Year 3 to Year 5 Children's Conceptual Understanding of the Mechanism of Rainfall: A Comparative Analysis

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This paper looks at the answers to a semi structured interview and drawings of a sample of 20 children in Year 3 and 5, on the topic of the mechanism of rainfall. The research project analyses the children's conceptual understanding of the formation of rain and compares their responses and drawings based on their year group. The paper also looks at the differences between children's drawings in Kent - England and the Basque Country – Spain, and identifies certain accessories and clothing such as umbrellas and raincoats that are only drawn by children in the Kent. The paper finishes with a discussion on how the findings of this paper can inform future teaching. A number of recommendations for future research are also addressed.

1. Introduction

According to the new curriculum in England (2014), children in Key Stage 2 (KS2) will be learning about the water cycle in year 4, through science; although the new curriculum also includes teaching the water cycle in geography throughout KS2, it is not statutory. It is generally accepted by the science education community that children come into school with their own understanding of the various scientific phenomena around them (Henriques, 2002, p.202). As children attempt to interpret scientific phenomena with their existing and often limited understanding of science, misconceptions are created (Vosniadou, 1994, p.46). Varda (1989, p.498) argues that teachers must be familiar with the way children view the world and make sense of it, in order to be able to tackle misconceptions and challenge their thinking appropriately.

The motivation for this study came from the fact that the science of rainfall received relatively less attention than any other earth science concept in academic research (Sackes et al., 2010, p.537). Although children's perception of the water cycle has already been investigated in different parts of the world, (Bar, 1989: Israel; Taiwo, Ray, Motswiri & Msene, 1999: Botswana; Za'rour, 1976: Lebanon; Villarroel and Ros, 2013: Spain; Sackes et al., 2010: Turkey and USA; Christidou & Hatzinikita, 2006: Greece) the importance of this paper lies on the fact that children's understanding of natural phenomena can be influenced by their geographical environment (Miner, 1992 cited in Sackes et al., 2010, p.538). Therefore, research in various regions in England is necessary for national and international comparisons.

1.1 Children's Conceptions of Rainfall

Rain is a part of children's everyday-life experience; however, even though children are very familiar with it, they are not aware of the 'hidden' and abstract mechanisms of rain. According to Bar (1989, p.481), in order for children to understand the water cycle, they

need to already have an understanding of the concepts of evaporation, condensation and free fall (gravity). Concepts such as evaporation, condensation and gravity can be abstract for children, and subsequently challenging to comprehend. Previous studies identified that children construct their own explanations as to how rain is formed from a very young age, by involving certain entities that can be seen when it rains; such as clouds, the sun and the sky (Christidou & Hatzinikita, 2006; Villarroel & Ros, 2013).

Research throughout the last fifty years identified certain patterns in children's understanding of rain. Although the majority of children in early years view rain as water, they fail to link clouds with the rain; instead they believe that rain comes merely from the sky (Inbody, 1963; Za'rour, 1976; Christidou & Hatzinikita, 2006). Findings from previous studies also identified that children's accuracy of scientific explanations about rainfall increases with age (Bar, 1989; Za'rour, 1976; Inbody, 1963; Sackes et al., 2010). Bar's report (1989) based on 300 Israeli children from ages five to fifteen, identified the age of nine as the appropriate age when children are capable of developing a scientifically acceptable conception of the water cycle. However, the children in Bar's research were picked at random, and all 300 came from an advantaged background instead of a variety of children from different socioeconomic backgrounds, or children from different ability groups. Bar's methodology was also limited to a single method, of oral interviews. One may argue that this questions the origins of the age of nine as the appropriate age to learn about the water cycle. When studying children's understanding of evaporation and condensation, Tytler (2000, p.464) indicated that at the age of six, children have the cognitive ability to grasp basic concepts about the water cycle.

Similar limitations to Bar's research were also identified in Sackes et al. (2010, p.538) study; where the sample size of children was small, they were not of equal gender and there was a lack of children from different socioeconomic backgrounds. In addition, their research was based solely on semi-structured interviews with children. Sackes et al. (2010, p.544) identified that a single method in a research triggers limitations, whereas more than two methods enable the researcher to examine how consistent and articulate children are with their responses. Although Christidou and Hatzinikita's (2006, p.189) approach was slightly different, by asking children to draw a 'rainy day' in order to initiate discussion and ask questions, the data taken was based on children's verbal explanations.

This paper aims to clarify:

i. The types of explanations children in year 3 and year 5 use when reasoning about rain formation;
ii. The similarities and differences between the elements related to the water cycle, found both in verbal and pictorial data, in both year groups;
iii. The observations made when comparing the data collected by the children's drawings of rain in Basque Country in Spain, with the children's drawings of rain in Kent in England.

2. Methodology

2.1 Participant

This research was conducted in a semi-rural primary school in Kent, in South East England. This part of England's climate is relatively quiescent, as it is the furthest from paths of most Atlantic depressions, which are associated with clouds and rain (Met Office, 2014). A total of twenty children participated in the study; ten children from a year 3 class and ten children from a year 5 class.

The children's parents were informed in writing about the nature and the methodology of the study. Written permission to conduct the interviews was obtained both by the head teacher of the school and the children's parents/carers. From the pool of children whose parents gave consent, ten children were then selected from each year. The selection process was based on the following three criteria:

1. An equal amount of boys and girls had to be selected.
2. The ten children had to represent the various ability levels in science, from the pool of potential participants.
3. Children had to give their verbal assent for participating in the study.

For the second criterion, the assistance of the teachers was crucial in identifying the appropriate choice of children that would represent the class' ability, based on the pool of children that returned the consent letters. None of the children interviewed were taught about rain formation or the water cycle prior to the interviews.

2.2 Procedure

The methodology of this research was heavily influenced by certain recommendations for future research by Sackes et al. (2010, p.544), which recognises that more multiple data collection techniques should be used in research of this nature. For this reason two different ways of gathering data, similar to Villarroel & Ros' (2013) research, were used for this study, in order to test the children's consistency and coherence of their ideas. In order to explore children's conceptual understanding of rainfall, the research consisted of two individual meetings, a semi-structured interview and a drawing session that did not take more than fifteen minutes each.

Semi-Structured Interviews

Prior to the main study, a pilot study was conducted with one child from each year (not participating in the sample); in order to test how clear the phrasing of the questions were, and how effective the use of a puppet was in stimulating children's cooperation in year 3. In the first instance, a semi-structured interview was conducted using a series of ten questions. The questions were based on a previous study by Miner (1992), who identified four major concepts within the water cycle; the nature of rain, the source of rain, the connection between rain and clouds, and the displacement of rain water. The same set of questions was used by Sackes et al. (2010), and similar questions were also used by Villarroel and Ross (2013). Christidou and Hatzinikita (2006) did not ask any questions in relation to clouds, unless the children themselves referred to clouds when describing rain formation. Questions in relation

to clouds and rain were included in this research, in order to reveal the children's understanding of the connection between the two.

The following questions were used to explore children's conceptual understanding: 1. Have you ever seen rainfall? 2. What do you think rain is? 3. Where do you think rain comes from? 4. How do you think rain is made? 5. Where do you think rain goes after it falls to the ground? 6. Where do you think the water goes when puddles and water on the ground go away? 7. Have you ever seen a cloud before? 8. What do you think clouds are made of? 9. Have you ever noticed that clouds look different on different days? 10. How do clouds look different when it rains? (Miner, 1992 cited in Sackes et al., 2010, pp.538-539).

Children were individually interviewed in the school's library, and the interviews were recorded in writing. No photos, voice or video recordings were made. A puppet was used with year 3 children in the first sessions, in order to stimulate children's cooperation. The puppet was made to pretend that it did not know what rain was; a particularly effective way to stimulate children's cooperation, identified by Villarroel and Ros (2013) when researching five to six year old children's understanding of rainfall. The effectiveness of the puppet was also confirmed during the initial pilot of this research.

Drawing Sessions

According to Farokhi and Hashemi (2011, p.2220), drawing can be seen as a communicative tool which can be far more descriptive than language. Dove et al. (1999, p.485) view drawing as an underused research method with children, which is very effective and can easily elicit ideas from children. However, the importance of the child's drawings lies on the researcher's knowledge of what each element of the drawing means to the child. Without the child's explanation of the meaning of his drawing, the drawing itself cannot indicate the child's perceptions (Karin, 2009, p.56).

Within four days of the initial interview the children were invited for a drawing session. They were asked for their assent to participate and then asked whether they would like to do a drawing of a rainy day. Sheets of A4 paper, pencils and four colouring pencils (blue, green, yellow and red) were available on the children's table. Although Villarroel and Ros (2013, p.4) chose not to include any coloured pencils in order to stop children from drawing for too long, this study identified colour as an opportunity; as questions were initiated as to why specific colours were used for clouds and rain droplets. The interviewer encouraged the children to draw whatever they wanted, as long as it was related to rainfall. The children were left to decide when the drawing was completed, and were praised once it was finished. While the children were drawing the pictures, the researcher would prompt them to explain what each element represented. Notes were taken at the end of the session, once the children left the room, to record each element from the children's drawings.

Data Analysis

To reveal patterns of children's understanding of the mechanism of rainfall, both the responses to the semi-structured interview questions and the children's drawings were

analysed, using the constant comparative method. This method enables theories to be enhanced, confirmed and updated, because of the constant comparison of data from new and old studies. Moreover, similar studies, including Villarroel & Ros (2013), Christidou and Hatzinikita (2006) and Sackes et al. (2010), identified the constant comparative method as an appropriate qualitative research method in the field of children's understanding of scientific phenomena.

A framework of codes was developed, based on a previous study that explored children's understanding of the mechanism of rainfall by Sackes et al. (2010). Sackes' coding system organised children's data from the interviews, into categories depending on the nature of their response. The children's responses were organised and compared, with Sackes' coding system as the basis for this study. New categories emerged from the children's data, based on their responses to the interview and their drawings.

A separate analysis was used exclusively for children's drawings, following Villarroel and Ros' (2013, p.7) proposed code system, to classify pictorial elements such as clouds, rain, grass and others from children's drawings. The elements displayed in each drawing were identified, recorded and classified. This allowed the researcher to identify patterns in the children's drawings. The data was also compared with the data collected by Villarroel and Ros' sample of children in Basque Country, Spain.

3. Results

The results from the semi-structured interviews and the drawings will be introduced at the beginning for both year groups. Subsequently, a separate analysis and outcomes related to the drawing task will be presented. The children's responses in the interviews will be organised in frequency tables, for direct comparisons across the two year groups. Table 1 and 2 organises children's responses into the four key concepts of rainfall (nature of rain, source of rain, connection between rain and clouds, and displacement of rain water), identified by Miner (1992); followed by model responses found in the children's answers. The answers are grouped in model responses and assigned a category, marked by the frequency of responses. If a child gave two different answers in response to one question, both answers were recorded and considered as two separate responses. The most frequent responses are in bold.

Table 1

Classification of Elements found in Children's Responses in Year 3.

Key concepts	Model responses found	Categories	Frequency of responses
Nature of rain	***"It's water."***	**Water**	**8**
	"It's something wet."	Sensory	2
	"It's a kind of weather."	Weather	1
	"I don't know."	Unknown	1
Source of rain	***"Rain comes from the clouds."***	**Cloud**	**7**
	"Rain comes from God."	God	3
	"Rain comes from the sky."	Sky	2
	"Rain comes from the sea."	Water Cycle	1

Connection between rain and clouds	***"Rain comes from grey clouds."***	**Cloud**	**6**
	"Rain comes from dark clouds."	Cloud	3
	"Rain comes from black clouds."	Cloud	3
	"Some of the clouds are white when it rains.	Cloud	1
	"Clouds change direction when it rains."	Situational	1
Displacement of rain water	***"Soil soaks the water."***	**Natural**	**7**
	"The sun dries the water."	Sun-made	5
	"Rain makes puddles."	Urban	4
	"Rain goes to drains."	Urban	2
	"Rain goes up in the sun or clouds."	Sun-Clouds	1
	"The water makes plants grow."	Natural	1
	"Wind pushes rain up in the sky."	Wind	1
	"Rain gets destroyed in the centre of the earth."	Disappearing	1
	"When the sun comes out rain goes back into the clouds."	Sun process	1
	"Water goes down the pipes and then out from our taps as fresh water"	Urban	1

Table 2

Classification of Elements found in Children's Responses in Year 5.

Key concepts	*Model responses found*	Categories	Frequency of responses
Nature of rain	***"It's water."***	**Water**	**9**
	"I'm not sure."	Unknown	1
Source of rain	***"Rain comes from the clouds."***	**Cloud**	**9**
	"Rain comes from the wet ground."	Water Cycle	2
	"Rain comes from the sky."	Sky	2
	"Rain comes from the sea."	Water Cycle	1
	"Rain comes from rivers."	Water Cycle	1
Connection between rain and clouds	***"Rain comes from black clouds."***	**Cloud**	**6**
	"Rain comes from dark clouds"	Cloud	5
	"Rain comes from grey clouds."	Cloud	3
	"Rain comes from white clouds."	Cloud	1
	"When it rains, the clouds build up and cover the sun."	Cloud	1
Displacement of rain water	***"The sun dries the water."***	**Sun-made**	**9**
	"Rain goes down the drain or the sewers."	Urban	6
	"Rain goes to the sea or river."	Urban	5
	"Water evaporates."	Water Cycle	2
	"Rain goes down beneath the ground."	Natural	2
	"When rain goes on soil it goes to plants."	Natural	1
	"Wind blows the rain water away."	Natural	1
	"Rain comes up as fog."	Natural	1

3.1 Children's Responses to the Four Concepts of Rainfall

Nature of Rain

For the nature of rain, the most frequent response to the question "what do you think rain is?" was 'water' in both years. It is worth mentioning that only one child from each year group was unable to identify rain as water. When drawing rain droplets, the majority of children in year 3 explained that rain is blue. Other responses included combinations of blue and grey, black and turquoise. Child 2 (female, year 3) stated that water is blue so rain must be blue, however rain drops fall really fast so you cannot see their colour. In year 5, four children described rain as colourless or see through, three children described it as a combination of blue and see through, two children described it simply as blue and one child described it as white with a bit of blue.

Source of Rain

In relation to the source of rain, the majority of children in both years explained that rain comes from clouds. Although two of the three children referred to God as the cause of rain (e.g. rain is God's tears, it rains when God has a shower, God makes rain with his special water power), they also included the possibility of clouds or the sky being involved in the formation of rain. The majority of the children that did not recognise clouds as the source of rain identified the sky as the origins of rain instead. Some accounts by year 5 children (rain comes from the sea, rivers, wet ground) in this section indicated some understanding of the water cycle, evaporation in particular; this however became apparent later on, when they were asked questions in relation to the displacement of water.

Connection between Rain and Clouds

Only one child out of the twenty children that were interviewed in year 3 was unable to identify clouds changing colour when it rains. The majority of responses in year 3 associated rain with grey clouds, whereas in year 5 the most popular association with rain was black clouds. Four children in each year used a combination of colours to describe the connection between rain and clouds (i.e. clouds are black, grey and white when it rains, clouds are black or grey when it rains, clouds look darker and grey when it rains); whereas the majority of children chose a single colour.

Displacement of Water

According to the information collected from the interviews, questions 5 and 6, regarding the displacement of rain water, produced the widest range of answers. The most popular response in year 3 was that soil soaks the rain water, followed by the sun dries the rain water. Although two children's explanations involved clouds when describing the displacement of water, only one of them linked water and clouds through some notion of evaporation. Child 3 (male, year 3) explained that "the sun reflects on puddles and melts water away, and then goes up in the sun or the clouds." This account was the closest scientific explanation that included some basic concepts from the water cycle, by a year 3 child.

All of the children in year 5, apart from one child, included in their explanations that the displacement of rain water is caused by the sun drying the water. The second and third most popular response involved urban observations, such as the rain water goes down the drain, the sewers, the river or the sea. Two children clearly identified the sun as the main agent that physically transforms water into clouds through evaporation. However, some of the children's responses to some extent demonstrated a basic scientific understanding of the notion of the water cycle. For instance, Child 12 (male, year 5) stated that the sun sucks the rain water and it becomes like a life cycle. Child 20 (male, year 5) indicated that clouds are like steam and turn to water, demonstrating notions of condensation. Nevertheless, the majority did not elaborate further as to what happens to the water when it dries out by the sun.

3.2 Children's Drawings

The children's drawings were also analysed independently from the children's responses to the interview questions. Following the classification of pictorial elements of rainfall in children's drawings by Villarroel and Ros (2013, p.7), two groups of data were identified and recorded; elements in drawings that were related to the water cycle, and elements that were not related to the water cycle. The elements in children's pictures were then categorised in relation to their nature and origin. New elements and categories emerged that were not found in children's drawings in Spain (Villarroel and Ros, 2013). This method was chosen for direct comparison with Villarroel and Ros' study (2013), and as a good starting point for organising children's pictorial representations of rainfall. Table 3 shows the elements found in children's drawing in year 3 and 5, grouped under the appropriate category.

Table 3

Classification of Pictorial Elements found in Children's Drawings

	Elements found in children's drawings		**Categories assigned**
	Year 3	**Year 5**	
Water cycle	The sun	The sun	Solar
	Clouds, grey clouds, white clouds, blue clouds, yellow clouds, paddles, glass, watering can, rain water barrel.	Clouds, grey clouds, white clouds, yellow clouds, puddles, river, sea.	Water reservoirs
	Rainfall, snow, rainbow, storm, thunder, wind, lightning,	Rainfall, thunder, lightning.	Atmospheric
	Cars, houses, roads, bicycles, traffic lights, shop.	Houses, garage, satellite dish, rocks, bushes, mud.	Urban
	Sky, hill.	Sky, hill.	Geographic
	Flower, grass.	Grass	Living beings
No water cycle related	Moon, stars.		Astronomic
	Relatives, children, police officers, car drivers.	Children, adults.	People
	Wellington boots, rain coats, hat, umbrella.	Wellington boots, rain coat, hat, umbrella.	Clothing/Accessories

Children's Drawings in Year 3 and 5

Certain similarities and differences appeared when comparing the drawings between the two years. The same clothing/accessories, solar and geographic pictorial elements were found in drawings from both years. The majority of the children drew clouds that were accompanied by rainfall. In year 5 seven children drew clouds, but only five of them coloured some or all of their clouds grey. In year 3 eight children drew clouds, and only half of them coloured some or all of them grey. Although children from both years drew some of their clouds yellow, their explanations were all different. For instance, Child 19 (male, year 5) stated that "some clouds are yellow because sunrays go through clouds". Child 16 (female, year 5) said that "clouds are yellow because of lightning". Child 4 (male, year 3) explained that clouds are blue and have yellow in the middle; rain comes from the blue part of the cloud and snow comes from the yellow part of the cloud. In year 3 only three children drew the sun, whereas in year 5 only two children included the sun in their pictures. Some children in year 3 offered explanations as to how certain atmospheric elements are linked with rain. For instance, Child 3 (male, year 3) stated that thunder is a type of rain. Child 4 (male, year 3) explained that "snow is rain water that freezes" and that winds come from clouds.

Children's Drawings in Kent in England, and Basque Country in Spain

The following comparisons were between Villarroel and Ros' sample of children in Basque Country in Spain, and the sample of the children in this study. It is worth mentioning that the children in Villarroel and Ros' study were five to seven year olds; therefore only pictures drawn by children in year 3 (seven to eight year olds) were considered appropriate for direct comparisons.

Basque Country is located in the North West part of Spain, bordered with France. Basque Country's oceanic climate of wet weather and moderate temperatures is similar to the climate found in Kent, rather than a Mediterranean climate; therefore, comparisons based on geographical location were of great interest. Villarroel and Ros' sample included 126 children from various ages between five to seven year olds. The key difference between the drawings from children in Kent and Basque Country was that clothing and accessories related to rain (wellington boots, rain coats, hats and umbrellas), were only drawn by children in Kent. It is worth mentioning that in order for clothing and accessories of that nature to emerge, people had to be drawn. In terms of the children in Kent, the majority of people that were drawn were either inside a car, wearing a raincoat, or holding an umbrella. Based on Villarroel and Ros' data, people (i.e. children and relatives) were also drawn by children in Basque Country; however, no evidence of clothing or accessories that would protect people from rain were identified. Elements that were only drawn by children in Basque County included: lake, steam, soil, caves, hail, trees, leaf, pipes, sewers, swings, planets, angels and pets. Key similarities between the two groups of children included: the sun, clouds, rainfall, snow, rainbow, storm, thunder, wind, cars, houses, roads, sky, grass, flower, moon, stars, children and relatives.

4. Discussions

Overall, findings from this study are consistent with studies by Bar (1989), Inbody (1963), Za'rour (1976) and Sackes et al. (2010), which identify that children's explanations of rain formation becomes more scientifically accurate as they get older. Children in year 5 were more likely to include notions of the water cycle, compared to children in year 3. In fact almost none of the children's explanations in year 3 involved any intended conception of evaporation or condensation. The children in year 5 that demonstrated some elements of the water cycle did so only through evaporation rather than condensation. More often, the children that were aware of changes in the colours of clouds before rainfall were also able to identify clouds as the source of rain. These findings indicate that if children can notice the changes in clouds when it rains, the connection between clouds and rain can then become an easier concept to understand. Although the majority of children in both years were able to identify the clouds as the source of rain, their understanding of what clouds are made of was limited. More children in year 5 than in year 3 stated that clouds are made of water. The most frequent answer in year 3 in response to what clouds were made of, was 'fluffy, soft things'; whereas in year 5, the most frequent answer was water.

Understanding the composition of clouds is a crucial element in understanding the water cycle, since it involves both concepts of evaporation and condensation. In relation to the drawing task, the results suggest very little differences between the elements in the drawings of the year 3 children and the year 5 children. However, there were some differences in relation to the frequency of certain elements linked to the water cycle. For instance, almost all of the children in year 5 included a water reservoir in their picture, whereas in year 3 only half of the children drew a water reservoir. Most of the water reservoirs found in pictures by children in year 3 were puddles, whereas pictures in year 5 included various natural reservoirs such as rivers and the sea. Based on their children's drawings, Villarroel and Ros (2013, p.8) concluded that at some point between five to seven years of age, children develop their conceptual understanding of rain formation by beginning to include elements such as water reservoirs. It can be argued that children in year 5 have a more enriched representation of the rain formation, since they have more elements related to water in their understanding of rain.

The current study was subject to the following limitations. As the research was a university assignment, it had to be compromised in a school that the researcher had previously taught in as a teacher. As a result, the children in year 3 were familiar with the researcher, whereas the children in year 5 were not. Also the time given was limited to two weeks, which forced certain compromises in the methodology; due to the time limitation there was a concern that parents would not give their consent for the children's interviews to be audio taped. The sample was also limited to twenty children because of the lack of consent from the parents, and the limited time for data collection. The interviews and the drawing task took place in the school's library, which was identified as the quietest room in the school; and although it was the quietest room, it was often used for interventions and various activities which sometimes made it noisy and distractive for the participants.

The UK spreads itself vertically across part of the northern hemisphere, and subsequently attracts various weather conditions. Future research could potentially explore how children

across the other regions of the UK view rain. Further comparisons could be investigated of children's understanding of rain in the Eastern and Southern parts of the UK, where the weather tends to be drier and warmer, with children's understanding in the Western and Northern parts, where the weather tends to be windy and wet. Children from different socioeconomic backgrounds could also be compared, as well as children from the countryside in comparison to children from inner cities.

The evidence of children's conceptual understanding of the mechanism of rainfall provided in this study, may lead to an approach by teachers that is more equipped to tackle misconceptions when introducing children to scientific phenomena, such as the water cycle. According to Vosniadou (1994, p.48-49), there are two kinds of conceptual change; *enrichment,* where new facts that are consistent with the knowledge that the child already has is added to the child's knowledge, and *revision,* when new facts are inconsistent with what the child already knows and inaccurate facts have to be revised and changed. Based on the data collected by this study, all children would need to enrich and revise certain aspects of their understanding of rain, in order to develop a scientifically accurate conception of the water cycle. For instance Child 1 (female, year 3) that stated that water comes from clouds, could be enriched by learning that clouds are made of water. The same child explained that water gets dried up by the sun and disappears, which is a concept that in part will need to be revised. Revision is certainly the most challenging and time consuming way of developing children's conceptual understanding. However, it is necessary, otherwise children are exposed to new facts that do not match their current understanding, resulting in change that can be very difficult to achieve. In effect, teachers need to be aware of their pupils' current conceptual understanding, in order to structure lessons throughout the term that will enable children to revise if necessary, and appropriately enrich their factual understanding based on solid foundations.

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