PRIMARY STUDENTS' ALTERNATIVE IDEAS ABOUT WATER

Bosnjak Stepanovic Marija – Maricic Olja – Natalija Pesut – Sanja Balac – Kozoderovic Gordana

doi: 10.18355/PG.2024.13.1.1

Abstract
Alternative ideas in knowledge refer to the situations where student's understanding of a certain concept differs from the scientific concept. During this investigation we were focused on identification and analysis of the most common students' alternative ideas about water in early science education. The sample consisted of 76 first and third grade students from three primary schools in Sombor, Serbia. The semi-structured interviewing technique was used for data collection. The proportion of mixed and scientific answers was higher among third-graders, while the spontaneous answers were more frequent among first-graders. These findings could be attributed to developmental differences and the impact of teaching. Our investigation can be useful starting point for the process of transformation of students' alternative ideas about water in everyday school practice.

Key words
Naive ideas, physical property of water, primary science education, scientific concept

Introduction

Scientific knowledge is mostly adopted in the process of teaching during formal education, aimed at enabling children for further education, long - life learning and better functioning in everyday life. Despite increased presence of science and technology in everyday life, the interest in science is declining among children, since they fail to make a connection between science concepts they learn at school and phenomena in real life (Harlen, 2010). As they gain experience of natural phenomena, children create their own explanations, and often they defy accepting new information if it does not fit their established pattern of thinking (Gooding & Metz, 2011).

Generally, students are not aware that their beliefs are not scientifically correct and have difficulties in changing them. The situation in Serbia implies that science teaching in our schools fails to sufficiently develop and support the process of conceptual change from spontaneous to scientific knowledge, and, even less, functional knowledge. It is proven that the pre-existing naive ideas as the most important factor influencing the process of learning (Harlen, 2011). The metanalysis revealed that there were 33 physics, 12 chemistry, and 15 biology concepts in science which predominantly caused misconceptions among students (Soeharto et al., 2019). This research implies the universal nature of misconceptions regardless of country of origin, school or age of students. However, the studies defining the specific causes and mechanisms of misconceptions are scarce.

Theoretical Background

Many scientists investigated the adoption of concepts of water and its physical properties because water is a part of children's daily experience in many ways, making it a suitable notion for forming a variety of alternative ideas. As for states of matter, it is established that the majority of children successfully make a difference between solid and liquid state, but not between liquid and gaseous state (Smolleck & Hershberger, 2011). It is shown that children don't distinguish the notions such as vapor, gas, fog and smoke, as well as the processes of melting, dissolving and disintegration. The research concerning phenomena of floating and sinking (Yin et al., 2008) proposed the list of ten most typical misconceptions with the most frequent arguments given by the students of elementary school to support their claims.

According to Klausmeier (1985) the concepts are the fundamental initiators of intellectual development of a child and that they play a central role in the development of cognitive structures and thinking. The intuitive explanations represent the foundations for more sophisticated interpretations which substantially affect the process of learning. Young children construct precursor models that function in their minds as intermediaries between mental representations of reality and scientific knowledge. Such models encourage children's thinking, forming the basis for a cognitive development towards complex thinking processes and mental models (Kambouri-Danos et al., 2019). Primary science teaching enables most of the children to progress to a certain level, whereby many children are stuck "half way", at the level where they dismissed spontaneous thinking, but not completely achieved scientific concepts (Pešić, 1995, p. 300). If spontaneous interpretation of scientific phenomena was not abandoned, it can coexist with what "the teacher said" and create a compilation of the facts (Bruce & Konicek, 1990, p. 681). The intensity of interference of those two concepts lead to corresponding delay when students try to produce the correct answer (Potvin et al., 2015).

The situation in which the students' ideas or students' understanding of a concept differs from the scientific concept is named differently in literature: misconceptions, preconceptions, naive theory/knowledge/ideas, everyday knowledge, naive/false beliefs, alternative ideas/conceptions (Smith et al., 1994). In this paper the term alternative or naive children's/students' idea is used. Identifying a nature of children's alternative ideas is essential for finding the most effective approach to the adoption of scientific concepts (Allen, 2010; Radovanovic & Slisko, 2014). The reconstruction of the pre-existing knowledge is accomplished by creating situations in which a child is unsatisfied with the existing (spontaneous) concepts and in which the new (scientific) concepts are understandable and credible (Posner et al., 1982). If concepts are more like complex clusters of related ideas than separable independent units, then the replacement during learning process looks less plausible (Smith et al, 1994). The studies investigating conceptual changes imply that it is gradual and evolutionary, rather than sudden and revolutionary process (Taylor & Kowalski, 2004).

Methodology and Methods

The aim of this investigation was to identify and analyse the most common students' preconceptions/misconceptions about water in primary science education. The intention was to provide adequate interpretations of the obtained answers aimed at better understanding of sources and origins of alternative ideas (Harlen, 2011).

Participants

The study was conducted on the sample of 76 first and third - grade students (38 students from each grade), attending three elementary schools in the town of Sombor, Serbia. Six or seven students from six classes in each grade were selected by stratified sampling, according to their score (formative/summative) in science: below average, average and above average in the subjects World around us and Nature and Society.

The reason for selection of students of these ages lies in the fact that teaching contents about water predominate in the first and third grade curricula (TLP1PE, 2017; TLP3PE, 2019), as shown in Table 1.

Table 1 Teaching content about water

	TEACHING CONTENT	GRADE
1.	Basic properties of water (colour, taste, smell, shape, volume, free surface)	I, II, III
2.	States of water and change of state	I, II, III
3.	Buoyancy of objects in water (float and sink)	I, III
4.	Solubility	I, III, IV
5.	Water cycle	II, III
6.	Water and other liquids (similarities and differences)	III

Procedure

For the purpose of this survey, the questionnaire and the attitude scale were constructed. The survey was anonymous and comprised of 19 open-ended and close-ended questions. The questions referred to the experiences and reflections of participants' educational work during lockdown and to the challenges they encountered during pandemic.

Data were collected in a period from May to August 2021 in Serbia and Germany.

In this study we investigated the way children understand and explain scientific facts through in-person 30-minute interviews for each student:

1. Is the mass of ice cube the same as the mass of the melted ice cube? Explain. (the principle of conservation of mass and volume)
2. Of what depends whether an object will float or sink? Explain. (buoyancy in relation to density)
3. Which property of water allows aquatic living beings (for instance fish) to survive during winter? (the anomaly of water)
4. Is there water in the air? (states of matter, water cycle)

The interviews were audio recorded and transcribed. The transcripts were analysed, interpreted and compared. Students' answers were grouped according to their quality into four classes (Petrovic, 2006):

- Spontaneous answers are referred as everyday experienced, based on practical and sensory-perceptive experiences without the presence and influence of teaching and scientific facts.
- Mixed answers contain certain features of both spontaneous and scientific answers: they rely on the experience with the presence of scientific knowledge, but expressed as clumsy linguistic constructions, answers learnt by heart, and associatively (often erroneously) connected information.
- "I don't know" answers is a group of answers where student is aware that he/she is not capable to explain the concept, or simply doesn't know particular facts or notions.
- Scientific answers are defined as all the answers derived from the properly adopted scientific concept which derives from different origins. The task of formal teaching is to predominantly contribute to student's scientific knowledge.

Spontaneous and mixed answers were considered as sources of alternative ideas. Particular answers which were registered in the highest percent as spontaneous and mixed were defined as the most frequent alternative ideas.

Methods

Descriptive statistical methods (frequencies and percentages) were used for quantitative analysis of children's answers from the interview. The results were grouped according to teaching contents (questions) and classes of answers (spontaneous, mixed, "I don't know" and scientific), through grades (I – first grade and III – third grade). Numerous authentic children's answers were cited within the qualitative data analysis. Those results were designed to clearly set out the following elements:

1. Problem / diagnostic question.
2. Typical answers (alternative ideas).
3. Student' explanations of alternative ideas.
4. Interpretations of the causes / roots of alternative ideas.

Results and Discussion

Percentage of classified students' answers to each question in both grades are shown in Table 2. It is evident that the proportion of spontaneous and mixed children's answers was higher than the "I don't know" and scientific answers.

Individual explanations of students' claims, grouped according to the classes of answers with appropriate interpretations are shown in Tables 3-6. The numbers in brackets after each claim represents the number of students sharing that claim.

Table 2 The percentage of students' answers grouped according to questions, classes and grades

	CLASSES OF ANSWERS (%)							
	Spontaneous		Mixed		„I don't know"		Scientific	
GRADE	I	III	I	III	I	III	I	III
1.	94.74	57.90	5.26	21.05	-	5.26	-	15.79
2.	92.11	7.89	5.26	92.11	2.63	-	-	-
3.	71.05	28.95	26.32	68.42	2.63	2.63	-	-
4.	86.84	47.37	7.90	7.89	5.26	15.79	-	28,95

Analysis of the answers to the first question (Is the mass of ice cube the same as the mass of the melted ice cube?) showed almost complete lack of understanding of the concept of conservation, in this case the mass, in both grades (I - 100%, III – 78.95%). Within those erroneous claims (Table 3), the most frequent misconception was that ice has greater mass than water (I - 75%, III – 84.38%), but there were some students that were convinced that water had greater mass than ice (I - 25%, III – 15.63%).

Table 3 Analysis of explanations of the student's answers gave to the first question: Is the mass of ice cube the same as the mass of the melted ice cube?

Class of answer		*Claim*
The mass is the same	Mixed	I grade - everything is water, just of a different shape (2)
	Scientific	III grade -when ice melts and if that water is frozen again, it will have the same mass (6)
Ice has greater mass than water in liquid state	Spontaneous	I grade -the ice is heavier because (it is frozen (11), of it's shape (8), has it's weight, and water doesn't (5)
		III grade -the ice is heavier because (of it's shape (16), water spills and therefore it has no weight (3)
	Mixed	I grade / III grade -the ice is heavier because water expands when it is cold (5) -when ice starts to melt, it's mass gets smaller (3)
Water in liquid state has greater mass than ice	"I don't know"	III grade (2)
	Spontaneous	I grade -it is easier for me to hold the ice cube (9)
		III grade -there is more of it, so it is heavier (3)

The students' answers to the second question (Of what depends whether an object will float or sink?) revealed that the great majority (92.11%) of first-graders thought that the buoyancy of an object depends solely on its weight, while 76.32% third-graders claimed that buoyancy depends on weight and density of an object. When asked to provide explanation for their claims, it was established that neither the students could explain how buoyancy depends on its weight and/or density, nor they could distinguish between these notions. The students' explanations grouped according to classes of answers with our interpretations are presented in Table 4.

Table 4 Analysis of explanations of the student's answers gave to the second question: Of what depends whether an object will float or sink?

Class of answer	Claim
"I don't know"	I grade (1)
	III grade -
Spontaneous	I grade -it depends of weight (29)
	I grade -the object with a hole sink (6)
	III grade -it depends whether an object is with the hole or not (3)
Mixed	I grade -it depends of the material (2)
	III grade -it depends of weight and density of the material (29) - it depends of the material (4) - it is not the same if it is fresh or saline water (2)

The third question (What happens with aquatic living beings (for instance fish) in water during winter? Which property of water is crucial for that?) revealed that only 44.74% third-graders knew that fish (just one of many groups of living beings in water) stay alive and go deeper, while the rest of the students gave a variety of interesting explanations analysed in Table 5.

Table 5. Analysis of explanations of the student's answers gave to the third question: What happens with aquatic living beings (for instance fish) in water during winter? Which property of water is crucial for that?

Class of answer	Claim
"I don't know"	I grade (1)
	III grade (1)
Spontaneous	I grade -they freeze (18) - they die because they don't have air (5) - they travel to warmer regions (4)
	III grade -they die (6) - they freeze (3) - they reproduce (1)

	- nothing happens (1)
Mixed	I grade -they hide (6) - they swim but slowly (4)
	III grade -they go down deep, they have winter supplies (10) - they stay alive (7) - they fall into winter sleep (7) - they hide (2)

At the last fourth question (Is there water in the air?) the students' opinions were divided. Half of the first-graders and 63.16% third-graders correctly claimed that there is water in the air, while the second half of the first-graders and 34.21% third-graders believed that there is no water in the air and explained it as shown in Table 6.

Table 6 Analysis of explanations of the student's answers gave to the fifth question: Is there water in the air?

Class of answer		Claim
"I don't know"		I grade (2)
		III grade (6)
There is water in the air	Spontaneous	I grade -when it is raining (6) - clouds are the air (4) - when it is hot, the air turns into water (2) - when we breathe sometimes it is wet if we drank water (1) - for fish there is and for humans there is no water in the air (1)
		III grade - there is when it is foggy (2) - there is only when it is raining (1) - if the air is not moist, we would have to drink water all the time (2)
	Mixed	I grade - the rain falls, the pond evaporates and converts into the air (2) -our breath is moist (1)
		III grade -there is when water vapor turns into rain (2) - the air flows by the river and it fills up with water (1)
	Scientific	I grade
		III grade -there is because water evaporates (5) - water can occur in gaseous state, therefore there is water in the air (4) - there is – clouds and water vapor (2)
There is no		I grade - if there was water in the air (we wouldn't be able to

Spontaneous	breathe (4), it would fall on the ground (2)) - the air doesn't contain water because (it is all around us (3), is transparent (4), is not wet (2), is oxygen, and water is liquid (2)) III grade - there is no water in the air (or else we would drown (5), air is different than water (7)

It was evident that they could not associate everyday experiences of condensation of water vapor from the air on windows, glasses and mirrors with the presence of water in the air.

Conclusion

Based on the analysis of interview results, it was possible to identify and classify the most common alternative ideas about physical properties of water which were present to a different extent among first and third-grade students in elementary school:

1. The mass of the ice cube and melted ice cube is not the same (the concept of conservation of mass has not been adopted).
2. Buoyancy of an object in water depends on its volume (size), shape, mass or weight (it is not understood that buoyancy of an object depends on the ratio of its density and density of water or other liquid).
3. During winter fish freeze/die/migrate to warmer regions (some children don't know that ice floats on the water surface, the knowledge about breathing of fish and their survival during winter is not adopted).
4. There is no water in the air (children are incapable to associate daily experiences of condensation of water vapor from the air on objects cooler than the environment with the presence of water in the air, gaseous state of water is not adopted).

Similar results were obtained in many previous studies (Yin et al., 2008; Allen, 2010; Smolleck & Hershberger, 2011; Potvin et al., 2015).

Further analysis of children's answers points to several main sources and directions which generate a variety of alternative ideas:

- Unfamiliarity with the scientific facts such as:
  - conservation of mass of objects, physical law that matter cannot be created from nothing, or disappear (the law of conservation of mass),
  - the way fish breathe (the ability of fish to use oxygen from water, thus it is not necessary for them to jump out of the water in order to breathe),
  - the anomaly of water (water at 0°C - 4°C has higher density than the ice and as a consequence the ice is formed on the surface of water ecosystems);
- Incapability to associate their own daily experiences with the problem to be solved:
  - the relation of density of water and ice is not connected with the experience of floating of ice in oceans, lakes or ice cubes in a glass of water,
  - the presence of water in the air is not associated with everyday experience like condensed water droplets on ice cold juice bottles, ice cream boxes or packs of frozen fruit or vegetables taken out of freezers, or with

evaporation of water during cooking food or blurred windows and mirrors in bathroom during showering with hot water;

• Misuse of particular notions:
- "shape" instead of "state"
- "weight" instead of "mass"
- "weight" instead of "density"
- "air" instead of "water vapor";

• Misattribution of traits to the phenomena and beings which don't possess them:
- fish migrate to warmer regions,
- solid objects or objects with constant shape have greater mass than liquid ones,
- objects with holes sink.

The results showed that alternative ideas about physical properties of water are more frequent among first-graders compared to third-grade students in elementary schools. The proportion of mixed and scientific answers is higher among third-graders, which is expected, taking into account developmental differences and the impact of teaching. As far as quality is concerned, alternative ideas are almost identical in both age groups and represent consequence of ignorance of scientific facts, inabilities to connect everyday experiences with a problem they are solving, misuse of particular notions, or misattribution of traits to the phenomena and beings which don't possess them. Among the identified sources of misconceptions, disability of associating the facts children learn at school with their daily experiences is the most prominent, so connecting those two worlds should be a compulsory element of everyday teaching and extracurricular activities.

The aim of this investigation was to identify and analyse existing alternative ideas about physical properties of water and to determine their prevalence among primary students. This study undoubtedly confirmed that the majority of students displayed familiarity with concepts about water at the level of spontaneous and mixed knowledge. Behind every claim there is a specific system of explanations and interpretations of natural phenomena and processes which requires attention and carefully designed teacher's intervention. However, it has been shown that prospective teachers have difficulties in analysing and categorising children's ideas (Gutierrez et al., 2019). The explanation could be found in the gaps between the expected science competencies of teachers and the science education of prospective teachers (Booi & Khuzwayo, 2019). Therefore, the improvement of science curricula in teacher education and continuous training and self-reflection of in-service teachers are essential for upgrading early science teaching. The results of this study can provide teachers with useful guidelines for teaching about water, but also can serve as an impulse for further investigation of children's alternative ideas in other disciplines of natural sciences.

Bibliographic references

Allen, M. (2010). Misconception in Primary Science. New York, NY: Open University Press.

Booi, K., & Khuzeayo, Me. (2019). Difficulties in developing a curriculum for pre-service science teachers. South African Journal of Education, 39(3), 1-13. https://doi.org/10.15700/saje.v39n3a1517
Bruce, W., & Konicker, R. (1990). Teaching for Conceptual Change: Confronting Children's Experience. Phi Delta Kappan, pp. 680-684.
Gooding, J., & Merz, B. (2011). From Misconceptions to Conceptual Change. Science Teacher, 78(4), 34-37. https://teaching.fsu.edu/wp-content/uploads/2018/01/tst1104_34.pdf
Gutierrez, M.P., Cruz-Guzman, M., & Rodriguez-Marin, F. (2019). Prospective early childhood teachers' difficulties in analysing children's ideas about the natural and social environment. South African Journal of Education, 39(2), 1-10. https://doi.org/10.15700/saje.v39n2a1608
Harlen, W. (2010). Principles and Big Ideas of Science Education. Hatfield, Herts: Association for Science Education.
Harlen, W. (2011). Teaching, Learning and Assessing Science 5-12 (4th ed). London: SAGE. https://doi.org/10.1080/10382046.2017.1320897
Kambouri-Danos, M., Ravanis, K., Jameau, A., & Boilevin, J. (2019). Precursor Models and Early Years Science Learning: A Case Study Realated to the Water State Changes. Early Childhood Education Journal, 47, 475-488. https://doi.org/10.1007/s10643-019-00937-5
Klaumeiser, X. J. (1985). Educational psychology. New York, NY: Harper & Row.
Pesic, J. (1995). Razvoj pojmova na ranom osnovnoškolskom uzrastu [Concept development at primary level]. Psihologija, Filozofski fakultet, Institut za psihologiju [Psychology, Faculty of Philosophy, Institute of Psychology], 28(3-4), pp. 283-302.
Petrovic, V. (2006). Razvoj naučnih pojmova u nastavi poznavanja prirode [Concept development in science teaching]. Jagodina: Faculty of Teachers in Jagodina, University of Kragujevac
Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-227.
Potvin, P., Masson, S., Lafortune, S., & Cyr, G. (2015). Persistence of the intuitive conception that heavier objects sink more: a reaction time study with different levels of interference. International Journal of Science and Mathematics Education, 13, 21-43. https://doi.org/10.1007/s10763-014-9520-6
Radovanovic, J., & Slisko, J. (2014). Investigative homework with apples: An opportunity for primary school students to learn actively the relationship between density and flotation. European Journal of Science and Mathematics Education, 2(1), 1-14. https://doi.org/10.30935/scimath/9396
Smith, J.P., Disessa, A A., & Roschelle, J. (1994). Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition. Journal of the Learning Sciences, 3(2), 115-163. https://doi.org/10.1207/s15327809jls0302_1
Solleck, L., & Hershberger, V. (2011). Playing with Science: An Investigation of Young Children's Science Conceptions and Misconceptions. Current Issues in Education, 14(1), 1-32.

Soeharto, S., Csapo, B., Sarimanah, E., Dewi, F., & Sabri, T. (2019). A Review of Students' Common Misconceptions in Science and Their Diagnostic Assessment Tools. Journal Pendidikan IPA Indonesia, 8(2), pp. 247-266. https://doi.org/10.15294/jpii.v8i2.18649

Taylor, A., & Kowalski, P. (2004). Naïve Psychological science: The prevalence, strength, and sources of misconceptions. The Psychological Record, 54, 15-25. https://doi.org/10.1007/BF03395459

Teaching and learning program for the first grade of primary education (TLP1PE). (2017). Belgrade: Educational Review, No. 10. 8 https://zuov.gov.rs/zakoni-i-pravilnici/ [viewed 18 December 2019].

Teaching and learning program for the third grade of primary education (TLP3PE). (2019). Belgrade: Educational Review, No. 5. 6 [viewed 18 December 2019].

Yin, Y., Tomita, M., & Shavelson, R. (2008). Diagnosing and Dealing with Student Misconceptions: Floating and Sinking. Science Scope, 31(8), 34-39.

Associate Professor Bošnjak Stepanović Marija
Department of Natural Sciences and Management in Education
Faculty of Education in Sombor, University of Novi Sad
Podgorička 4, 25000 Sombor
Serbia
marija.bosnjak@pef.uns.ac.rs

Assistant Professor Maričić Olja
Department of Natural Sciences and Management in Education
Faculty of Education in Sombor, University of Novi Sad
Podgorička 4, 25000 Sombor, Serbia
olja.maricic@pef.uns.ac.rs

Natalija Pešut
Department of Natural Sciences and Management in Education
Faculty of Education in Sombor, University of Novi Sad
Podgorička 4, 25000 Sombor, Serbia
nanazujovic@gmail.com

Sanja Balać
Department of Natural Sciences and Management in Education
Faculty of Education in Sombor, University of Novi Sad
Podgorička 4, 25000 Sombor
Serbia
sanjabalac@gmail.com

Professor Kozoderović Gordana
Department of Natural Sciences and Management in Education
Faculty of Education in Sombor, University of Novi Sad
Podgorička 4, 25000 Sombor
Serbia
gocakozoderovic@gmail.com