

perception.

The movement between imagination and reality. From the perspective of cultural-historical theory, imagination is not a fantasy world isolated from reality, but has a dialectical relation with it. This dialectical relation usually exists with more differentiated forms of consciousness when children take different positions (being in and out of an imaginary situation) during play (Fleer, 2011). According to the study results shown in Table 4, the play participants could have different positions simultaneously but still engage in a shared topic during play. Yao and his father usually played their roles in play, and they had relatively identical positions in terms of their transitional actions, but his mother always positioned herself outside the imaginary situation. Yao personally experienced the movement between different positions, and interacted with his parents who also positioned themselves differently. He had a special experience in the multi-layer relations between these different positions, which Kravtsov and Kravtsova (2010) have suggested is important for children to engage in self-assessment and to see themselves above the situation.

In this study, it is difficult to identify the boundaries between the imaginary world and the real world during the family collective play. They were dialectically related through the players' dual positions. This is in line with previous conceptions about the intertwined positions children usually take during play (e.g., Bretherton, 1984; Giffin, 1983). For example, Yao signaled his thinking about how to act as the Earth when he was still performing in the role of the Earth (see Table 4). Yao held a dual position, as he stood between the real discussions and his imagining of the moving Earth. The parents, especially the mother, usually provided their guidance for Yao's performances outside the imaginary situation, which may result in Yao's awareness of the scientific laws he performed inside the imaginary situation. At this moment Yao possibly held a dual position. Yao was not forced to stay outside the imaginary situation to be conscious, but the parents' suggestions, such as '...Rotate on its axis and at the same time... The ball also moves around itself...', were prompts for Yao to be aware of the real situation when he was still within his role as the Earth revolving around the Sun.

Fleer (2014) also found that adults' suggestions support children in paying attention to key features of an imaginary situation. Adults may have different social positions from a child during play; however, because of the common goal for continuing the play plot they still engage in the shared imaginary situation with the child. Their deliberate actions may contribute to a child's consciousness of his/her imaginary acts in play. When a child thinks about their thinking, he or she is performing at a much higher cognitive level. The dual thinking can be seen now as a form of meta-cognition, which has been shown to be "so important in learning to learn, also develops as the child finds it necessary to describe, explain and justify their thinking about different aspects of the world to others" (Siraj-Blatchford, 2007, p.14).

Consciousness of the scientific reality. Sustained communication (verbally or nonverbally) was found in this study to be meaningful in making the dual thinking possible, when new meanings were negotiated, critiqued, evaluated and simultaneously exemplified, demonstrated and re-imagined, as was shown in the final column in Table 4. In this study, through the above mentioned communicative process, the child was given more conditions for experiencing the dual positioning, which marked a relatively higher level of consciousness of the rules specified through roles, actions and objects played together in an imaginary situation (see Table 4). Sustained communication helps Yao become aware of the shared sense field in play when he was trying to act out his self-imagining. In communicating with his parents during play, Yao changed his thinking through the new meanings given to the objective situation (such as the ball, the barrel and the circling movement), and simultaneously, he tried to perform exactly what his parents did (such as the actions shown for Earth rotation and revolution) in order to achieve a shared sense with them. We can see how important this social way (specifically the communication) is in a child's process of thinking consciously about the scientific rules.

Table 4. *Scientific meaning making in family collective play*

Meaning category	Meaning focus	Social position (who/where)			Social Ways (Verbal/Nonverbal communication)
		Mother	Father	Yao	
Objects	Light-the sun Bright side-day Dark side-night	Out	Out	Out	<i>(Explanation, Demonstration, and Exemplification) (E1)</i> Li: This side...this looks like the sun. (Li pointed at the camera held by the researcher.) That is the sunlight. For example, Yao is now standing here (the bright side). This is the day time...If you stand here (the dark side), the dark night, and you are in sleep.
	Barrel-the sun	Out	Out	Out	<i>(Negotiating language) (E3)</i> Li: ...Dad puts this (a cylindrical barrel) as the sun... Yao: A rocket... Li: If it is the sun... Yao: It is a rocket. (Li put the cover off) Shu: We pretend it is the sun. Pretend.
Roles	Li-The earth Yao-The rocket	Not in play	Dual	Dual	<i>(Following) (E2)</i> Yao: Dad, catch me! Li: You cannot be attracted (by the earth). Quickly come here! He said I am the earth and can attract him. He is the rocket.
	Li-The earth Shu-The moon	Dual	Within	Dual	<i>(Critical questioning) (E2)</i> Shu: You will do hard landing. Ok, how can you... Yao: I moved around two moons and I will do the hard landing. Shu: Why there are two moons? He is the earth and I am the moon.
	Father-The sun Yao-The earth	Out	Dual	Dual	<i>(Leading questions) (E3)</i> Shu: How does it make the rotation and revolution? (Yao held the ball and moved around his father) What are you doing? Yao: Earth orbiting. <i>(Critical questioning) (E3)</i> Shu: This is earth orbiting? (Shu and Li laughed) You are the earth and your dad is the sun. You were doing earth revolution...
Actions	Turning around Li-Earth orbiting	Not in play	Dual	With in	<i>(Explanation) (E2)</i> Li: Rocket, I attract you and you move around dad. Earth-orbiting, earth-orbiting (Li held the hand of Yao and made him move around him) ...Then, (you are) now beyond the earth gravity. Go away, go away...Come here, come here, quickly! Come back to the earth now. (Yao quickly climbed into the bed, and then rolled down toward Li.)

Walking toward Shu-Firing at Shu	Dual	Dual	With in	<i>(Following) (E2)</i> Li: Yes, then, for example, (you are going to be) fired at that planet. Shu: Fire at me – the other planet. Quickly, launch it now. Wu... (Yao held the father's hand and walked toward Shu.)
Holding the hand of Shu-Moon landing	Dual	Within	Dual	<i>(Leading question) (E2)</i> Shu: Will you make for a soft landing or a hard one? Yao: I will do hard landing.
Opposite move-Earth rotation	Out	Dual	Dual	<i>(Re-questioning) (E3)</i> Shu and Li: How does it rotate on its axis? Show us again. (Yao held the ball and moved around his father from the opposite direction.)
Spinning and circling-Earth rotation and revolution	Out	Within	Out	<i>(Explanation & Demonstration) (E3)</i> Shu: ... Baby, let mum tell you. Making a rotation means when you move in a circle you also rotate around yourself on one side. Make sense? This is the rotation on its axis. (Shu held the ball and made it spin when she moved around the father.)
Moving back and force-Earth rotation	Out	Within	Dual	<i>(Re-demonstration) (E3)</i> Shu: Ok, you show us once again... Rotate on its axis and at the same time... The ball also moves around itself... (Shu made the demonstration with gestures. Yao held the ball and moved it back and forth when turning around his father.)
Circling the barrel-Earth revolution	Out	Out	Dual	<i>(Evaluating ideas) (E3)</i> Li: You demonstrate it. (Yao made the ball move around the cover of the barrel) That's right. Move around the sun, right? Right, move like this, but it also rotates around itself at the same time.
Self-spinning-Earth rotation	Out	Out	Dual	<i>(Exemplification & Evaluating ideas) (E3)</i> Li: ... For example, dad will stand up and move around myself. That is the rotation on its axis. Make sense? Yao: Dad, dad... (Yao stood up and made a rotation around himself) Li: Yes, that's right, earth rotation! <i>(Re-demonstration) (E3)</i> Shu: Yes. You make an earth rotation again. (Yao made a couple of rotations around himself).

Making Conscious Key Scientific Concepts in Play – Collectively Supported Play.

The collectively engaged family play indicates a conscious moment, where shared sustained thinking (Siraj-Blatchford, 2007) was achieved. The social way here was actually a form of shared sustained imaginary conversation (Fleer, 2011) between the parents and Yao about the imagined scientific reality, such as the Earth rotation and revolution. During the sustained conversations within or around an imaginary situation, the parents are able to continually share their scientific understandings and help the disassociation and re-association process as shown through a child's imagining and re-imagining. The creation of a shared imaginary situation enables the parents to continually interact with Yao and to help him decide what to accept or reject within their imaginary situations, which results in the collectively supported process for Yao to arrange and rearrange his thinking towards a proper imagining that is also agreed by the parents.

The meaning of the shared sustained imaginary conversation here is to realize a form of collective consciousness, which may contribute to a child's self-consciousness in the future. It is not a simple conversation but a special social way to support the regulation of the child's individual imagining. As shown in Table 4 (in E3), Yao re-visited his imagining of the Earth rotation many times when his parents question and re-question his performance as the Earth. It seems that Yao tried to find out the way to be the Earth that can also be accepted by his parents, so that he seems to play in his role with the question - 'Am I right?'. Elkonin (1978) also mentioned that through a meaningful communication, a child is able to continuously co-ordinate his or her point of view in terms of other possible points of view. This collectively built imaginary situation plays an important role in fostering a child process of examining his own conceptual understandings (Fleer, 2013). The collective consciousness mentioned here actively supports self-engagement in meaning making, which may result in a higher level of generalization leading to the child's development of conceptual thinking.

Conclusion

Through a cultural-historical framework, this study has sought to fill the gap in

understanding of how scientific learning takes place during play. The theoretical findings provide a new lens for investigating scientific learning in the context of a shared imaginary situation, and the results further confirm Vygotsky's theorization of the dialectic nature of imagination in play. This study takes into account the child's collective family play as a dialectical process for learning science concepts not directly visible. The parents' play participation was evident here as they intentionally helped the child's active imagination of certain science phenomenon, such as the Earth's rotation and revolution during play. The movement between individual and collective imagining was achieved when parents shared their culturally and historically built scientific knowledge with their child, and at the same time also tried to link this with the child's individual imagining. The key was the parents' supported examining and re-examining of the child's individual imagining around a specific science phenomenon, as was evident in the sustained shared imaginary situation during family collective play. The findings reveal that a form of shared sustained thinking was achieved when meaningful communication happened (e.g. negotiating, evaluating, critical questioning) in play. This in turn supported the child's consciousness of scientific concepts. It is through collectively family play, that a dialectic between imagination and consciousness of certain scientific concepts was demonstrated.

Unlike the previous studies focusing more on the classroom science learning or children's ideas around certain science topic, this study carefully examined the collective environment created through the shared imagining between parents and their child. The findings reveal that collective play can provide the social supports for a child's imagining of particular scientific phenomenon not directly observable, and through family collective play, a higher level of thought of scientific reality is fostered.

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