EDUCATION ABOUT DIET THROUGH CHEMISTRY LEARNING

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Abstract

In the last century chemistry played an important role in improving the quality of living. However, uncontrolled application of many chemistry achievements has resulted in a range of problems (environment pollution, foods production…) requiring solution in the current century. Solving the problems, apart from chemists, should involve every individual who will take care of what he is taking or giving back to the living environment, who will take care of his health that well-balanced diet is one of the prerequisites for. Starting from the aforementioned, it was assumed that introduction of foodstuffs as teaching content and/or teaching aids in the teaching of chemistry, at different levels of education would provide for observation/problem solving of well-balanced diet and developing of chemistry literacy, vice versa. Therefore, the present paper examines possibilities of presenting various foodstuffs and additives at the beginning of teaching themes (transition to scientific concepts is best realized through spontaneous concepts), at the end of teaching themes (systematizing numerous scientific concepts) and within knowledge testing. Investigations were carried out with primary school students (103) by applying diverse teaching methods and forms of work. Such approach to learning (from spontaneous concepts through chemistry concepts to well-balanced diets, or from foodstuffs over spontaneous concepts to scientific ones) brought about the climate, where a student gets the impression that he only expands the knowledge he already possesses, the possibility of developing chemistry (scientific) literacy and accomplishment of education about importance of well-balanced diet.
Key words: *diet, foodstuffs-teaching aid, chemistry education, primary school.*

Introduction

In modern society one of the key areas of scientific interest is diet and health. In undeveloped countries the problem of food is a direct cause of high mortality rates of the population. In developed countries many diseases result from unsatisfactory care of the environment in addition to poorly-balanced diet, primarily in the period of child's growth. The available data show that in the world 20 000 of obese children suffer diabetes Type 2 (most frequently diagnosed in people over 40) whereas around 400 000 suffer glucose intolerance (hidden diabetes). About one million of the obese children are at risk of cardiovascular disease, including high blood pressure, elevated blood lipids and have two or more factors for metabolitic syndrome (MS). Among American youth around 30% of children have MS, while 9 of 10 children have at least one component of this syndrome (Goran ea al, 2004). In Serbia 35% of obese children was diagnosed with MS (Dimitrijevic-Sreckovic et al, 2007). High percentage of metabolic syndrome in children indicates that establishing a healthy diet in youth is a priority. Therefore, from the earliest childhood and throughout primary and secondary education proper eating habits should be developed and nurtured.

Food is directly linked to chemistry because it is a combination of foodstuffs consisting of nutrients both organic and inorganic in nature. Fig. 1 shows links between food and chemistry, foodstuffs – spontaneous concepts from everyday life and scientific chemistry concepts, that are studied on three levels in the chemical education - micro, submicro and symbolic (Johnstone, 1982; Gabel, 1999) (steps 1 and 2), scientific concepts and healthy diet (which implies choice, combination and amount of foodstuffs, steps 3, 4 and 5).

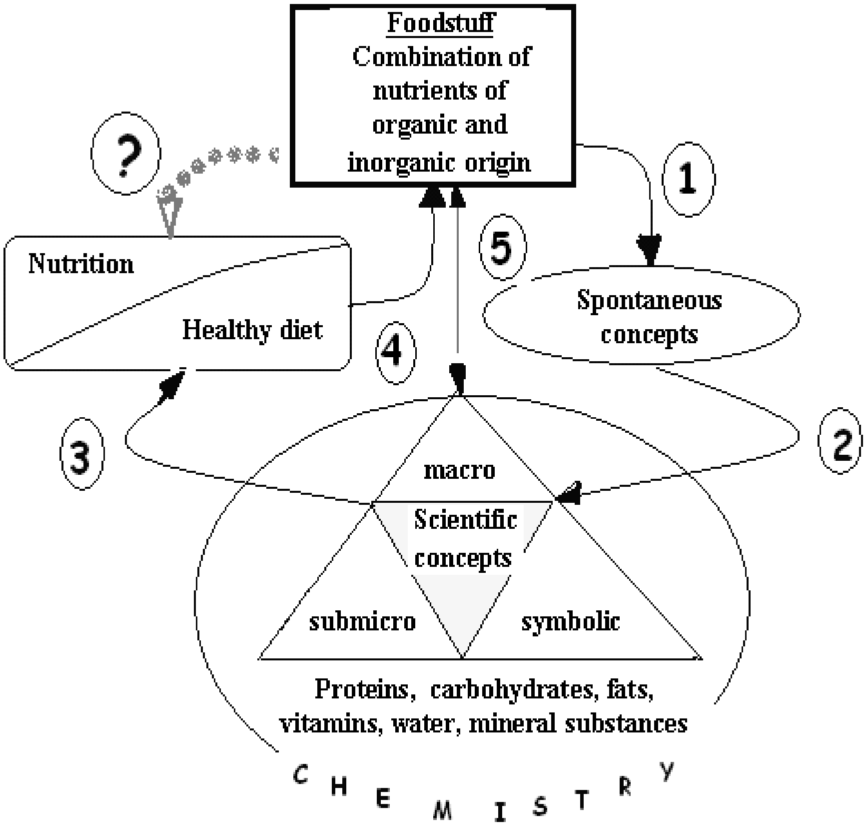

Figure 1. **Links between food and chemistry, foodstuffs, spontaneous concepts from everyday life and scientific chemistry concepts and healthy diet.**

Learning of chemical composition, chemical and physical properties of proteins, fats (lipids), carbohydrates, vitamins, water and minerals in chemistry education is important because it provides insight into:

- their role in living organisms,
- relation between structure and function of those molecules i.e. how their interactions enable life to be created, maintained and sustained, and
- their role in consumption of energy necessary for synthesis of their own biomolecules, mechanical work and membrane transport.

One can conclude that nutrients intake is important as a source of molecular fuel (energy) and monomer units for the synthesis of their own complex structures, molecules important for work of bio-catalysts, mineral substances with various functions. That leads to an assumption that introduction of foodstuffs as a teaching content and/or teaching aid in chemistry education at various levels of teaching would contribute to perception, understanding and solving of diet problem and, *vice versa,* to better development of chemical literacy. Therefore, the present paper examines possibilities of teaching of foodstuffs and additives in different stages of the teaching process - at the beginning, during and at the end of a teaching topic as well as in knowledge testing. At **the beginning of a *teaching topic*** the transition to scientific concepts is best realized through spontaneous concepts (Steiner, 1989; Sae, 1990; Havard, Barnes and Hollingsworth, 1989; Carlson, 1988; Louters and Huisman, 1999; Pharr and Stoner, 1991; Korolija, Jovic, Steljic and Mandic, 2005; Oliver-Hoyo, Allen, Solomon, Brook, Ciraolo, Daly and Jackson, 2001; Herman, 1998). Complex chemical composition of foodstuffs makes possible to systemize numerous scientific concepts at **the end of a *teaching topic* (**Montes and Rockley, 2002**).** Within **knowledge testing** complex systems allow presenting theoretical and practical problems (Domin, 1999; Lyle and Robinson, 2001; Middecamp and Kean, 1988).

Research presented herein was carried out with (106) primary school students ages 14-15. A variety of logical-receptive and logical-practical teaching methods (conversations about foodstuffs nutrients, quality, preparation and storage of food, demonstration experiments and laboratory experiments) and work forms were applied.

From foodstuffs and spontaneous concepts to scientific chemistry concepts

Teaching of foodstuffs at the beginning of teaching topic

At the beginning of the study of an extensive teaching topic it is very important to enable the student to obtain background information (provide perspective) about the concepts (Friedmann, 1990), the content and extent of which they will be covered. It is best to carry out the introduction into the teaching topics through pieces of information that students are familiar with from everyday life (spontaneous concepts). The application of spontaneous concepts at introductory classes provides for students' maximum activity, independent work, asking questions and finding answers, as required by contemporary teaching (Treagust et al. 2003; Shiland, 1999).

In our country the topic *Biologically important compounds* is found in primary and secondary school chemistry curricula. Foodstuffs can be a very suitable content and teaching aid for introductory classes into this teaching topic dealing with carbohydrates, proteins, lipids and vitamins (steps 1 and 2, Fig. 1), but also for other topics in organic and inorganic chemistry. In the selection of foodstuffs the major criteria are:

- availability,
- all substances studied in the topic should be included,
- testing of physical and chemical properties of substances should be performed through simple experiments suitable for students' independent work (Schmidt, 1997),
- observed properties of some foodstuff ingredients should become a basis for learning about classes of chemical compounds i.e. become background information for introduction to scientific concepts.

In the current paper introductions into the teaching topic were done by using various foodstuffs (milk, eggs, beer) and additives, however, only milk was chosen as an example.

Milk is a foodstuff whose properties (spontaneous concepts) children become familiar with in early childhood. *Where do milk's properties come from? Why should we drink milk?* These questions are commonly asked by children. To answer them, transition to scientific concepts is required. This transition is possible to perform *via* guided inquiry i.e. by asking additional questions, hypothesizing, and obtaining answers through independent experiments or through discussion (Table 1).

Classroom application: Students (ages 14-15) included have learned, in the previous and ongoing school year, topics from general, inorganic and organic chemistry and mastered techniques of individual work on simple chemical experiments. That enabled them to draw conclusions about milk to a great extent independently. An approach "practical knowledge in action", i.e. "problem-based approach" was chosen therefore, to apply previously acquired knowledge in determining origins of milk properties, familiar from everyday life. This approach was chosen because Serbian high school students (15-year-olds) placed 41st among 57 countries in the latest international test PISA 2006 (The Program for International Student Assessment) organized by OECD (Organization for Economic Cooperation and Development) and administered in 2007 (OECD, PISA, 2007). It was shown that students had *"factual knowledge"* but did not apply it adequately in real life situations.

In the beginning of the work, which lasted 90 minutes, students described milk properties and asked questions (Table 1, columns 1 and 2) about things they wanted to know. They found solutions by working in groups of three. Every group considered one property. Using previously acquired knowledge they asked additional questions (column 3, Table 1), suggested hypotheses and experiments and carried the experiments out (column 4 (P), Table1).

On the basis of observations during laboratory work, the students were very successful in proving of hypotheses and drawing conclusions (83.1% of correct responses recorded on work sheets). Previous knowledge of chemistry and experiments performed did not allow complete understanding of milk properties what led to Demonstration experiments (casein precipitation, lactose identification, testing of electrical conductivity in whey). By discussing the results of demonstration experiments and laboratory practices, students acquired the new knowledge about this important foodstuff, initial knowledge about compounds that are nutrients found in milk i.e. about scientific concepts, proteins, carbohydrates and fats. The results of experiments also made it possible to propose hypotheses and find solutions for causes of phenomena and changes observed in milk processing (Why does milk froth when it is cooked? Why does milk get burned when it is cooked?)

Through discussion about milk color, spoilage and preserving and information given on the milk packaging the students realized the necessity of knowing about nutrients' physical and chemical properties i.e. the necessity to know scientific chemistry concepts and the comprehensive role of chemistry as a science.

From scientific chemistry concepts through foodstuffs to healthy diet

Learning about foodstuffs at the end of teaching topics

The major goal of contemporary teaching is that students attain knowledge applicable in real life, which enables various problem-solving solutions (Domin, 1999 a, b). This was the reason why the degree of learned scientific concepts related to the topic *Biologically important compounds* was tested through the questions concerning foodstuffs consumed in everyday life. The result achieved (38.6 ± 11.2%) demonstrated that knowledge attained about proteins, carbohydrates and lipids was not functional. Therefore, scientific concepts in the mentioned topic were systemized using an egg, a complex system (egg cell) that contains all components necessary for development of a living being. These facts made possible for students to propose the hypotheses about classes of compounds that egg contains.

Table 1. Milk (foodstuff) – teaching content and aid at introductory classes into teaching topic *Biologically important compounds*. A pathway from spontaneous to scientific concepts.

What is the starting point? Foodstuff properties – spontaneous concepts	Questions related to spontaneous concepts	Guide to discovery – questions initiating proposals of hypotheses and experiments to test them	Laboratory practice (P) Demonstration experiments (E) Discussion (D)
Liquid	Why is milk a liquid?	Is milk polar or non-polar liquid? Does milk contain water?	Testing of milk polarity. **(P)** Proving the presence of water in milk. **(P)**

What is the starting point? Foodstuff properties – spontaneous concepts	Questions related to spontaneous concepts	Guide to discovery – questions initiating proposals of hypotheses and experiments to test them	Laboratory practice (P) Demonstration experiments (E) Discussion (D)
White color	Why is milk white in color?	Is milk a mixture or a compound? Is milk homogeneous or heterogeneous mixture? Are all milk components in liquid phase at room temperature?	Testing milk water solution by using light. **(P)** Determination of milk freezing temperature. **(P)** Precipitatation of casein. **(E)** Testing of electrical conductivity of whey. **(E)** Detecting lactose in whey**. (E)**
Taste	What gives milk a pleasant taste?	How does fresh milk taste – sweet, salty, sour, bitter…? What determines the taste of milk?	Testing of acid-base properties. **(P)** Detecting milk components. (**E)**
Milk fat	What floats on milk surface?	Why does milk have fat "feel"? Why does it leave fat stain on the paper? How does fat percentage of milk affect its density?	Finding out milk density: – by measuring volume and mass **(P)**, - with aerometer.**(P)**
It froths when cooked	Why does milk froth when it is cooked?	What is the composition of froth?	Detecting protein presence in froth **(E)**
Gets burned when cooked	Why does milk get burned when it is cooked?	What color is the residue on the bottom of a milk container?	D
Gets spoiled if left standing	Why does milk get spoiled when left standing at room temperature?	Can some other sciences be of help in giving answers?	D

Classroom application: During teaching topic study students had acquired knowledge about biologically important classes of compounds. In addition, they had an opportunity, during demonstration experiments, to observe chemical transformations specific for certain groups of compounds and to learn about corresponding reagents. By applying their knowledge they were supposed to set hypotheses about the presence of certain groups of organic and inorganic compounds in different parts of an egg. Later, they chose experiments and carried them out independently to prove the hypotheses. Egg components tested and determined through laboratory practice, which were considered as nutrients are presented in Fig. 2.

Each experiment within the laboratory practice was performed in at least two groups of students, providing conditions for symmetric cognitive conflicts. Some experiments performed by students were limited by equipment and chemicals available. The students presented the results of experiments, explained them and drawn the conclusions on classes of compounds contained in a foodstuff. The success rate in determining egg composition was 37.5-95%. The difference in positive results between determination of water in egg whites (95%) and yolks (55%) was due to different presence of water in those egg parts, mixture of ingredients and how they affect observation of changes in anhydrous copper sulfate. The surprisingly low score (37.8%) was obtained for determination of carbonates, an inorganic component of the egg shell. The probable reason was the fact that the exercise was performed at the end of the topic "Biologically important compounds". That caused students to omit inorganic compounds when considering egg components and choosing experiments for their determination.

Scores obtained for all experiments (average achievement of 53.1%) were not high. However, it should be noted that the students included in this experiment had only two years of chemistry, did not have enough expertise in experimental techniques used and examined components in a very complex system, making scores obtained reasonable. Also, the results were the basis for further discussion (*pro et contra*) on determining presence of certain components i certain egg parts.

Testing egg's components, based on scientific concepts, enabled the discussion about its nutritional and energy value, proteins that contain essential amino acids, vitamins found in egg whites and yolks, their digestibility i.e. on the importance of egg in healthy diet (steps 3, 4 and 5, Fig. 1). Knowledge about composition of various foodstuffs allows for combining them and the outcome is a well-balanced diet.

Healthy diet implies the choice of quality foodstuffs and their consumption in certain amounts. The problem situation resulting from the experiment of weighing total egg's mass and its parts indicated existence of gases that gather in an air cell over time and are released when egg is cracked. Linking this experiment to the one for determining egg's age in a physiological solution provided the solution of the problem situation, and, in addition, the way to properly choose a quality foodstuff. The discussion that followed involved the eggshell porosity, possibility of egg contamination by *Salmonella Enteritidis* and application of heat treatment to prevent egg poisoning by bacteria.

When systematization of a content of the teaching topic *Biologically important compounds* is based on foodstuffs, the attained knowledge about classes of compounds becomes applicable in everyday life. This was confirmed by students' test scores (73.2% ± 12.8%) after systematization of teaching content, as carried out in the described manner. The difference in test scores before (38.6 ± 11.2%) and after content systematization was statistically significant ($p<0.001$).

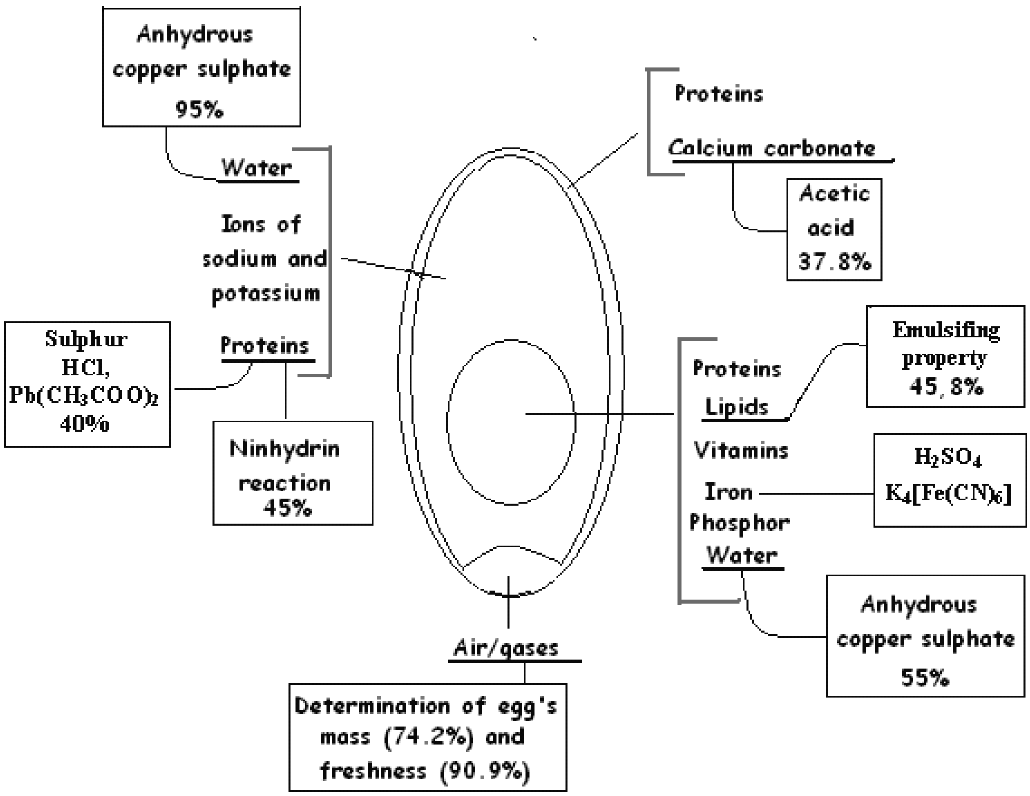

Figure 2. Egg (foodstuff) – teaching aid used to systematize scientific concepts of the teaching topic Biologically important compounds. Presentation of components, experiments applied to determine them (demonstration experiments and experiments performed by students themselves) and student success rate (percentage of correct answers) in explaining the results obtained.

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Questionnaire

The questionnaire was given after the application the presented ways of teaching about diet through chemistry education. The importance of the quality of applied model was confirmed by the questions (Q) and answers (A). Here are the selected ones.

Q: Was this way of learning chemical concepts interesting for you?

A: Very much (62%), Much (28%), Little (8%), Without answers (2%)

Q: Which characteristics of applied approach were the most imortant?

A: Work with real foodstuff. New knowledge about foodstuffs. Chemical explanation of foodstuffs. Chemistry in everyday life.

Q: How much the questions about milk helped you to give explanations about the causes of the observed properties.

A: Very much (10%), Much (68%), Little (8%), Not at all (2%), Wwithout answers (12%).

Q: Give the names of foodstuffs you would like to research in the classroom.

A: pastry, beer, cakes, chocolate, chewing gum, jam, meat....

Such approach of learning (from spontaneous concepts through chemistry concepts to well-balanced diets, or from foodstuffs over spontaneous concepts to scientific ones) brought about the climate, where students get the impression that they only expand the knowledge they already possess (increased intrinsic motivation for learning).

Foodstuffs used to check knowledge

Foodstuffs, being complex systems, also enable setting theoretical and practical problems when knowledge is checked. This section of the present paper outlines the method for checking functionality of knowledge attained in the teaching topic *Biologically important compounds* by using an egg (foodstuff). Knowledge was checked in two ways: by testing and by solving practical laboratory problems.

Checking knowledge by the test. Examples of questions asked:

Questions related to statements: What is an average mass of a chicken egg? Why do chickens peck sand and pebbles? What biologically important compounds can be found in an egg? What can be a substitute for an egg in a diet? How many eggs can an adult person consume weekly compared to young people? What happens with egg's components during heating?

Multiple-choice questions are related to: ions and atoms that build compounds – egg composition, testing egg's freshness, egg preservation.

Alternative choice questions (true-false type): Egg contains water. Egg white is a pure substance. There are both acid and base compounds in the egg. Yolk contains water. Eggshell is porous. A hard part of the eggshell can become soft. There are vitamins only in the yolk. Yolk is easier to digest than egg white.

Checking knowledge by practical problems solving was realized by giving tasks for testing foodstuff's properties (egg) and determining foodstuff's components, without giving any instructions for the experiment design. The only help offered was choice of reagents. Using the learned theoretical knowledge about reactions and reagents, respectively, characteristic for identifying some classes of compounds, the students can make an assumption of what type of compound is found in a foodstuff, and prove the assumption by conducting the appropriate experiment. Students obtain useful information about foodstuffs' composition and properties by summing up the results of practical work.

Instead of a conclusion

Foodstuffs, due to their complex chemical composition and being an unavoidable ingredient of everyday life, play important role in all segments of chemistry education. Work with foodstuffs allows for "passive" theoretical knowledge learned in the existing educational system to become applicable in food choice and consumption throughout the entire life. Thus, the link **foodstuff ↔ diet** is translated with time into the link **foodstuff ↔ healthy diet.** At the same time, chemistry literacy is increased as well as interest in learning natural sciences.

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References

Carlson, B.L. (1988). A Chemistry Experience for Gifted and Talented Elementary Students. *Journal of Chemical Education*, 1, 58-60.

Dimitrijevic Sreckovic V., Colak E., Djordjevic P., Gostiljac D., Sreckovic B., Popovic S., Canovic F., Ilic M., Obrenovic R., Vukcevic V., Nikolic D., Nisic T., Milic G., Pejcic G. (2007). Prothrombogrnic factors and reduced antioxidative defense in children and adolescents with pre-metabolic and metabolic syndrome. *Clinical Chemistry and Laboratory Medicine*, 45 (9), 1140-44.

Domin, D.S. (1999a). A Content Analysis of General Chemistry Laboratory Manuals for Evidence of Higher-Order Cognitive Tasks. *Journal of Chemical Education*, 1, 109-112.

Domin, D.S. (1999b). A Review of Laboratory Instruction Styles. *Journal of Chemical Education*, 4, 543-547.

Friedmann, H.G. (1990). Fifty-Six Laws of Good Teaching. *Journal of Chemical Education*, 5, 413-414.

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future. *Journal of Chemical Education*, 4, 548- 553.

Goran M.I., Bergman R.N., Alila Q. et al. (2004). Impaired glucose tolerance and reduced beta-cell function in overweight latino children with positive family hystory fot type 2 diabetes. *J Clin Endocrinol Metab*, 89 (1), 207-12.

Havard, R. E., Barnes, S., Hollingsworth, P. (1989). Chemistry Laboratory Program for Gifted Elementary School Children. *Journal of Chemical Education*, 6, 512- 514.

Johnstone, A.H. (1982). Macro- and micro-chemistry. *School Science Review*, 64, 377-379.

Korolija, J., Jovic, G., Steljic, B., Mandic, Lj. (2005). Presentation and consolidation of physical and chemical changes of substances through pupils' active work. *Journal of Science Education*, 2 76-79.

Louters, L.L. and Huisman, R. D. (1999). Promoting Chemistry at the Elementary Level. *Journal of Chemical Education*, 2, 196-198.

Lyle, K.S. and Robinson, W.R. (2001). Teaching Science Problem Solving: An Overview of Experimental Work. *Journal of Chemical Education*, 9 1162-1163.

Middecamp, C. and Kean, E. (1988). Problems and ''That Other Stuff'': Types of Chemical Content. *Journal of Chemical Education*, 1, 53-56.

Montes, L.D. and Rockley, M. (2002). Teacher Perceptions in the Selection of Experiments. *Journal of Chemical Education*, 2, 244-247.

Oliver-Hoyo, M., Allen, D., Solomon, S., Brook, B., Ciraolo, J., Daly, S. and Jackson, L. (2001). Qualitative Analysis of Fourteen White Solids and Two Mixtures Using Hausehold Chemicals. *Journal of Chemical Education*, 11, 1475-1478.

Pharr, C.M. and Stoner, M.R. (1991). Chemists Visit Kids. *Journal of Chemical Education*, 10 855-856.

Organization for Economic Co-operation and Development (OECD-PISA) (last revised 2007). *Executive Summary PISA 2006: Science Competencies for Tomorrow's World*/ Pisa project, http://www.pisa.oecd.org/

Sae, A.S.W. (1990). People's Chemistry Solving Poeple's Problems. *Journal of Chemical Education*, 10, 895-896.

Schmidt, M.H. (1997). Using ''Household Chemistry Projecs'' To Develop Research Skills and To Teach Scientific Writing. *Journal of Chemical Education*, 74, 393-395.

Shiland, T.W. (1999). Constructivism: The Implications for Laboratory Work. *Journal of Chemical Education*, 1, 107-109.

Steiner, R.P. (1989). Chemistry in the Elementary School: Can We Make It Work. *Journal of Chemical Education*, 7, 571-572.

Treagust, D. F., Chittleborough, G. and Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, 11, 1353-1368.

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