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THE ABILITY OF CHILDREN AGED 6 AND 9 YEARS, RESPECTIVELY, TO DETECT ERRORS IN A NARRATIVE BASED ON INCORRECT INFORMATION ABOUT EVAPORATION IN THE WATER CYCLE

ROZPOZNAWANIE NIEPRAWIDŁOWOŚCI W NARRACJI OPARTEJ NA BŁĘDNYCH PRZESŁANKACH DOTYCZĄCYCH ZJAWISKA PAROWANIA W PROCESIE OBIEGU WODY PRZEZ DZIECI SZEŚCIO- I DZIEWIĘCIOLETNIE

Streszczenie: Pełne zrozumienie zjawiska parowania dokonuje się w wieku 11 lat, jednak podstawami do jego pojęcia dzieci dysponują już w okresie przedszkolnym. W artykule przedstawiono wyniki badań, które ukazują rozumienie zjawiska parowania przez dzieci sześcio- i dziewięcioletnie. W badaniach wykorzystano metodę narracji opartej na błędnych przesłankach, celem sprawdzenia, czy i w jakim stopniu dzieci dostrzegają, że przedstawiona narracja jest błędna i jak potrafią uzasadnić przebieg tego zjawiska. Metoda błędnej narracji nawiązuje do filmów z gatunku fantastyki naukowej, które oparte są na udowodnieniu widzowi nieprawdy poprzez osadzanie fabuły filmu na błędnych przesłankach. Badania wykazały, że połowa dzieci wiedziała o zjawisku parowania istniejącym w procesie powstawania chmur, ale tylko połowa z nich potrafiła wskazać błąd w narracji (co czwarty badany). Powodem takiego wyniku, jak wskazano, jest niski poziom krytycznego myślenia i słabo ustrukturalizowana wiedza na temat zjawiska parowania w obiegu wody w przyrodzie.

Słowa kluczowe: zjawisko parowania, powstawanie chmur, dzieci przedszkolne, uczniowie wczesnej edukacji, narracja oparta na błędnych przesłankach.

Abstract: Children begin to fully understand evaporation at the age of 11 years, but they already have some idea of this phenomenon in preschool age. The paper presents the results of a research exploring the understanding of evaporation by 6- and 9-year-old children. The research used the method of a narrative based on incorrect information in order to verify whether and how well children would discover the errors in that narrative and how they could explain the process of evaporation. The incorrect narrative method is inspired by the science fiction film genre, which uses false assumptions to prove something that is not true. According to the research, half of the children knew that evaporation accompanies the process of cloud formation, but only half of the children who knew that (one-fourth of the respondents) could detect an error in the narrative. The reason for that is believed to be children's lack of critical thinking and limited structured knowledge of evaporation in the water cycle in nature.

Keywords: evaporation, cloud formation, pre-school students, primary school students, incorrect narrative.

Introduction

Children start school with an extensive background of personal experience on the basis of which they form spontaneous concepts (Klus-Stańska 2019; Wiśniewska-Kin 2016; Filipiak 2008). Those concepts are hard to change through the process of formal education (Kampeza, Delserieys 2020). One of the concepts that children develop early in their lives is of the water cycle and the accompanying evaporation process (Kambouri-Danos et al. 2019; Malleus et al. 2017; Hannust, Kikas 2012). Children learn about the water cycle in preschool education (Guz 1993). It is explained to them by analogy to a steaming kettle. Consequently, children wrongly imagine that vapour, which in fact is invisible, looks like steam that forms a visible cloud (Henriques 2002). The water cycle in nature is explained to children in general terms, in a way that is adequate to their mental capacity, without going into details of the behaviour of water molecules (Adbo, Taber, 2009; Russell et al. 1989). Children are shown a diagram with arrows indicating the directions of the process. Presentation of the water cycle suggests that precipitation balances evaporation (Cardak 2009). Meanwhile, in order to understand the water cycle, it is important to know what happens to water molecules (Åkerblom et al. 2019; Fragkiadaki, Ravanis 2015). It is believed that a child is capable of fully understanding the water cycle, including the evaporation phenomenon, at the age of 11 years (Bar 1989). Because evaporation is frequently mentioned in preschool and primary school education (e.g. in the context of weather conditions), it is important to determine how young children understand this phenomenon in order to provide them with suitable educational content (Klus-Stańska 2019; Wiśniewska-Kin 2016).

The extent to which children understand the phenomenon of evaporation is most often assessed through a conversation or interview (Åkerblom et al. 2019; Malleus et al. 2017; Ahi 2017; Fragkiadaki, Ravanis 2015; Saçkes et al. 2010; Taiwo et al. 1999; Bar and Galili 1994; Guz 1993; Bar 1989) or through tests (Malleus et al. 2017; Savva 2014; Platten 1995). Questions are most often asked directly (e.g. *what is a cloud…*, *how is it formed…*, *what is it made of…*), helping to better understand the conceptual structure and misconceptions that we already know a lot about (Henriques 2002). We know that six-year-old children understand the natural water cycle and associate cloud formation with evaporation (Guz 1993). What we do not know, however, is how children apply their knowledge in problematic situations that require controlling the correctness of information. It is necessary to control information whenever children come into contact with excess information, e.g. when they watch a film (Barnett et al. 2006).

According to the constructivist theory, in order to absorb information, the mind must first adjust that information to its existing knowledge structure. If information fits that structure, it is assimilated. If not, the mind may try to restructure its knowledge system so as to accommodate new information, or otherwise to reject it (Filipiak 2008). Determining how children cope when confronted with an incorrect narrative is a way to evaluate children's knowledge and their ability to apply it in practice.

The narrative is defined as a statement that is supposed to present facts in a way that the recipient is ready to accept (Korolko 1990). It is commonly used by teachers as a basic method to communicate information (Mółka, Mółka 2018; Klus-Stańska 2002). In research, the narrative is used mainly as evaluation of the responses of children (Kulas 2014; Nowak-Dziemianowicz 2014; Kos, Urbaniak-Zając 2013). It is less frequently used to understand the child's reasoning. Rochel Gelman (1980) used a panda puppet to present incorrect counts of objects in order to determine whether a child has mental rules to count objects. In Poland, a similar diagnostic task was developed by Edyta Gruszczyk-Kolczyńska (2013, p. 31–44). It is assumed that if a child has a mental rule to count objects correctly, he or she will detect the mistake made by the puppet and if not, he or she will assume that the puppet's count is correct.

The research presented in this paper used a narrative that was based on incorrect information about the water cycle. The narrative was incorrect, because it disregarded the phenomenon of evaporation, which, in education, "closes" the natural water cycle. The description of the water cycle explains that water moves through rivers to seas and oceans and back to the atmosphere, where clouds form. If evaporation is removed from process, rainwater that flows from rivers into seas and oceans may increase their level. This, in turn, may result in the flooding of cities. The purpose of the research was to determine whether and to what extent 6- and 9-year-old children would accept that narrative.

Research programme

The research results discussed in this paper are part of a wider research[1]into children's ability to assess and predict weather conditions in different parts of the world[2]. The procedure, the results of which are described in this paper, concerns two questions that the researcher asked at the end of the research. The first question was: *How are clouds formed*? The aim of this question was to determine how many children will attribute the formation of clouds to evaporation. The second

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2 The results of the research are presented in two separate papers (in progress).

question concerned the narrative that was created for the purpose of the research, which suggested a possible natural disaster: *When rain falls from clouds, it reaches the ground and creates rivers. The water in these rivers flows into seas and oceans. More and more water flows into seas and oceans all the time. Do you think the level of water in the sea will increase and could flood a city*? The narrative that described – in a simplistic way – the water cycle purposefully omitted the phenomenon of evaporation. The purpose of the research was to determine whether and how well children would see that the narrative was wrong and could explain the process of evaporation.

The qualitative research, which used the above procedure, was conducted in a group of 42 children: 21 children from the most senior preschool group (6,3 to 7 years old) and 21 students of the 3rd grade of primary school (9,4 to 10,3 years old). There were 14 boys and 28 girls in the group. The research was conducted at the beginning of 2021 and the responding students had learned about the natural water cycle in the three weeks preceding the research. Consents from the principals, teachers, parents and children themselves were obtained prior to the research. The research method was one-to-one conversation in a separate room within preschool or school premises.

Results

When asked *How do clouds develop*? 11 children said they did not know (4 preschool students and 7 primary school students), and 1 mentioned "speech balloons" in a comic book. 7 children (4 preschool students and 3 primary school students) provided a non-scientific explanation. Meanwhile, 22 children (13 preschool students and 9 primary school students), representing more than half (52,38 pct.) of the respondents, explained the effect of evaporation in typical school terms. One of the respondents mentioned different air temperatures, but could not say anything about that. Below are some scientific-like answers in which children used the keyword: *vapour* and its derivatives (P – a preschool student, S – a primary school student):

- (3P) *When the sun comes, water evaporates and clouds are formed.*
- (6P) *Evaporation. It means that when water flows into the sea, the heat evaporates, it goes up, and clouds are formed, and it happens over and over again.*
- (14P) *First the rain falls, it sinks into the soil, then it evaporates and clouds are formed.*
- (20P) *It rains wand water drops fall into water; after the storm, the sun shines and it heats water, vapour raises up from water and then clouds are formed, and it rains again.*
- (9S) *The sun makes water evaporate and go up.*

When answering the question, the children either described the water cycle diagram or they mentioned steam going up from a boiling kettle. All the children attributed the formation of clouds to raising vapour that transforms into a cloud up in the sky. They did not explain how exactly vapour turns into a cloud. The children said that clouds form because the sun heats water, making it evaporate and move up. In physical terms, it is a big oversimplification to say that "water evaporates and a cloud is formed" (Grabowski 2017), but this is what children are told at school (Klus-Stańska 2019) and, as a result, they develop wrong notions of the process (Henriques 2002). Because the teachers of the children attending the research confirmed they had discussed cloud formation prior to the research, it may be assumed that half (52 pct.) of the children said what they had learnt at school. One of the students (15S) said *Our teacher once told us…*, after which he mentioned a diagram of the mixing of air masses: *they are red and blue, and they blend and a cloud is formed, but I do not know exactly how.*

Some children (7) also made non-scientific, simplistic references, which they could not explain in greater detail, for example to smoke from a chimney (2P), a cloud formed by fog or a whirlwind (1S, 1P), and others said that the sun creates a cloud (16P). One of the children (12S) stated *that water is condensed and it goes up* – assuming that water rises up due to a phenomenon that is opposite to evaporation. The answers quoted here confirm previous findings (Bar 1989).

The question *Can the level of water in the sea increase and flood a city?* was introduced by a narrative describing the water cycle, in which evaporation was omitted. The children's answers were classified according to the criterion of correctness and certainty of the explanation given. Studies show that the conviction that what one says is true is one of the indicators of changing perception of the world (Jelinek 2020; Bryce, Blown 2012; Ellis, Bjorklund 2005). It was determined that children who construct spontaneous (intuitive) as well as scientific-like concepts are certain of their veracity. Their certainty on the intuitive level is based on their personal experiences (they say: *because you can see it*). Meanwhile, their scientific-like concepts are based on what adults have told them. The transition level, when the outline of a concept is formed, involves construction of concepts on the basis of new knowledge and realization that what one believes may not necessarily be true. In the research, it was assumed that the fact that a respondent is not certain of his or her beliefs proves the existence of a transition stage (Lee et al. 2020). The children who responded immediately were considered to be certain that what they though was true. On the other hand, if a child took some time to answer the question and appeared surprised and confused, it was assumed that he or she was uncertain. In the latter case, the children were hesitant to answer and were clearly dubious.

When asked *Can the level of water in the sea increase and flood a city*, 6 children said *I don't know* (5 preschool students and 1 primary school student). The most frequent answer was a definite confirmation – *yes, the water in the sea rises*: 19 children (10 preschool students and 9 primary school students) said so. These children did not elaborate on their answers. They did not have (or did not take into consideration) any information, when constructing their answers. They assumed that the adult narrative was true and seemed certain that the water level in the ocean increases as a result of the inflow of river water.

The second category of children's answers was a confirmation of the adult narrative accompanied by an attempt to downplay the effect of a possible natural disaster implied in the narrative. This category included 6 answers (3 from preschool students and 3 from primary school students):

- (2P) *Yes, but the drops are so small that it will take a very long time.*
- (2S) *Perhaps it does not rise all the time, but maybe if it rained for half a year…*
- (4S) *Yes, but if it is drizzle, then* [water level rises] *only by a centimetre, and if it downpour, then more.*
- (21S) *It will flood us, but not very much, because there will not be that much* [rain].

Those children agreed with what the researcher said, namely that water flowing from a river raises the sea level; they felt that there was something wrong with the narrative, but they could not tell what exactly. They seem to have felt cognitive dissonance and had the need to explain that there is a way to reduce the impact of the natural disaster implied by the narrative. Their answers included an explanation (*the rain would have to be heavy and it would take a long time to flood a city* and they were internally coherent (*the water level will rise if there is heavy rain, the water level does not rise immediately*), which means that the children's responses were in fact theories (Gopnik 2010). Importantly, 3 of the children who mentioned evaporation when answering the first question did not take it into account when answering the second question.

The third kind of response was negation of the researcher's narrative, though accompanied by uncertainty. This kind of answer was given by 5 respondents (2 preschool students and 3 students). Uncertainty could be seen in the way the children gave their answers. The children often paused, using "uh" and "uhm" figures. They changed their opinion as they spoke, looking for arguments to prove their point (diSessa 2017). They said:

- (12P) *does not rise… the ocean moves closer and then withdraws* [the waves] *and it does not really rise.*
- (1S) *no, it does not raise…, but* [water] *flows into… it stops before the sea.*
- (9S) *no…, because water soaks into the ground, through sand.*
- (12S) *no… because water* [from the ocean] *flows into a river and flows to the mountains.*

Below is a more elaborate answer of a preschool student (10P) who mentions the flow of water between reservoirs, causing excess water to spread over a larger area:

- Researcher: *Can the level of water in the sea increase and flood a city?*
- Child: *No, because water flows all the time to different places.*
- R: *Where does it flow to?*

- Ch: *For example, to the Baltic Sea.*
- R: *And does water rise there?*
- Ch: *No, because it flows to the ocean.*
- R: *And does the level of water increase there?*
- Ch: *It does, but slowly and water escapes to the sea.*

Below is another example of a child's response. This time, a primary school student (16P) mentions his own experience of a flood in Warsaw.

- R: *Can the level of water in the sea increase and flood a city?*
- Ch: *Not if the ocean is big.*
- R: *Even if it rains for a long time?*
- Ch: *Then there will be a flood, like there was in Warsaw.*
- R: *Will it flood the whole Poland?*
- Ch: *Not the whole Poland, but there will be small ponds in some areas.*

The children who negated the adult narrative noticed the problem in the researcher's question. Their knowledge was vast enough and they were brave enough to contradict the researcher, though were unable to explain the phenomenon in scientific-like terms. Their explanations were against the laws of physics (e.g. *water from rivers stops before the sea*; *water flows to the mountains*). They were unable to give more elaborate explanations to the researcher.

5 children (1 preschool student and 4 primary school students) seemed certain when they negated the researcher's narrative. 2 children did not explain their interpretation and 3 mentioned the process of evaporation. For example: (13P) *Water does not rise, because when water evaporates, then as if an invisible mist goes up, forming clouds.* Below is an answer given by one of the primary school students (14S):

- R: *Can the level of water in the sea increase and flood a city?*
- Ch: *I don't know but it had better not.*
- R: *Why have we not been flooded so far?*
- Ch: *Because water turns into vapour.*

Conclusions and discussion

The answers given by the children in the research confirmed previous findings (Fragkiadaki, Ravanis 2015; Taiwo et al. 1999; Guz 1993; Bar 1989). Artificialism (*wind makes a cloud*) and technical artificialism (*cloud is made by smoke from a chimney*) were observed in children's reasoning. Half of the respondents (52 pct.) provided a scientific explanation related to evaporation. Those children attributed the formation of clouds to the sun and sun rays that heat water. Heat causes water to go up as vapour. These findings are confirmed by Guz's study (1993), in which 15 pct. of 6-year-old respondents associated the phenomenon of evaporation with cloud formation.

The fact that only half of the respondents (52 pct.) knew about the phenomenon of evaporation and correctly (in school terms) explained the formation of clouds (in question 1) suggests that teaching the process of evaporation in the water cycle through diagrams is not very effective. Previous findings suggest the same (Moyle 1980; Russell et al. 1989).

Meanwhile, children seem to have well assimilated the explanation of water formation by reference to steam from a boiling kettle (school narrative). On the other hand, according to some studies (Henriques 2002), associating visible steam with clouds makes children wrongly conclude that clouds are formed from visible (!) vapour, which, in fact, is invisible.

The errors in the narrative used in the research were detected by one in four respondents (10 children, 23,81 pct.), who mentioned the evaporation phenomenon (though more than half of the respondents – 52% knew about evaporation). Of those students, 3 gave a meaningful explanation, 2 gave no explanation, and 5 were not certain of what they said. There may be at least two reasons for this. One is that knowledge about evaporation may still be poorly assimilated in the knowledge structure, making children unable to use it to explain the errors in the narrative. Such an interpretation would be in line with the results of previous studies (Åkerblom et al. 2019; Kambouri-Danosi et al. 2019; Malleus et al. 2017).

The second reason is the children's low level of critical thinking and their belief that *adults are always right*. In the research, even the children who knew about evaporation and experienced some cognitive dissonance, did not question what the teacher said. This is because they are used to thinking that the teacher is always right (Rybska, Wiśniewska-Kin 2020; Wiśniewska-Kin 2016). Children are taught that adults are never wrong and that they must accept whatever they are said unquestioningly, not being allowed to contradict the adult. In the research, the children's low level of critical thinking could be the cause for the disparity between knowledge of the phenomenon of evaporation and the use of that knowledge to explain errors in the narrative.

The research did not ask children directly about the source of their knowledge but they said spontaneously where they know it from. They mentioned parents and teachers as the source of their knowledge. Some of them also mentioned films and the Internet. The fact that children mention the sources of their information proves that their mind records the context in which they acquire that information (episodic memory). Thus, children distinguish between their own observations and information provided to them by others. Studies on cognitive development in children prove that the older children are, the more they rely on the media as a source of information (Barnett et al. 2006). Until develop their critical thinking, children tend to accept information unquestioningly. Meanwhile, children are often exposed to false information (e.g. from the media) and develop misconceptions about the world (Jaszczuk et al. 2018). The key conclusion for teachers is to monitor the ideas that children form and to organize teaching in such a way that children acquire the information they need to develop concepts on the scientific level (Wiśniewska-Kin 2016; Yang et al. 2014).

Conclusion

Evaporation in the water cycle is one of the most difficult concepts for preschool children and for children in the third grade of primary school. Their existing knowledge (presentation of the phenomenon of evaporation in the water cycle and observation and recording of the weather) was used only by one in four students to explain errors in the incorrect narrative. A narrative that is founded on incorrect information and leads to a wrong conclusion is an attractive research tool to explore children's understanding of natural phenomena.

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