EFFECT OF INSTRUCTION ON 1st GRADERS' THINKING PATTERNS REGARDING THE DESCRIPTION OF WATER WITH EVERY DAY AND SCIENTIFIC CONCEPTS[1]

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In this paper we focus on the question how the 1st graders' everyday concepts change on the effect of instruction planned on the basis of the Rostock Model, and especially how the everyday and scientific concepts connect with each other. We used knowledge space theory to explore the connections among the 'everyday' and 'scientific' concepts regarding the 1st graders' description of water, and to answer the following research questions: (1) What are the characteristic models of the pupils' thinking patterns in describing water with everyday and scientific concepts? (2) Is there any change in the pupils' thinking patterns during their instruction? Our research shows that the teaching unit planned on the basis of the Rostock Model has significant effect on the 1st graders' thinking patterns in describing water with everyday and scientific conceptions. The best model for the representation of children's cognitive structure regarding the water contains only everyday concepts before the teaching unit. After the instruction this model changes into models containing both everyday and scientific conception, however these concepts are either totally separated from each other or scientific conception is built on the everyday conception. However in pupils' thinking patterns the 'particle' has two meanings: particle with macroscopic properties or particle in the continuous substance. Because of the lack of the formal thinking in pupils' mind we could not find the 'scientifically preferable' model to be a good model for representation of children's thinking patterns.

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Keywords: 1st graders, thinking patterns, water, modelling, every day concepts, scientific concepts, effect of instruction, interview

Introduction

The key factor in understanding and explaining properties and transformation of matter is the acceptance and use of particulate nature of the substances. Several papers deal with the possible kinds of the children's conceptions regarding the structure of matter.

Using phenomenographic approach Renstroem (1988) describes the following levels: (1) Homogeneous substance: The substance is not delimited from other substances and it lacks substance attributes. (2) Delimited substance units: The substance is delimited from other substances and it exists in more than one form. (3) Substance units with 'small atoms': They may different from the substance in which they are embedded. (4) Aggregates of particles: The substance consists of infinitely divisible particles, which may not consist of the substance. (5) Particle units: The substance consists of particles which are not divisible into other particles and which have certain attributes (such as form and structure) that may explain macro-properties of the substances. (6) The substance consists of systems of particles: Different macro-properties of the substance can be accounted for in terms of properties of the particles and particle systems.

On the basis of a longitudinal study on the progression in children's understanding of particle theory Johnson (1998a, 1998b) suggests four models for identification of children's conceptions. (1) 'Continuous substance' model: Particle ideas have no meaning. Nothing that resembles having particles of any description is drawn. (2) 'Particles in the continuous substance' model: Particles are drawn, but the substance is said to be between the particles. The particles are additional to the substance. In this model particles are often said to be drops, grains and dust, instead of the chemical particles (atoms, molecules and ions). (3) 'Particles with macroscopic character' model: Particles are drawn and are said to be the substance. There is nothing between the particles. Individual particles are seen as being of the same quality as the macroscopic sample, literally small bits of it. (4) 'Collective properties of the particles' model: Particles are drawn and are said to be the substance. The properties of a state are seen as collective properties of the particles. Similar models were used during the analysis of the high school students' responses regarding the composition of moist air (Tóth, 2004).

Some research shows that children tend to use their everyday concepts in describing and explaining the properties and transformation of the substances (see for example Barker, 2003 and references therein). However older students often use the molecular (scientific) model, but in different ways to scientists do - as Taber (2002) points out in his book on the chemical misconceptions. Experts (scientists) use properties of particles (molecules, ions) to explain macroscopic phenomena. Contrary this, according to the students, macroscopic phenomena due to the properties of substances which is transferred to the molecular level, and the molecules ascribed macroscopic properties used to explain the properties of substances.

According to the theory of conceptual change (Carey, 1985; Posner & Strike & Hewson & Gertzog, 1982) natural scientific learning has to change the children's everyday ideas into scientific knowledge. The Rostock Model developed by Schneider et al. (2006) is a didactic concept for the scientific learning in primary schools. 'The concept is based on the preposition that learning is a long-term process, based on instruction, independent activity, and cooperation, that considers the pupil as a learning subject and that, above all, prioritises the acquisition of interrelated and generative conceptual knowledge. The model is organised not on the basis of individual lessons but rather on the basis of more comprehensive and complex (thus interdisciplinary) teaching units.' (Schneider et al. 2006, p. 1.) Now the concept is being tested in schools on the 'properties, structure and cleaning of water' as interdisciplinary teaching unit from grades one through four in Germany, Hungary and Lithuania.

The preliminary results (Tóth et al., 2007b) show that 1st graders - independently from their nationality and school - have ideas about the properties of water (melting, evaporation, dissolving solid substances) similar to those described in the literature (Piaget and Inhelder, 1974; Slone and Bokhurst, 1992; Nakhleh and Samarapungavan, 1999; Russel et al., 1989; Stavy, 1990a, 1990b; Tytler, 2000 etc.). We (Tóth et al., 2007b) observed differences between children's groups from different schools both in the overall performance and even more in the cognitive organisation of their knowledge. Using knowledge space theory (see later in details) applied to interview data we could clearly show that children's framework for explanation of phenomena with water properties is due to their everyday experiences, pre-school instructions and to the macroscopic view of matter (Tóth et al., 2007b). In this paper we focus on the question how the 1st graders' everyday concepts change on the effect of instruction planned on the basis of the Rostock Model, and especially how the everyday and scientific concepts connect with each other.

The aim of the study

We used knowledge space theory to explore the connections among the 'everyday' and 'scientific' concepts regarding the 1st graders' description of water, and to answer the following research questions:

1. What are the characteristic models of the pupils' thinking patterns in describing water with everyday and scientific concepts?
2. Is there any change in the pupils' thinking patterns during their instruction?

Research methodology

Collecting data. We used structural interview before (pre-test) and after the teaching unit (post-test 1) at the end of the academic year of 2004/2005 (pre-test: May 2005, post-test 1: June 2005). An additional interview (post-test 2) was conducted at beginning of the next academic year (post-test 2: September 2005), too. During the interviews interviewers carried out experiments regarding the properties of water (evaporation, melting, making solutions, purifying water), and asked the children one by one at a time, and recorded responses in written form or by tape-recorder.

According to the Rostock Model (Schneider et al. 2006) the teaching unit 'Water' focused on the characteristics, occurrence and structure of the water, and was organised around three dimensions. (1) Knowledge and understanding: The children can name the aggregate states of water, and learn how to purify water. The children can explain the terms of surface water and ground water, mineral water, drinking water and salty water, water in use and wastewater. The children know that a drop of water is made up of many small water particles. (2) Abilities: The children develop their ability to express their thoughts in a group discussion, and to do simple experiments. (3) Attitudes: The children develop the need to work together with other children, to inquire about the causes and conditions of events and processes, to try something out, and to be careful about how they use water. (Model for planning a teaching unit can be found in paper by Schneider et al. 2006.)

Four classes with 84 1st graders (aged 7-8) participated in the survey: two classes from Rostock, Germany (N = 41), one class from Budapest, Hungary and one class from Debrecen, Hungary (N = 43 for the Hungarian sample).

Data analysis. Responses were evaluated not as 'right' or 'wrong' but with identifying category 'everyday' and 'scientific' description of water. Response was identified as 'everyday' (E) when the pupil used only everyday concepts (e.g. existence, utilisation, importance, occurrence of water, etc.) during the interview. These 'everyday' concepts mainly regard the description of water at macroscopic level. Category 'everyday' and 'scientific' (E+S) means that pupil described water using not only everyday but scientific concepts (e.g. substance, particle, movement, distance, etc.), too. If the pupil described water only with sub-microscopic (particulate) concepts his or her response was identified as 'scientific' (S) category.

After identifying categories, knowledge space theory (KST) was used to explore the connections among the categories. Knowledge space theory was developed by Doignon and Falmagne (1999), and its application to science concepts have been previously demonstrated by Taagepera et al. (1997, 2000, 2002), Arasasingham et al. (2004, 2005), and Tóth et al. (2006, 2007a, 2007b, 2007c). In this theory, the organisation of knowledge in students' cognitive structure is described by a well-graded knowledge structure. Although KST was originally developed for modelling the hierarchical organisation of knowledge needed to answer a set of problems in science and mathematics, the formalism of this theory can be extended to any hierarchically organised input data (see for example: Tóth and Ludányi, 2007a).

For the KST analysis, responses were scored in a binary fashion, according to whether they contained the given category (1) or not (0). Theoretically we can have 2^n possible response states (where n: the number of the categories, in our case: n = 2), from the null state where none of the identified categories were used to the final state where all the categories were appeared in the pupils' description. A set of response states gives the response structure (see Figure 1).

Figure 1. A typical response structure (post-test 2). (E: everyday; S: scientific; N: number of pupils)

(E)	(S)	(N)
0	0	6
1	0	31
0	1	20
1	1	23

We suppose five theoretically possible models for representation of pupils' knowledge structure regarding the 'everyday' (E) and 'scientific' (S) description of water (Figure 2). Starting from these models we could derive the corresponding knowledge structure (Figure 2), and we determined the level of the significance (p) characterising the goodness of how the assumed model fits to the original response structure. For the calculations, a Visual Basic computer program (Potter) was used, and the probability for lucky-guess and careless-error was estimated as 10%. Details of the KST analysis were published earlier (Tóth et al. 2006, 2007a, 2007b, 2007c).

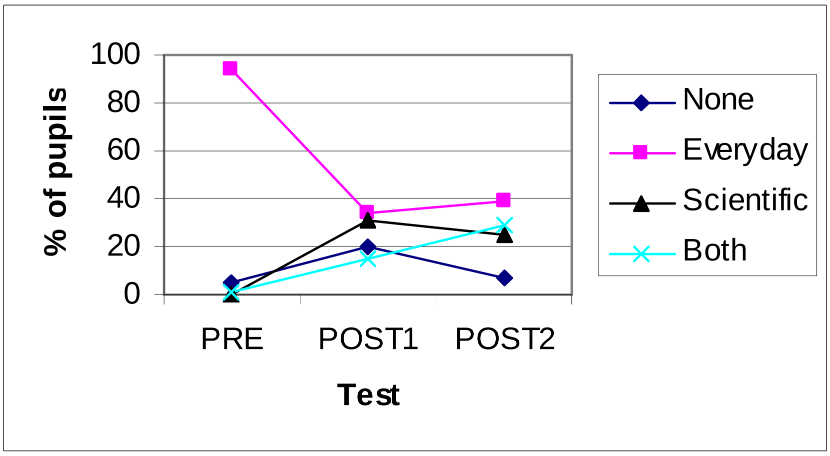
Figure 2. The supposed models (I-V) for representation of the pupils' knowledge structure. (E: everyday; S: scientific)

Model	**Representation**		**Knowledge structure**
I	**(E)**	⇒	**0 0** **1 0**
II	**(S)**	⇒	**0 0** **0 1**
III	**(S)** ↑ **(E)**	⇒	**0 0** **1 0** **1 1**
IV	**(E)** ↑ **(S)**	⇒	**0 0** **0 1** **1 1**
V	**(E)** **(S)**	⇒	**0 0** **1 0** **0 1** **1 1**

Results and discussion

Figure 3 shows the distribution of different types of pupils' responses. It is seen that percentage of pupils giving description with everyday concepts decreases, while the relative number of children using scientific, or everyday and scientific concepts increases markedly on the effect of instruction. It also seems that teaching has little effect on the no answers but mainly allows a shift of everyday concepts towards the scientific ones.

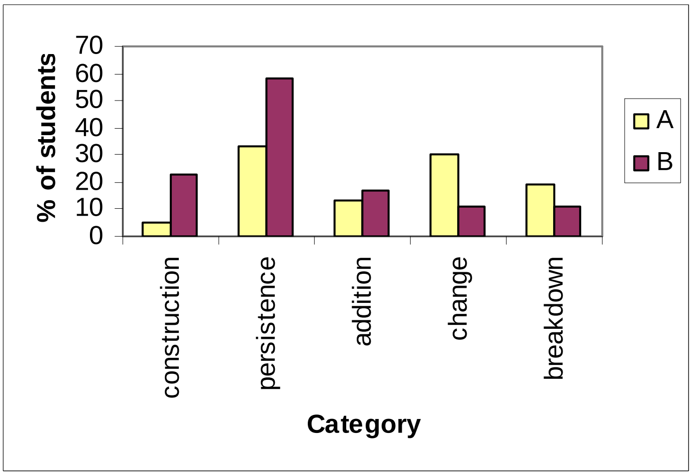
Figure 3. Distribution of different categories obtained from the pupils' responses in the pre-test, post-test 1 and post-test 2.



During our analysis of the pupil's results, we noticed that after completing the teaching unit, very few children had undergone a complete change in their explanatory concepts, although many children had somewhat changed their understanding of the subject matter. Conceptual changes occur in a variety forms, as was suggested by Schneider et al (2006): (1) Conceptual construction: there are no initial conceptions which can be used as links for new information. (2) Conceptual persistence: no changes in the initial conceptions take place. (3) Conceptual addition: pre-existing conceptions are enhanced by new conceptions. Both concepts can exist together in a parallel manner. (4) Conceptual change: pre-existing conceptions are fully replaced by other conceptions. (5) Conceptual breakdown: pre-existing conceptions are rejected but no new conceptions are built up.

Figure 4 shows the distribution of the students among these categories on the effect of instruction (A) and the summer holiday (B). This figure shows that there were no changes in the initial conceptions (conceptual persistence) in case of about one third of the children. It is also seen that mainly conceptual change took place on the effect of instruction. The summer holiday had no dramatic influence on the pupils' conceptions, more than half of the children retained their conceptions (conceptual persistence) constructed after the instruction. Simultaneously two opposite effects on the pupil's conceptual development can be observed: about one fifth of the children having no initial conceptions created new conceptions (conceptual construction) while about one tenth of pupils rejected their pre-existing conceptions without building up new conceptions (conceptual breakdown).

Figure 4. Effect of instruction (A) and the summer holiday (B) on the pupil's conceptual development.

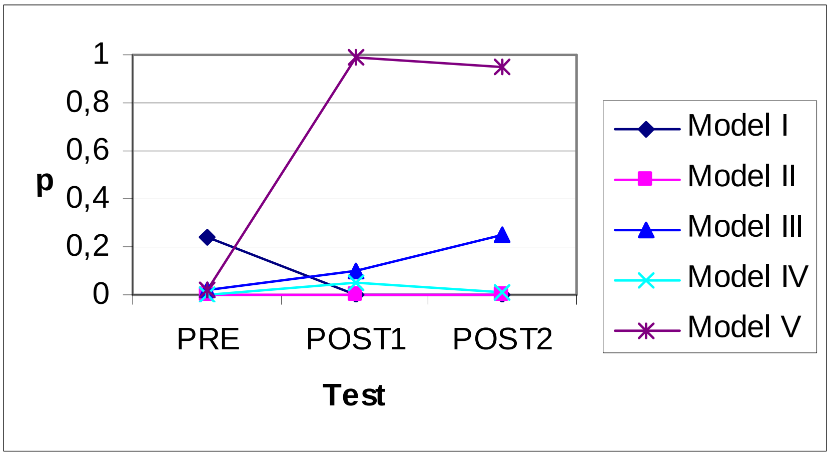


Modelling pupils' thinking patterns

Based on the data obtained from the categorisation of pupil's responses we assumed and inspected five models for the connection of the different conceptions in the children thinking patterns (Figure 2). *Model I* means that children use only everyday concepts in their description of water, while the *Model II* means the descriptions with scientific concepts. According to the *Model III* children typically use both conceptions in their responses and the scientific concepts are built on the everyday concepts. *Model IV* is the 'scientifically preferable' model in which pupils understand the relationship between their scientific and everyday conceptions. This usually means that pupils use the particulate representation of the water to explain the macroscopic properties. In *Model V* both everyday and scientific conceptions exist in the pupil's thinking patterns but these conceptions are totally separated from each other.

Figure 2 also shows the corresponding knowledge structure derived from the *Models I-V*. Ideally, in case of *Model I* we can get two types of responses: (1) no response, or response does not refer to any of the identified categories [0 0]; (2) responses relate to the everyday conceptions [1 0]. Similarly, according to the *Model II* pupil's responses can be assigned to (1) no response [0 0]; or (2) response regards the scientific conceptions [0 1]. From the *Model III* we can derive three groups of the responses: (1) no response [0 0]; (2) responses relate to the everyday conceptions [1 0]; and (3) responses containing both everyday and scientific concepts [1 1]. Similarly, *Model IV* (the 'scientifically preferable' model) gives also three types of the responses: (1) no response [0 0]; responses regarding the scientific conceptions [0 1]; and (3) responses with both everyday and scientific concepts [1 1]. Finally, in the case of *Model V* children's responses can be categorised into four groups: (1) no response [0 0]; (2) responses with everyday conceptions [1 0]; (3) responses with scientific conceptions [0 1]; and (4) responses covering both types of the conceptions [1 1].

Figure 5. Effect of instruction and summer holiday on the level of significance (p) in the case of different assumed models (I-V)



During the KST analysis from the databases similar to one shown in Figure 1 we could calculate the level of the significance (p), a statistical parameter characterising how well the assumed knowledge structure fits the original response structure. As it is seen in Figure 5 there is a dramatic change in the children's thinking patterns on the effect of instruction. Before the instruction (pre-test) *Model I* is the best-fitted representation for the children's responses. It means that mainly everyday conceptions are the characteristic of the children's thinking patterns about the water. After the instruction the significance of the *Model I* decreases while that of the *Models III* and *Model V* increases. This indicates that pupils tend to use scientific concepts either building on the everyday conceptions (*Model III*) or independently from the everyday concepts (*Model V*). *Model V* keeps its high level of the significance even after the summer break. It means that children accept the scientific interpretation of the water, but they do not able to find the right connection between the everyday and scientific conceptions. However, it is noted that children use scientific conceptions in different ways to scientists do. In their descriptions of water at particulate level children mainly use the 'particle in the continuous substance' and the 'particles with macroscopic properties' models.

Conclusions

Our research shows that the teaching unit planned on the basis of the Rostock Model has significant effect on the 1st graders' thinking patterns in describing water with everyday and scientific conceptions. The best model for the representation of children's cognitive structure regarding the water contains only everyday concepts before the teaching unit. After the instruction this model changes into models containing both everyday and scientific conception, however these concepts are either totally separated from each other or scientific conception is built on the everyday conception. However in pupils' thinking patterns the 'particle' has two meanings: particle with macroscopic properties or particle in the continuous substance. Because of the lack of the formal thinking in pupils' mind we could not find the 'scientifically preferable' model to be a good model for representation of children's thinking patterns.

As part of a longitudinal research the Rostock Model is now tested in grades two and three focusing on the teacher unit 'Water'.

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