DEVELOPMENT OF CHILDREN'S UNDERSTANDING OF THE SURFACE ORIENTATION OF LIQUIDS

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ABSTRACT: In this chapter is analysed the development of children's understanding of the concept of horizontal position of the liquid surface. Numerous studies have found that most children and approximately 40% of the adult population behave as if they do not know that liquid remains horizontal, regardless of the orientation of its container. The sample consisted of students from six classes in elementary school "Ivo Lola Ribar" and "Dositej Obradovic" in Sombor (Serbia). The project "Water is precious" was implemented in three of tham and lasted from March to June 2015. The paper presents the experience and difficulties in adopting corect concept about surface orientation of liquids. Based on the study findings, conclusions were drawn and possible solutions were offered. The study has once again confirmed that the one-time doing of experiments, without continuity in observation and experimentation is insufficient to properly and permanently adopt certain scientific notions and concepts such as horizontal position of the liquid surface.

Key words: Scientific concepts and notions, basic properties of a liquid, science in primary school teaching

INTRODUCTION

Teaching practice in Serbia is mostly focused on the implementation of the curriculum, innovative methods are rarely used, as well as, correlation between the subjects. Students are not required to predict and present different ideas and arguments, check them and provide evidence (Bošnjak, Branković, Gorjanac Ranitović, 2013; Cvjetićanin, Branković, Petrović, 2014).

Teaching methods based on inquiry-based activities, like project-based learning, have proven their effectiveness, in stimulating the interest of students, improving the level of their achievement and developing their functional knowledge and critical thinking (Expert Group of the European Commission, 2007).

The project-based learning means acquiring knowledge during the course of the project, which have to comply with the following elements:selection of topics from real life, challenging leading question, the students' voice and choice, developing skils of 21st century (cooperation, communication, critical thinking and the use of technology), students research, find innovation, conduct self-evaluation and public presentation of their results ((Larmer & Mergendoller, 2010; Chard, 2002 by: Curtis, 2002). In the proces of project-based learning project task has to be in the form of research, research topic combines different scientific areas and involves cooperative learning (David, 2008).

We conduct action research to investigate the practical possibilities of introducing project-based learning in teaching practice in Serbia, through the identification of specific features, problems and difficulties in its implementation and to find possible improvements. The research revealed one part of the study findings related to adoption correct concept about surface orientation of liquids by students of the third grade of elementary school. For proper understanding of the research problem the developmental abilities of children are important. Child's development is reflected in its specific ways of understanding the world around them, including the space. Before they go to school, children have acquired the implicit and the non-numeric knowledge of shape, position, distance, spatial orientation and directions.

Epistemological Interpretation of Space

Genetic construction of space, besides the whole mental development, is in line with the whole biological evolution. Construction of space derives from position of our bodies and our senses, develops through the perceptive and sensory-motor evidences of space, and finally is shaped by deductive geometrical operations within the intellectual part of our brain cortex (Piaget, 1994, p. 132). The basic spatial relationships are based on elementary topological relations such as proximity,distinction (separation) and continuity, which further depend on the initial sensory actions such as view centering and touch (Piaget, 1994, p. 163).

According to Poincare (Jules Henri Poincare) the one who could follow movements in the outside world, has to coordinate its own movements, and from this coordination could follow the structure of "group" (movement of the body itself, form a single "group"). Poincare boldly asserts that "for a completely motionless being, there would be neither space, nor geometry." Piaget concludes that the fundamental consequences of the previous statement are that "some of the displacements of the body initiates structuring of the external developments according to a correlative model, which is a mixture of convention and experience. Thanks to the same process, three dimensional concepts and Euclidean structure are attributed to the external space"(Piaget, 1994, p. 170-171).

A precondition for the proper construction of the space, is structuring the child's intuitive space per axes that is provided by vertical and horizontal objects. The vertical position of the body, that is established very early in the childhood (second half of the first year of life), does not allow the child to intuitively present himself verticals and horizontals, or that coordinate them with each other, until seven, eight years of age (Piaget, 1994, p. 144). Perceptual coordinates (horizontal and vertical) depend on the perceptual activity of comparing and bringing to relation observed objects and reference elements. Perceptual activities develop and enrich through a series of stages, in order to integrate with the intelligence about the age of eight, or nine.

For the understanding of space, and subsequently surface orientation of liquids, it is important to develop the concept of conservation. Conservation is the ability to view that quantitative properties of matter (quantity, mass, weight, length, area, volume) remain unchanged, although it changes its external characteristics (shape, place and order in space). This becomes apparent for child only on the basis of the conclusion which is not derived from the observation, but is the result of intellectual constructions performed by using mental operations. Thus, the conservation of quantity of matter and length occurs about 7-8 , the conservation of weight around 9-10, and volume conservation only about 11-12 years of age (Korać, 2012, p. 10).

Quantity conservation is achieved by learning that the parts unify into a whole, through reversible composition based on the relationships of the one part to the whole, without determining quantitative relations between the parts ($A+A' = B \Rightarrow A < B \wedge A' < B$).Therefore elementary coordinate systems are firstly built, before any metrics, as correspondence of parts arranged in two or three dimensions, followed by compositions of "displacement", before their metric quantification, as change of the order or position. Developing capacity to construct the one part that can be repeated, and thus can serve as a unit, the process of constructing concept of measures is brought to the end, which logically and genetically runs almost in parallel to the process of number concept construction. However, for mathematization of space, except metric quantity, it is necessary to develop a formal thinking, and for it characteristic propositional logic (Piaget, 1994, pp. 196-205).

Picturesque spatial intuitions are formed in true geometric operations through three systems of spatial operations:

- Transformation of close figure (topological relations) - from ten to eight years of age;
- Coordination of the observation points from which the figures are transformed (projective relations) - about eight, nine years of age;
- Transformations that are consequence of displacement and that are related to the coordinate axes (Euclidean relations including similarities to) - about the eighth, ninth years of age (Piaget, 1994, pp. 191-192).

In addition to the mathematical (geometric) space which is the result of subjective coordination, there is a physical (empirical) space that applies to objects and their own properties. The physical space is no object property that can be extracted from its context, or, all the transformations that are logically possible (within the mathematical space) are not physically realizable. In the course of cognitive development, originally developed intuitive space, due to the separation of spatial operations, is replaced by formalized (matematical) and experiential (physical) space. Thereby, individual actions are a source of physical findings (including physical space), while the general coordination of actions are a source of logical-mathematical knowledge (including geometric space) (Piaget, 1994, pp. 237-241).

The Development of Space Understanding

Piaget defines four basic stages of cognitive development: sensorimotor (0-2 years og age), preoperational (2-7 years of age), the stage of concrete operations (7-11 years og age) and the stage of formal operations (11-15 yearsof age). Passing through various stages during the child's development, cognitive development is reflected in its specific ways of understanding the world around it, including the space.

During the sensorimotor stage a child develops coordination schemes between eye and hand and adopts the concept of object permanence. Preoperational stage is characterized by the development of symbolic thinking which is also reflected through development of speech. At the stage of concrete operations child is able to perform basic operations with concrete objects such as classification and seriation. Through the last stage, stage of formal operations child acquires the ability of abstract thinking, hypothetical reasoning and metacognition.

Before going to the school, the child has acquired the implicit and non-numerical knowledge about the shape, position, distance, spatial orientation and directions. Proper understanding of the space also depends on the egocentrism of the child, because it is centered on the individual aspects of the space and relations of elements in it, but not on an objective system of relations (spatial coordinates). Thus, the child from the age of seven and up to the age of nine, ten, will draw crossed paths parallel, because it focuses on each of them individually, rather than on their mutual relationship. (Korać, 2012, p. 13-14).

Mistakes that children make when draw horizontal and vertical lines are the result of concentration on the relations of those lines which are the nearest (liquid surface in a glass compared to glass) rather than on relations of distant lines (liquid surface in a glass compared to the surface of the table) (Bryant, 2009, pp. 13). A typical is the famous Piaget's problem of water level (WLT -Water Level Task) ie, the problem of horizontality of liquid surface in inclined containers.

Piaget and Inhelder devised the water level task (WLT) to study children's understanding of the spatial-coordinate system. Bottle half-filled with water were presented to child and after that, a similar empty bottle researchers tilted at various angles. Child had to indicate the direction of the water level if this bottle will be half-filled with water. Results showed that different errors were typical at the preoperational and concrete-operational developmental stages (Pascual-Leone & Morra, 1991).

Later research shown that many people (bouth, adult and children) do not know that water surfice remains horizontal, regardless of the orientation of its container. They have problem with water level representation, not because they are lacking the relevant knowledge, but rather because they are attempting to solve a different problem, a problem represented in an object - relative, as opposed to an environment-relative coordinate system (McAfee & Proffitt, 1991).
Around the age of eighth, ninth the child's intuitive space is structured by the coordinate axes that are provided by vertical and horizontal structures. Nine year old child still has problems with the logical implication, such as establishment of a connection between two ideas or two premises, as well as transitive inferences, which are the basic logical precondition that underlies measurement.

METHODS

The research problem was investigation of the process of adopting the scientific concept of horizontal position of the liquid surface. The choice of research problem derives from the awareness and experience about the difficulties in the acquisition of complex concepts. Result was adoption of unrelated facts by students, not the concept itself, which would be a necessary precondition for the creation of functional knowledge. Project-based teaching has been recognized as a possible solution to overcome these problems by increment students' motivation and contribute to a fuller and deeper adoption of scientific concepts.

The aim of this research was to detect difficulties in adopting corect concept about surface orientation of liquids and to find possible ways of improvements.

The study sample consisted of 116 third grade students (59 students in the experimental group and 57 students in the control group) from six classes in elementary school "Ivo Lola Ribar" and "Dositej Obradovic" in Sombor (Serbia), and in three of tham are implemented the project "Water is precious", which lasted from March to June 2015.

RESULTS AND FINDINGS

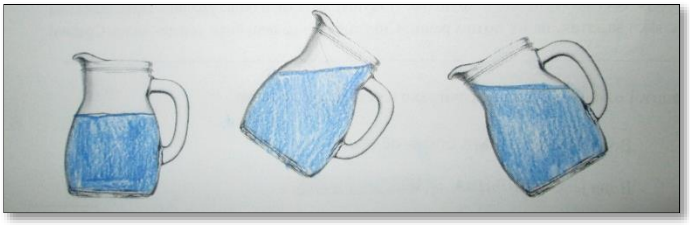
The studentsof the experimental group were asked to do the experiment with a bottle and colored liquid in it. They were supposed to rotate and tilt the bottle and at the same time observe the position of the liquid surface. After the experiment, they should have to conduct a conclusion on whether the position of the liquid surface changes when changing the position of the container, or remains in the same position. During the experiments we observed that many students had difficulties to distinguish change of the shape of liquid surface from change of the position of liquid surface (Figure 1). It was necessary to correct the experiment in a way that a ruler or a piece of paper was leaned in parallel to the surface of the liquid, and then, tilt the bottle to observe whether a piece of paper/ruler remained parallel to the surface. This approach was helpful for some students, but not for all.

Figure1. Observing position of the liquid surface when changing the position of the container

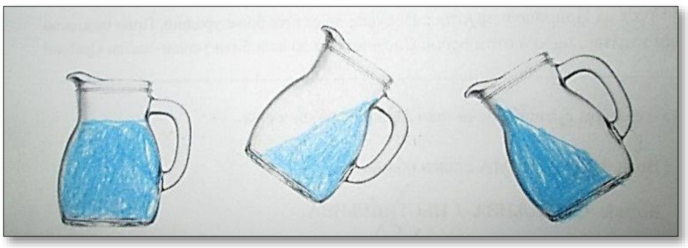
Check a thorough understanding of this seemingly simple and widely known scientific facts about the horizontal position of the water surface by question where they were supposed to draw the position of the liquid surface in an decanter or bottle represented in several different positions, confirme difficulties noticed during the experiments.

A few examples of solutions of the WLT at the initial test is shown on the Figure 2.

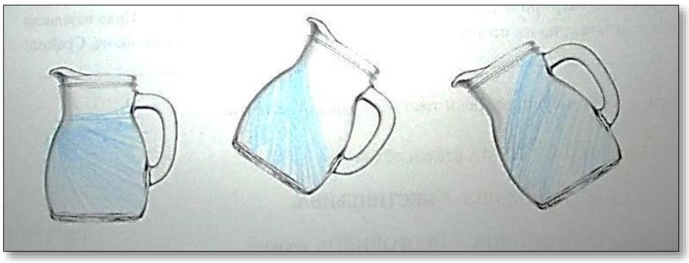
In tasks where they were supposed to draw the position of the liquid surface in an upright decanter or bottle, or, inverted bottle, there were no significant differences between the results achieved in experimental (E) and control (C) group, as well as, at the initial and final test in both group. Percentage of correct answer is between 90% and 100 %, which means that vast majority of students have no problem to draw the position of the liquid surface in these cases, regardless of whether they carried out experiments or not.



a) Appropriate inclination and the horizontality of the liquid surface



b) In the tilted decanters inclination of liquid surfice is on right side, but horizontality still missing.



c) In the tilted decanters inclination of liquid surfice is on wrong side and horizontality missing too.

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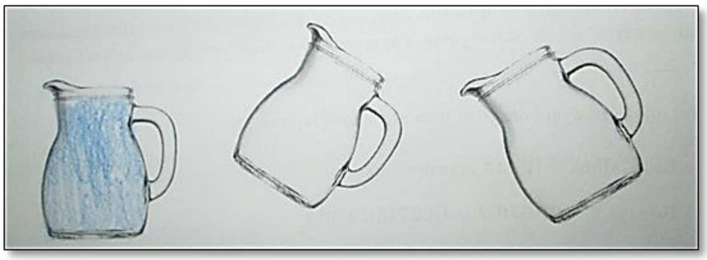
d) In the tilted decanters liquid takes up lengthwise half of the decanter.



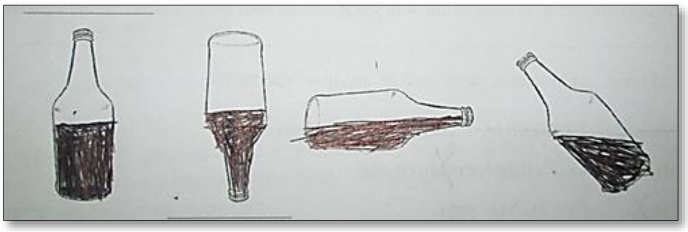
e) Liquid **is** not drawn in the tilted decanters.

Figure2. One example of correctly and four examples of incorrectly drawn fluid level in the tilted decanters at the initial test

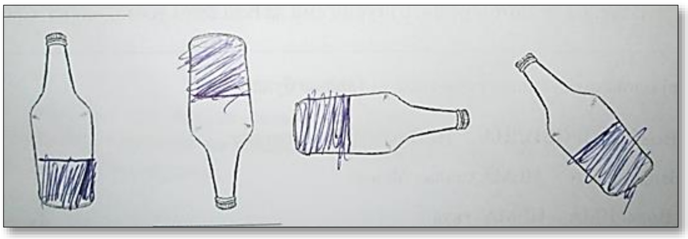
If we analised their drawings about position of the liquid surface in a tilted decanter/ bottle, both, experiemntal and control group showed worse results at the initial test. Percentage of correct answers in experimental gorup is: E_R - 28,33% respectively E_L – 31,67%, and in control group is K_R – 44,1% and K_L – 4 7% (index L and R indicate the part of the task where the decanter tilted to the right, respectively, to the left side).

In the final test, the percentage of correct answers was higher for 10 - 15% in the both groups regardless of the experimental experience of students of E group. But the result is generally very low, because the percentage of correct answers in group E is 44%, and in the K group 58% .

A few examples of solutions of the WLT at the final test is shown on the Figure 3.

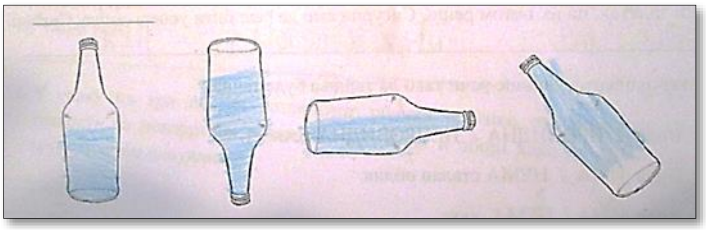


a) Appropriate inclination and the horizontality of the liquid surface

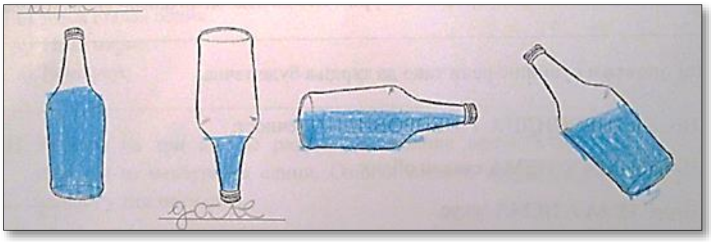


b) In all bottle positions the liquid has the same shape and position.

c) In the tilted bottles liquid takes up lengthwise half of the decanter.



d) At the bottom of the inclined bottle has no liquid.



e) In an inclined bottle surface of the liquid is not horizontal; in the inverted bottle presented volume of liquid is noticeably smaller than in other positions.

Figure 3. One example of correctly and four examples of incorrectly drawn fluid level in the tilted decanters at the final test

Results indicate that in tasks where they were supposed to draw the position of the liquid surface in an upright decanter or bottle, or, inverted bottle, there were no significant differences between the results achieved at the initial and final test, or between experimental and control group. We can conclude that students have no difficulty with surface orientation of liquids, in these two position. However, when they were supposed to draw the position of the liquid surface in a tilted decanter/ bottle students showed much worse results at the initial test. In the final test, the percentage of correct answers was slightly higher, but still very low, if we take into account experimental experience acquired in the meantime.

It seems that students have trouble understanding the concept that water level remains horizontal regardless of how the bottle is tilted through the verbal instruction. Or they maybe do not realize that is necessary to use reference outside the frame of the decanter/bottle. Same research suggest that practical experience promotes a functionally relative perspective, in which the orientation of the liquid's surface is evaluated relative to the container as opposed to being related directly to the surrounding environment (Hecht & Proffitt, 1995).

CONCLUSION

Results show that almost half of the students even after conducting the experiment has not been able to properly draft the position of the liquid surface in the tilted bottle. This result can be explained in two ways. First, that students of this age (9-10 years) are not developmentally ready for the WLT yet because they have not coordinated the horizontal and vertical axes within a single system of reference, ie, that tilted container still confusing tham. The mistakes that children make when drawing horizontal and vertical lines are the result of concentrating on the relations of those lines that are closest (Bryant, 2009, p. 13). Some studies with American children found that children did not perform the WLT correctly before adolescence. (Geiringer & Hyde, 1976; Liben, 1978).

We also drew to the conclusion that is necessary a lot more practical experience in experimentation with focused observation position of surface of the liquid in the tilted containers that problem would be permanently overcome. Confirmation of such a claim we find in many studies about effectiveness of instruction on spatial skills. The results from different studies suggest that the WLT is teachable and that certain age groups are more responsive to teaching than others. Many of them describe a relationship between cognitive development and instruction effect on the WLT (Li, 2000). Some results indicate that children improve more on the WLT with the combination of instruction and practice than with practice alone (Li, Nuttall, & Zhao, 1999).

The results also have shown that single application of project was insufficient to support students' properly and permanently adopted certain scientific terms and concepts. That is why this education program should be applied permanently and as an integral part of the teaching process, not as a supplement to regular teaching activities. On the contrary, continuous application of project teaching would encourage independent research work of pupils, which means that they express their own assumptions, assessments, carry out examinations/experiments, notice and corrects their own mistakes and finally formulate and write down correct conclustions (Pavkov-Hrvojević at all, 2016).

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