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Globalne ocieplenie i zmienność poziomu morza: badanie poziomu rozwoju intelektualnego preadolescentów i adolescentów w wieku 11–15 lat

Studia Pedagogiczne. Problemy społeczne, edukacyjne i artystyczne 2014, t. 24: 357–375

Introduction

One of the consequences of climatic warming is the rise in the level of the oceans. According to the report published in 2007 by the Intergovernmental Panel on Climate Change (IPCC)[1], since 1963, for the whole planet, the mean sea level has been increasing by 1.8 mm each year. Starting in 1993 the rate rose to 3.1 mm per year. In 2013, IPCC presented a report[2] that predicted how much the sea level would rise. It said that before the end of twenty-first century the sea level would rise somewhere between 29 cm and 81 cm and would have an impact on one person in 10 or, in other words, on 600–700 million people. However, this sea level elevation is not uniform. Satellite data as well as hydrographic observations show that there are important spatial variations due to the limited evolution of the temperature of the sea and the salinity linked to modifications of the circulation of some major ocean currents.

How is it possible to explain the phenomenon of the increase in sea level? The first cause in the rise of the sea level results from a thermal expansion of the oceans: the more water is heated, the larger the volume that it occupies. The warming of the oceans represents the largest change in the energetic content of the earth. In 2013, IPCC reported that

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[1] http://www.ipcc.ch/, http://www.ipcc.ch/publications_and_data/

[2] http://www.ipcc.ch/report/ar5/wg1/, http://www.climatechange2013.org/images/report/WG1AR5_Chapter13_FINAL.pdf

between 1971 and 2010 the oceans absorbed 90% of the energy collected on earth. This warming has the most impact on the first 75 m of the surface of the oceans. During this period, the temperature increased by +0.11°C a decade, or +0.44°C in less than 40 years. So, the first reason for the sea level rise, which explains 25% of the phenomenon, comes from the thermal expansion of the oceans, that is to say, that hotter water occupies a larger volume.

The second reason is the reduction of the cryosphere. The cryosphere corresponds to the part of the surface of the earth where the water is in the solid state, ice or snow, including river ice, lake ice, sea ice, zones covered with snow, glaciers and frozen soil. Not only has the volume of the cryosphere shrunk, but the rate at which it is shrinking has accelerated. The mass of glaciers covering Greenland (IPCC, 2013) is decreasing by 50 to 100 Giga metric tons/year or approximately 55 to 110 Giga English tons/year. This contribution of additional water raises the sea level from 0.14 to 0.28 mm/year.

The IPCC report of 2007 claimed that the melting of glaciers and polar ice caps Greenland and Antarctic creates around 50% of the sea level rise. More precise studies conducted from 1993 to 2003 showed that the thermal expansion and ice melting each had the same influence on the elevation of the sea, around 50% apiece. Moreover, if all mountain glaciers melted at the same time, the sea level would rise by 30 cm. If all the glaciers on Greenland melted, the sea level would rise by 7 m. Parts of coastal glaciers along both icecaps melting add about 500 thousand million tons of ice every year. This added volume of ice elevates the sea level. Having envisaged that and taking into account different forecast models, IPPC predicts that before 2100 the sea level will rise between 12 cm in the optimistic scenario to 100 cm in the pessimistic scenario. In its last report (IPPC CLIMATE changes, 2013), predictions were revised to be approximately one meter. For the representative concentration pathways model (RCP8.5), the increase for the same period will be between +0.52 and +0.98 m.

Going over the main points of the problem, it is possible to say that the elevation of the oceans level results from:

- thermal expansion under the influence of climatic warming,
- water added by melting ice or by the displaced water volume stemming from icebergs, where glaciers fall directly into the sea.

The objective of this study is to determine if preadolescents and adolescents understand the mechanism and consequences of the rise in sea level. Moreover, we are interested in checking if this understanding evolves with age, and to find the factors which influence this understanding.

The rest of the paper is organized as follows. Section 2 presents an historical overview of some aspects of development psychology. Section 3 contains the methodological background. The results of an empirical study are listed in Section 4. Finally, we present some discussion and conclusions.

Some aspects of developmental psychology

In chapter 7 of the book "The Child's Conception of Physical Causality" Piaget[3] examined the issue of **conservation** of different objects of different densities, different materials, on the water level. The responses of children go through three stages. In the first stage, the child predicts and explains the phenomenon of a rise in water level on the basis of weight. In the second stage, the child explains that a large object will raise the level of water more than an object of smaller volume. When a child explains the phenomenon, he always bases his explanation on weight. Only in the third stage does a child attribute the rise in the water level to the volume of the submerged object. The child's thoughts are characterized by **egocentrism**. Understanding of the causal phenomena can be explained by a process of gradual **decentering**[4]. Piaget & Inhelder[5] showed the same method when they studied the construction of the concepts of substance, weight and volume. It involves presenting the child with two perfectly identical balls of plasticine. The child confirms that they are the same. The task is then to perform transformations on one of the two balls and to ask child to judge whether it has the same amount of material as the non-transformed ball. To claim weight conservation, one proceeds in the same way by asking the same questions about weight. Do the ball and the cylinder weigh the same or does the ball weigh more than the cylinder or does the ball weigh less than the cylinder? To check the conservation of volume, the two subjects are placed into two jars filled up ¾ of the way with water. The child is asked to confirm that the water levels in both jars are identical. Then he is asked to describe the situation when the two objects are put in the jars. Does the water go up, remain at the same level or go down? The results show that for the three concepts: substance, weight and volume, the child's understanding of these phenomena

3 Piaget J., *La causalité chez l'enfant*, Paris 1927.

4 S. Desrochers, *La causalité chez l'enfant: faut-il abandonner les idées de Piaget?*, „Archives de Psychologie" 2005, 71, 25–47.

5 J. Piaget, B. Inhelder, *Le développement des quantités physiques chez l'enfant*, Paris 1941.

goes through three stages, namely from non-conservation (incorrect answers) through an intermediate stage (some correct answers) to conservation (correct answers). This transformation can be found in the concept of conservation of matter, weight and volume. As a result, conservation of matter is observed in 7–8-year-olds, conservation of weight appears at 9–10 and conservation of volume emerges at 11–12 years.

In the 1960's, the researchers focused on conservations in general (substance, weight, volume, number, etc.). Their works were dedicated to the following issues:

- the sequence of mastery of the conservations (substance, weight, volume);
- the impact of age on conservations, and its comparison with that predicted by Piaget & Inhelder;
- the impact of gender on conservations and the explanation for any impact;
- the existence of universalism for conservations;
- verification of the sequence of conservations.

All works on the question of the order of mastery were carried out under the assumption that the Piagetian stage theory is valid. The order that topics are mastered is as follows: first of all, the conservation of substance, followed by the conservation of weight, and finally the conservation of volume[6]. There are some works in the field for individuals with special educational needs, with intellectual disabilities[7] and with visual impairment[8]. In this study, these groups are omitted.

The question of the age at which a child masters the conservations has been widely studied. If there is agreement on the age for substance conservation (in

6 A. Fieller, *Comparison of the Development of Formal Thought in Adolescent Cohorts Aged 10 to 15 Years (1967–1996 and 1972–1993)*, "Developmental Psychology" 1999, vol. 35, No. 4, 1048–1058; E.D. Hobbs, *Adolescents' Concept of Physical Quantity*, "Developmental Psychology" 1973, Vol. 9, No. 3, 431; K. Lovell, E. Ogilvie, *A Study of the Conservation of Substance in the Junior School Child*, "British Journal of Educational Psychology" 1960, 30, 109–118; K. Lovell, E. Ogilvie, *The Growth of the Concept of Volume in Junior School Children*, "Journal of Clinical Psychological Psychiatry" 1961, 2, 118–126; F. Longeot, *Expérimentation d'une échelle individuelle de la pensée logique*, "B.I.N.O.P." 1966, 22, 306–319; *Manuel de I'Echelle de Développement de la Pensée Logique*, Paris 1974; E. Lunzer, *Some Point of Piagetian Theory in Light of Experimental Evidence*, "Journal of Child Psychology and Psychiatry" 1960, 1, 191–202; I.C. Uzigiris, *Situational Generality of Conservation*, "Child Development" 1964, 35, 831–841.

7 B. Inhelder, *Diagnostic du raisonnement chez les débiles mentaux*, Paris 1943.

8 M. Gottesman, *Conservation Development in Blind Children*, "Child Development" 1973, 44, 824–827.

general, 7–8 years) and for weight conservation (9–10 years)[9]: The discussion about the age of volume conservation is still open. There are two types of research:

- the validation of the results of the Geneva school;
- research that shows that it is only somewhere between adolescence and adulthood that one masters the underlying concepts of conservation of volume[10].

Lovell & Ogilvie[11] found that 78% of English children aged 11 understood conservation. Lunzer validates this result[12]. In the Manual of Longeot's test, Longeot[13] presented the experiments on conservation of volume and the dissociation of volume and weight, the results obtained for the sample of 210 individuals (30 per age group) allowed him to conclude that 30% of 9-year-olds, 60% of 10–11-year-olds and 70% of 12-year-olds understand conservation. American children average age 12.07 showed similar results[14].

According to Elkind[15], it is only in young adulthood one observes mastery of conservation of volume. In two consequent developmental studies, with 674 and 469 subjects aged 11–12 years to 17–18 years, he observed the following distribution: 27% to 32% of subjects 11–12 years mastered conservation of volume, 36% of 12–13 years, 54% of 13–14 years, 48.4% of 15–16 years, 65% of 16–17 years and 74% of 17–18 years. Uzigris[16] found a similar result

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9 K. Lovell, E. Ogilvie, *The Growth of the Concept*, 118–126; B. Inhelder, *Diagnostic du raisonnement*.

10 C. Nadel, A. Schoeppe, *Conservation of Mass, Weight and Volume as Evidenced by Adolescent Girls in Eighth Grade*, "Journal of Genetic Psychology" 1973, 122, 309–313; H. Protinsky, G. Hugston, *Adolescent Volume Conservation. A comparison of Three Tests*, „The Journal of Psychology" 1980, 104, 27–30; J.O. Towler, G. Wheatley, *Conservation Concepts in College Students: A Replication and Critique*, "Journal of Genetic Psychology" 1971, 188, 265–270.

11 C. Nadel, A. Schoeppe, *Conservation of Mass*, 309–313.

12 E. Lunzer, *Some Point of Piagetian Theory in Light of Experimental Evidence, "Journal of Child Psychology and Psychiatry" 1960, 1*, 1, 191–202.

13 F. Longeot, *Expérimentation d'une échelle individuelle de la pensée logique*.

14 C.R. Hayes, R.W. Kulhavy, *Conservation Level and Category Clustering*, "Developmental Psychology" 1976, 12, 179–184.

15 D. Elkind, *Children's Discovery of the Conservation of Mass, Weight, and Volume Piaget's Replication Study II*, "Journal of Genetic Psychology" 1961, 98, 219–227; D. Elkind, *Quantity Conceptions in Junior and Senior High School Students*, „Child Development" 1961, 32, 551–560; D. Elkind, *Quantity Conceptions in College Student*, „Journal of Social Psychology" 1962, 57, 459–465.

16 I.C. Uzigiris, *Situational Generality*, 831–841.

for 11–12 years in a study of 120 Americans. Only 20% of individuals 12 years old have mastered conservation of volume. Observing a North American population, Hobbs[17] confirmed that at the age of 11–12 years, only a minority of subjects did not know the displacement law. Nadel & Schoeppe[18] observe that only 29% of subjects with an average age of 13.06 years mastered conservation of volume). Rogers[19], in his research with 378 Australians aged 11–12 years, found that 52.4% mastered conservation of volume. In the "weight – volume dissociation" task Augé & Lehalle[20] showed that 47% of French 13–15-year-olds responded correctly".

Let us look at the issues of the "**conservation of volume**" task for young adults. Hall & Kingsley[21] reported that 29% of psychology students still did not get this task right. Hobbs[22] confirmed the difficulties that high school students had while solving the conservation of volume task. In 1977, White & Friedman[23] used the same experiments as Elkind[24] did, for 60 American college students. Their results showed that 63% of college students mastered "volume"). When those subjects who had not solved the conservation of volume task can see the water level rise due to the immersion of a solid, and are again asked the question of the conservation of volume, we find that 82% of subjects understand conservation of volume. For adults with an average age of 33 years and with a low educational level, from grade 3 to grade 8, only 24% understand conservation of volume (Graves[25]). A more detailed analysis showed that African-Americans were less successful than white Americans with this task; however, this difference had not been observed for conservation of mass or conservation of weight (Graves).

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17 E.D. Hobbs, *Adolescents' Concept*, 431.

18 C. Nadel, A. Schoeppe, *Conservation of Mass*, 309–313.

19 K.W. Rogers, *Regression in the Performance of Australian Boys and Girls on a Volume Conservation Task*, "Journal of Genetic Psychology" 1982, 140, 221–228.

20 C. Augé, H. Lehalle, *Effet de «signification et conservation du volume»*, „Enfance" 1986, 39(1), 43–51.

21 V.C. Hall, R.C. Kingsley, *Conservation and Equilibration Theory*, "Journal of Genetic Psychology" 1968, 113, 195–213.

22 E.D. Hobbs, *Adolescents' Concept*, 431.

23 K.M. White, B. Friedman, *Conservation of Volume in College Students: Challenging Elkind*, „The Journal of Genetic Psychology" 1977, 131, 183–193.

24 D. Elkind, *Children's Discovery*, 219–227; D. Elkind, *Quantity Conceptions*, 551–560.

25 A.J. Graves, *Attainment of Conservation of Mass, Weight and Volume in Minimally Educated Adult's*, „Developmental Psychology" 1972, 7, 2, 223.

What about the elderly? In the research of Hornblum & Overton[26], 75% of participants with an average age of $7^3/_{12}$ years solved the "occupied volume" task (in the approved manner), whereas 56.7% of them gave the correct answer in the "displacement volume" task. Longeot[27] used the Piaget Scale for the test of **conservation of volume** to compare passive and active retired men (average age of 72.05) from the same professional groups (engineers, teachers). The results showed that over 90% of participants solved the task successfully. The two groups did not differ (Marendaz[28]).

While Piaget & Inhelder[29], Lunzer[30], Longeot[31] were proving that gender did not affect the quality of results on the retention volumes; Elkind[32] showed that there was a significant difference (significance level 0.1) between boys and girls from 11–12 to 17–18 years (12 degrees). He stated that boys solved the tasks related to the conservation of volume better than girls did. Hobbs[33] and Rogers[34] confirmed this result for 11–12-year-olds, namely that 30% of girls and 60% of boys mastered the law of volume of water displaced. Rogers[35] also noted this difference among young Australians (8–9 years and 10–11 years). The same facts were observed by Hobbs[36] for older individuals. (Among high school students,) 40–50% of the boys and 20–30% of the girls understood conservation of volume. While all 18 year-old boys understood this law, only 50% of girls gave the correct answer. Graves[37] found a shift in favor of men (with a mean age of 33 years) and a low educational level only for the conservation of volume. The average score for women is 1 and for men is 1.43. The study Protinsky & Hugston[38] conducted among 70 young American students (average age 19.07 years) indicates that 91%

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26 J.N. Hornblum, W.F. Overton, *Area and Volume Conservation among the Elderly: Assessment and Training*, "Developmental Psychology" 1976, 12, 1, 68–74.

27 F. Longeot, *Expérimentation d'une échelle individuelle de la pensée logique*.

28 C. Marendaz, *Dépendance-independance à l'égard du champ, activité opératoire et sénescence*, „L'Année Psychologique", 1984, 2, 185–205.

29 B. Inhelder, J. Piaget, *De la logique de l'enfant à la logique de l'adolescence*, Paris 1955.

30 E. Lunzer, *Some Point of Piagetian Theory*, 191–202.

31 F. Longeot, *Expérimentation d'une échelle individuelle de la pensée logique*.

32 D. Elkind, *Quantity Conceptions*, 459–465.

33 E.D. Hobbs, *Adolescents' Concept*, 431.

34 K.W. Rogers, *Regression in the Performance*, 221–228.

35 *Ibidem*.

36 E.D. Hobbs, *Adolescents' Concept*, 431.

37 A.J. Graves, *Attainment of Conservation*, 223.

38 H. Protinsky, G. Hugston, *Adolescent Volume Conservation*, 27–30.

gave a correct answer and logical justification for the same task as Elkind[39] and 63% for the dissociation of volume and weight task.

To answer the question of universalism, the experiments have to be conducted on populations of different cultures. It is necessary to note that these kind of studies, where the conservation of volume in the framework of a comparative cultural approach, are not very numerous. In general, the majority of studies were conducted among Western populations to find the age of complete mastery. De Lemos[40] showed a difference in results for the tasks of conservation between aboriginal peoples of Australia. The full-blooded Australian aboriginal children have poorer results than those of half-blooded children. Dasen[41] completed the comparative analysis of 12–14 years old Eskimos, Australia aborigines, and the Ebrié people in Côte d'Ivoire in Africa, concluding that 50% of the Ebrié Africans, 35% of the Eskimos, and 20% of the Australian aborigines mastered the conservation of volume. To study the conservation of volume in Papua New Guinea, Ebri Price[42] used two different experiments. One experiment by Jones[43] with students from Papua New Guinea is especially interesting. He noted that only 36% of 16–17 year-olds understand conservation of volume. Nyiti's[44] research of 14-year-olds in the Meru tribe of Tanzania was exceptional. It showed that 67% of those educated in school and 70% of non-educated participants understand conservation of volume.

To conclude this section, we state that the differences in the intellectual development of the children can be partially explained by the lifestyle, the education, and by the methodological issues (the experimenter speaks a foreign language, the individual does not declare his / her age correctly, etc.). In our case, we will focus only those regarding the conservation of volume.

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39 D. Elkind, *Quantity Conceptions*, 459–465.

40 M.M. De Lemos, *Development of the Concept of Conservation in Australian Aborigine Children*, „International Journal of Educational Psychology" 1969, 4, 255–269.

41 Dasen P.R., *Concrete Operational Development in Three Cultures*, „Journal of Cross-Cultural Psychology" 1975, 6, 156–172; P.R. Dasen, *Are Cognitive Processes Universal? A Contribution to Cross-Cultural Piagetian Psychology*, in: *Studies in Cross-Cultural Psychology*, ed. N. Warren, vol. 1, 155–201, London 1977.

42 J.R. Price, *Conservation Studies in Papua New Guinea: A Review*, „International Journal of Psychology" 1978, 13, 1–24.

43 J. Jones, *Cognitive Studies with Students Papua in New Guinea*, Educational Research Unit Report 10, Port Moresby 1973.

44 R.M. Nyiti, *The Development of Conservation in the Meru Children of Tanzania*, "Child Development" 1976, 47, 1123–1129.

Methodology

Problematic

According to IPCC, the process of climate warming is caused by human activities. If we want to modify this process, it is necessary to make people to understand the reasons of this phenomenon and its influence on human activities. We suppose that someone able to understand the elementary physics is also capable of explaining the phenomenon of global warning and its consequences for the earth. That is why we focus our attention on the problem of the estimation of the intellectual development of preadolescents and adolescents of different ethnic groups organizing Piagetian experiments (mass, volume conservation).

Hypothesis

We make the hypothesis that to understand the mechanisms that underlie the elevation of the ocean level, the subjects must understand conservation of volume. As it shown, 15–16 year-olds have less of a problem understanding the phenomenon of conservation of volume and, thus, are able to understand the mechanism of the rise in the level of the ocean. The work in psychology shows that a child of 9 or 10 understands that the rise of the water level comes from adding water (Inhelder & Piaget[45], Piaget[59], Twilde[67]). Children who are (11–12 years old) should correctly answer the question about the glacier. But these children still have difficulties in understanding the effects of a melting iceberg and the associated changes in the sea level. Understanding of the questions related to the volume displaced emerges between 11–12 and 15–16 years of age (Elkind[46], Fieller[47], Inhelder & Piaget[48], Longeot[49], Piaget[50], Rogers[51], Uzgiris[52],

[45] B. Inhelder, J. Piaget, *De la logique*.
[46] D. Elkind, *Quantity Conceptions*, 459–465.
[47] A. Fieller, *Comparison of the Development*, 1048–1058.
[48] B. Inhelder, J. Piaget, *De la logique.*
[49] F. Longeot, *Expérimentation d'une échelle individuelle de la pensée logique*.
[50] J. Piaget, *La causalité chez l'enfant*.
[51] K.W. Rogers, *Regression in the Performance*, 221–228
[52] I.C. Uzigiris, *Situational Generality*, 831–841.

Twilde[53]). Therefore, we suppose, that older children (14–15 years) should respond more easily to both questions on the melting of glaciers and the melting of icebergs and understand the process of climate warning better. We should observe a difference in performance between the children and adolescents of European origin, and children and adolescents from Guyana and New Caledonia (Dasen[54], Price[55] and Jones[56]). The Europeans answer more correctly than the other children.

Material and methods

To verify (the) main hypothesis we selected 514 children of (who were) 11–15 years old.

G1 – French from region of Midi-Pyrénées, France – 91 persons,
G2 – Indo-Guyanesians from French Guyana – 185 persons,
G3 – Europeans from New Caledonia – 130 persons,
G4 – Kanaks from New Caledonia – 108 persons.

All these children were educated at the French colleges with the same program on Life and Nature Study (Science de la Vie et de la Terre).

To understand the impact of global warming on rising sea levels, we have proposed a "**glacier-iceberg**" experiment. The experimenter shows seven views of glaciers. He explains what a glacier is. He provides information on the glacier's size, length, and thickness. He explains the action of the glacier on the landscape. The eighth view shows a glacier on the edge of the sea. A question was asked. When the glacier is completely melted, what will happen to the sea level? Does the level rise? Does the level stay the same? Or, does the level go down? I don't know. The subject chooses one of the four answers. Then the experimenter shows seven views of an iceberg. He explains what an iceberg is. He provides information on its size, length, and thickness. The eighth view shows the iceberg in the sea. A question was asked. When the iceberg is completely melted, where will the sea level be? Does the level rise? Does the level stay the same? Or, does the level go down? I don't know. The subject chooses one of these four answers. The authors have created an experiment.

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53 J. Twildle, *Is the Concept of Conservation of Volume in Solids Really More Difficult Than for Liquids, or Is the Way We Test Giving Us an Unfair Comparison?*, "Educational Research" 2006, 48, 1, 93–109.

Results

We will review the correct answers of the children and adolescents. Then, we will look at the responses to both situations (glacier and iceberg).

Data from children

The table 1 shows: 1) the vast majority of children correctly answer the question about the melting glacier. Performances don't vary between the groups ($\chi^2 = 6.131$, $p < 05$ d.dl3); 2) 18 children from G1, 21 from G2, 9 from G3 and 10 from G4 correctly answer the question about the iceberg. Performances don't vary between the groups ($\chi^2 = 5.15$, $p > 05$ d.dl3); 3) the majority of children believe that when the iceberg is completely melted, the sea level rises. Performances vary between the groups ($\chi^2 = 9.096$, $p < 05$ d.dl3). The two by two comparisons show that performances vary between group 2 and group 3 ($\chi^2 = 4.907$, $p < 05$ d.dl1). Only some subjects think that the sea level drops; 4) for the four groups, it is easier to correctly answer the question about the glacier than about the iceberg. The differences are statistically significant (G1 McNemar's test $\chi^2 = 29.032$, $p < 0001$ d.dl1; G2 McNemar's test $\chi^2 = 44.462$, $p < 0001$ d.dl1; G3 McNemar's test $\chi^2 = 40.196$, $p < 0001$ d.dl1; G4 McNemar's test $\chi^2 = 26.281$, $p < 0001$ d.dl1).

Table 1. The results for children

Groups	Glacier				Iceberg			
	Rise	Same level	Drop	I don't know	Rise	Same level	Drop	I don't know
G1 n = 50	**44**	5	1	0	32	**18**	0	0
G2 n = 88	**72**	6	10	0	60	**21**	6	1
G3 n = 53	**50**	2	1	0	44	**9**	0	0
G4 n = 42	**39**	1	0	2	31	**10**	1	0

Data from adolescents

Table 2 shows: 1) the vast majority of adolescents correctly answer the question about the melting glacier. Performance varies among the groups

($\chi^2 = 10.033$, $p < 05$ d.dl3). The two by two comparisons show: Performances vary between group 2 and group 3 ($\chi^2 = 4.646$, $p < 05$ d.dl1) and between group 2 and group 4 ($\chi^2 = 7.068$, $p < 01$ d.dl1); 2) 15 children from G1, 34 from G2, 25 from G3 and 11 from G4 correctly answer the question about the iceberg. Performances don't vary between the groups ($\chi^2 = 7.473$, $p > 05$ d.dl3); 3) the majority of adolescents believe that when the iceberg is completely melted, the sea level rises. This is true for the four groups ($\chi^2 = 1.662$) > p.05 d.dl3). Only some subjects think that the sea level drops; 4) for the four groups, it is easier to correctly answer the question about the glacier than about the iceberg. The differences are statistically significant (G1 McNemar's test $\chi^2 = 48.020$, p. < 0001 d.dl1; G2 McNemar's test $\chi^2 = 53.018$, p. < 0001 d.dl1; G3 McNemar's test $\chi^2 = 48.020$, p. < 0001 d.dl1; G4 McNemar's test $\chi^2 = 24.038$, p. < 0001 d.dl1).

Table 2. The results for adolescents

Groups	Glacier				Iceberg			
	Rise	Same level	Drop	I don't know	Rise	Same level	Drop	I don't know
G1 n = 41	**38**	3	1	0	26	**15**	0	0
G2 n = 97	**84**	9	4	0	59	**34**	4	0
G3 n = 77	**74**	3	0	0	49	**25**	3	0
G4 n = 66	**65**	1	0	0	51	**11**	3	0

Responses to both situations (glacier and iceberg)

Data from children

The table 3 shows: 1) Between 15% and 26% of children respond correctly to both tasks (iceberg and glacier). Performances don't vary among the four groups ($\chi^2 = 2.119$, p. > 05 d.dl3). 2) For the four groups, the more common responses are R-R. Performances vary significantly among four groups ($\chi^2 = 10.291$, p. < 02 d.dl3). The two by two comparisons show that performances vary between group 2 and group 3 ($\chi^2 = 8.641$, $p < 001$ d.dl1) and between group 3 and group 4 ($\chi^2 = 3.923$, $p < 05$ d.dl1).

Table 3. The results for children

Groups	Responses to the two tasks (iceberg and glacier)								
	R-SL	R-R	R-D	SL-R	D-R	D-SL	SL-D	SL-SL	I don't know
G1 n = 50	**13 (26%)**	31 (62%)	0	1	0	0	0	5	0
G2 n = 88	**20 (23%)**	48 (54%)	4	5	8	2	1	0	0
G3 n = 53	**8 (15%)**	42 (79%)	0	2	0	1	0	0	0
G4 n = 42	**8 (19%)**	30 (71%)	1	1	0	0	0	0	2

R – rise; SL – same level; D – drop

Data from adolescents

The table 4 shows: 1) between 16% and 34% of adolescents respond correctly to both tasks (iceberg and glacier). Performances don't vary among the four groups ($\chi^2 = 6.271$, $p > 05$ d.dl3); 2) the most common responses are R-R, for the four groups. Performances vary significantly among the four groups ($\chi^2 = 10.448$, p. < 02 d.dl3). The two by two) comparisons show that performances vary between group 2 and group 4 ($\chi^2 = 8.422$, $p < 05$ d.dl1).

Table 4. The results for adolescents

Groups	Responses to the two tasks (iceberg and glacier)								
	R-SL	R-R	R-D	SL-R	D-R	D-SL	SL-D	SL-SL	I don't know
G1 n = 41	**12 (29%)**	26 (63%)	0	1	0	0	0	2	0
G2 n = 97	**33 (34%)**	48 (49%)	2	7	5	0	0	2	0
G3 n = 77	**24 (31%)**	47 (61%)	3	2	0	0	0	1	0
G4 n = 66	**11 (16%)**	52 (78%)	3	0	0	0	0	0	0

R – rise; SL – same level; D – drop

Discussion

We made four assumptions: 1) the children should correctly answer the question about the glacier; 2) the children still have difficulties in understanding the effects of the melting iceberg and the associated changes in the sea level; 3) we suppose that older children (14–15 years) should respond more easily to both questions about the melting of glaciers and the melting of the icebergs; 4) we should observe difference in performance between the children and adolescents of European origin, and children and adolescents of Guyana and New Caledonia. The Europeans answer more correctly.

The data show that the majority of children correctly answer the question about the melting glacier. Our results confirm those of Inhelder & Piaget[54], Piaget[59] and Twilde[67]. The interest of this research is to extend this result to new populations of French Guyana children, European children of New Caledonia and Kanak children. To our knowledge no research has focused on French Guyana children nor on Kanak children.

As our hypothesis has indicated, children have serious difficulties with the melting iceberg. 36% of French children from France, 23% of French Guyana children, 17% of European children from New Caledonia and 23% of Kanak children give a correct answer. This result shows the difficulties of understanding the law of displacement volume are the same for the children from France, for the European children from New Caledonia, for French Guyana children and for Kanak children. This result is consistent with Piaget's theory. The difficulties in the construction of knowledge are shared by all of humanity. We will note that only 6% of children think that when the glacier melts the sea level remains the same and 5% felt that it drops.

As expected, all adolescents correctly answer the question about the melting of the glacier. In contrast, only 36% of French adolescents from France, 35% of French Guyana adolescents, 32% of Europeans from New Caledonia and 16% of Kanak adolescents correctly answer that question. This result was not observed in the psychological literature. In our study, performances are lower than those of Elkind[55], Rogers[74] and Augé & Lehalle[31]. How can we explain this? The methodology differs. In all the previous research, the assessment of understanding of the conservation of volume is achieved with small solids: a play

54 B. Inhelder, J. Piaget, *De la logique*.
55 D. Elkind, *Quantity Conceptions*, 459–465.

dough ball, a metal ball, a cube, etc. … The size of the solid is reduced. The solids are real. The subject sees these solids. He sees the water in the jars. In our study, we present slides of a glacier or of an iceberg. The size, weight, and surface are all gigantic. We believe that it is easier to put academic knowledge into practice in the situation with small solids than in our situation. We indicate that an iceberg is as high as a building with four floors. We always give a local example that it is as high as the hospital building. In our experiment, students must put knowledge of physics into practice while they think about being in a science and life and earth class.

In our work, each situation is presented on a slide. The experimenter gives the instructions. The task is collective. Typically, the task is individual, with real objects. It is perhaps more difficult to grasp the causality of events when you see a picture than when one is faced with a real material. A surprising result is that the adolescent makes the same type of mistake as the children. They believe that when the iceberg is completely melted, the sea level rises. One possible explanation is that the subject reasons like this: when the ice melts, it turns into water. If I add water to water it makes more water. With more water, the level rises. In everyday life, this reasoning can explain many situations. This is what is called a misconception or a naive reasoning. There is a vast literature on the naive conceptions in physics (Krist[56], McCloskey[57]). Most of the research focuses on the trajectory of the falling bodies. Our research shows that there are also naive conceptions about physical phenomena linked to global warming. In our study, these naive conceptions are very powerful. Between 54% and 79% of children and between 49% and 78% of adolescents use a naive conception. We found that children from European New Caledonia have a greater use of this type of reasoning (79%) than those from French Guyana (54%) and that European New Caledonia children have a greater use of this type of reasoning (79%) than Kanak children (71%). We observe that adolescents from New-Caledonia have a greater use of this type of reasoning (61%) than those from French Guyana (49%).

Our results show that between 15% and 26% of children and 16% and 36% of adolescents have the physical model (the correct answer to both the glacier and the iceberg tasks). With the physical model and with naïve reasoning we can explain well over 75% of the responses of both children and adolescents.

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56 H. Krist, *Development of Naïve Beliefs about Moving Objects. The Straight-down Belief Action*, "Cognitive Development" 2000, 15, 281–308.

57 M. McCloskey, *Intuitive Physics*, "Scientific American" 1983, 248, 4, 122–130.

Conclusions

Our results show that both children and adolescents from France, from French Guyana, and from New Caledonia (Kanaks as well as Europeans) understand that as the glaciers melt, the sea level rises. Our results confirm those of Inhelder & Piaget[58], Piaget[59] and Twilde[67]. We found that all adolescents encounter serious difficulties when the water level rises from the volume of water displaced. Between 15% and 26% of children and 16–36% of adolescents reason in accordance with the physical model. In our study, performances are lower than those Elkind[59], Rogers[74] and Augé & Lehalle[31]. Our results show that subjects use a naive type of reasoning: when the ice melts, it turns into water. If I add water to water it makes more water. With more water, the level rises. This type of reasoning is an illustration of naive conceptions in physics. Recent work in the field of reasoning has been made in the context of of the new paradigm (Baratgin & Politzer, G.[60]; Baratgin, Over & Politzer[61]; Baratgin, Over & Politzer[62]). This postulates that subjects reason in a probabilistic manner. This research focuses on the logical connectors. Future research on the understanding of physical phenomena should be based on a probabilistic approach.

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58 B. Inhelder, J. Piaget, *De la logique*.

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SUMMARY

This paper intends to study the level of the intellectual development of French-speaking preadolescents and adolescents from 11 to 15 years old and from four different ethnic groups in order to investigate their abilities to understand the phenomenon of global warming. The empirical studies proved that despite the growing tendency in the level of the intellectual development for older children from different ethnic groups, it is obvious that the level of understanding of the physical phenomenon is still very low.

KEY WORDS: intellectual development, preadolescent, adolescent, global warming, physical phenomenon, Piagetian-type experiment.

STRESZCZENIE

W pracy zbadano poziom rozwoju intelektualnego preadolescentów i adolescentów mówiących po francusku w wieku od 11 do 15 lat i pochodzących z czterech grup etnicznych w celu ustalenia możliwości zrozumienia zjawiska globalnego ocieplenia. Badania empiryczne wykazały tendencję wzrostu z wiekiem poziomu rozwoju intelektualnego młodzieży z różnych grup etnicznych, jednak nie jest on wystarczający do zrozumienia podstawowych zjawisk fizycznych będących podłożem globalnego ocieplenia.

SŁOWA KLUCZOWE: rozwój intelektualny, preadolescent, adolescent, globalne ocieplenie, zjawiska fizyczne, eksperymenty Piaget.

FRANK JAMET – Maître de Conférences en psychologie, Université de Cergy-Pontoise
JEAN BARATGIN – Maître de Conférences en psychologie,
CHArt (Paris), Université de Paris et EPHE
DARYA FILATOVA – dr hab. Instytut Pedagogiki i Psychologii, WAiP,
Uniwersytet Jana Kochanowskiego w Kielcach
e-mail: daria_filatova@interia.pl

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