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# Teaching and Learning Method for Enhancing 15-16 Years Old Students` Knowledge as One Of Scientific Literacy Aspect in Chemistry: Results Based on Research and Approbation

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**Abstract:** Knowledge is one of the basic aspects of scientific literacy. For targeted enhancement of scientific literacy it is necessary to diversify the methodical activities. The results of the research indicate on the necessity to enhance the formation of scientific literacy in chemistry lessons by motivating students to think about the nature as unified system. Based on the results of a pedagogic research the new teaching and learning method was developed, called the *TETRA*-method. The tetrahedral spatial mind model is used for the application of this method which is based on the fact that our environment is dimensional. The actions of the model are oriented to discovery and understand various thematic interconnections which form connected knowledge. The results obtained in the approbation of the method indicate that during chemistry lessons students showed greater interest, concurrently the level of students` knowledge level raises up. The obtained students` knowledge which is based on understanding enhances activation of the students' cognitive processes. By the developing such students' competences which are creating scientific literacy is important to show meaning of knowledge in chemistry influence on the environment and society.

***Keywords:*** *chemistry, scientific literacy, chemical literacy, knowledge, spatial mind model.*

**Introduction**

Students' less willing to learn chemistry subject is a problem of the 21st century for many European countries included Latvia and Lithuania. That also could be a reason for students` comparatively low achievements at international research programmes OECD, TIMSS, ROSE and national researches (Mozeika & Cedere, 2008) in sciences. However if a student does not have interest and understanding of chemistry that can possibly lead to a situation in further future students will have difficulties to understand nature as an entirety. Therefore promotion of scientific & chemical literacy in schools has a significant meaning with future prospect (Bybee, 1997; Kelly, 2007). Historically the aim of scientific literacy was developed from making sciences understandable to everyone and are creating "scientifically literate personality" who is able to use the obtained knowledge and skills in its further life. In nowadays **scientific literacy** (DeBoer, 2000; Brown et. al. 2005) **is defined as knowledge and understanding of scientific conceptions and processes which by collaboration and improvement of civil and cultural environment are needed for formation of individual judgments and decisions** (Reveles et. al. 2004; OECD, 2007). More often scientific literacy is used in two ways – one for those who advocate a central role for the knowledge of science and second for those who see scientific literacy referring to society usefulness (Holbrook & Rannikmäe, 2009). This concept also is incorporating specific types of abilities and skills which are more often understood as the term *competences* which include basic elements such as knowledge and skills for real life and their active using. It rises up the issue to look for balance among the students` interest, knowledge and understanding in the learning of chemistry.

Students` interest should be implicated in *active learning*. It is recommended to include the active using knowledge and skills in the learning process (Prince, 2004; Van Aalsvoort, 2004; Holbrook & Rannikmäe, 2007). **Practically it could be realized by activating *Functional science literacy* in chemistry where** the **accentuation** more directed on such components as the skills to use knowledge, attitudes and motivation of activity **(Ryder, 2001;** Jong, 2006; Nentwig et al., 2007). Chemical literacy is one of component of scientific literacy. It characterizes the activation of knowledge, skills, acquirements and other elements retaining the solidarity with the adequate educational aims (Holman & Hunt, 2002; Roberts, 2007).

In this article we will debate on students' knowledge as aspect of chemical literacy, see Figure 1, where the accent is going on those knowledge (included understanding) which promotes students` cognitive interest, chemistry in context for practical knowledge using, learning and thinking skills for chemical knowledge development. Note the activation of cognitive processes has a significant role in enhancing formation of scientific literacy.

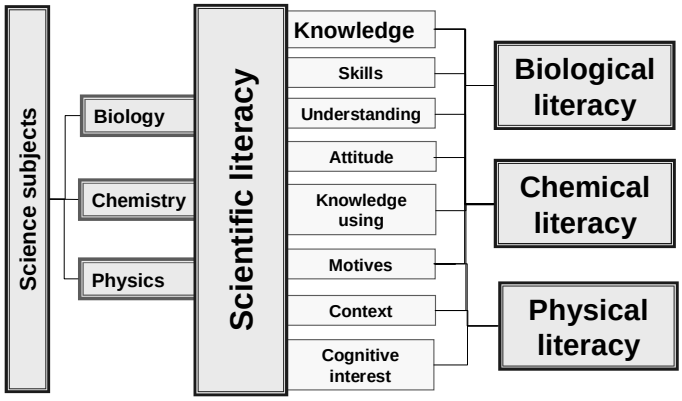



Figure 1. Knowledge as the component of Chemical literacy

Students' knowledge has to be developed by diversifying teaching methods, creation of systematic core of knowledge, skills and attitudes. Ever new and progressive methodical solutions enhance interesting and effective learning process both for students and teachers. At present choice of teaching and learning methods which promote the forming on understanding based knowledge is problematic especially in chemistry. The study is oriented firstly to analyse the students' knowledge level in chemistry; secondly new teaching and learning method (developed by author D. Mozeika) will be tested for the determination of an improvement of students` knowledge level.

The main questions of the study are:

- Are there significant differences between 15-16 years old Latvian and Lithuanian students` knowledge level about various processes in nature?
- Does the developed teaching and learning method enhance students` knowledge level?

**Study background**

Study consists of two parts:

1) pedagogical research (particularly in section research methodology, results)
2) teaching and learning method (particularly in section method description, results of pilot approbation process)

Based on the results of pedagogical research it was develop up the *TETRA*-method in chemistry for enhancing students` knowledge level in scientific literacy context.

**Pedagogical Research**

**Methodology**

Incorporating questions on food, importance of water in different processes of nature and social life was used in the survey. Students' knowledge on such global and essential topics as pollution of the air and water was tested. Questions on substance structure were incorporated to identify the level of understanding students have on physical and chemical transformations of substances and whether their knowledge is based on understanding.

The questionnaire *My understanding about substances and their transformations* consisted of 15 closed type questions with four answer variants were included in the test. Students had to choose one correct answer. Students` knowledge was tested. Perceptual evaluating scale was equate to four category scale: 0–30% (low level of knowledge) – 1; 30-60% (average knowledge) – 2; 60-75% (good knowledge) – 3; 76-100% (very good knowledge) - 4.

The questions were composed according to chemistry subject curriculum for 15-16 year old students which in Latvia correspond to grade 9, in Lithuania – grade 10. Totally 299 students from Latvia and Lithuania were involved in survey for comparison. The research was carried out in school year 2008. The quantitative processing of the data was done by using the SPSS program, version 17.0.

**Research Results**

There is shown in Figure 1 that respondents from Latvia have chosen much more correct answers than Lithuanians. Using statistical analysis, it was found out that the values of only 11 answers provided by Latvian and Lithuanian respondents to the questions in the questionnaire were of statistically significant difference, see appendix, Table 2. 38% of Latvians know better the correct answer to the question *The colorfully effects of fireworks result from burning of metals* than 17% of Lithuanians.

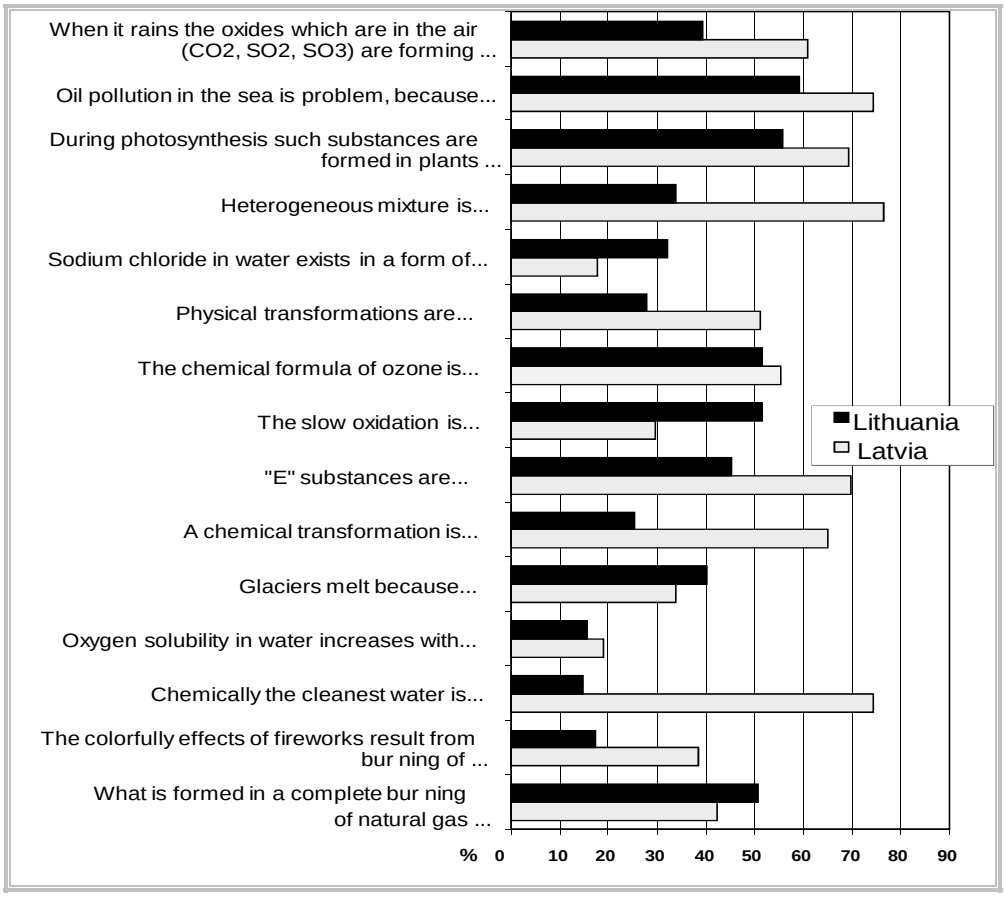



Figure 1. Students` knowledge level in chemistry, distribution of correct answers in %

Statistical data analysis shows that the mean rank of Latvian students' right answers is 162.9 (Mann-Whitney test U=8507.5, p<.001). These values are of statistically significant difference. 75% of students in Latvia know that *Chemically the cleanest water is in spring* and only 15% of students from Lithuania have chosen the right answer. Statistical data analysis shows that the mean rank of Latvian students' right answers is 186.4 (Mann-Whitney test U=4338.0, p<.001). These values are of statistically significant difference. *A chemical transformation is rusting of iron* was the right answer in questionnaire and it was chosen by 65% of Latvian students and 25% of Lithuanian students. These values are of statistically significant difference because mean rank of Latvian students' right answers is 174.1 (Mann-Whitney test U=6525.5, p<.001). The similar situation is with the evaluations of proposition *"E" substances are* ... The correct item was "food additives" and more than three quarters of Latvian students have chosen it. The half of Lithuanians has chosen the right answers. These data are of statistically significant difference (p<.001).

52% of Lithuanians and 30% of Latvians knew that *The slow oxidation is rotting* and these values are of statistically significant differences the mean rank of Lithuanian students' answers is

168.1 but Latvian students' – 135.6 (Mann-Whitney test U=8334.5, p<.001). The propositions *Sodium chloride in water exists in a form of ions* was chosen by 32% Lithuanians and 18% Latvians. The knowledge of this phenomenon in both countries is low and values are of statistically significant difference, mean rank of Lithuanian students' answers is 161.4 (Mann-Whitney test U=9153.5, p<.001). *Physical transformations are formation of snowflakes* was correct answer and it was chosen by 51% of students in Latvia and 28% of students from Lithuania. Statistical data analysis shows (appendix) that the mean rank of Latvian students' right answers is 162.7 (Mann-Whitney test U=8143.0, p< .001). These values are of statistically significant difference. 76% of students in Latvia and 34% of students in Lithuania know that *Heterogeneous mixture is petrol with water* and these values are of statistically significant difference, the mean rank of Latvian students' right answers is 176.0 (Mann-Whitney test U=6190.5, p<.001).

Also, Latvian students (69%) knew better than Lithuanians (56%) that *During photosynthesis such substances are formed in plants glucose and oxygen* and these values are of statistically significant difference, the mean rank of Latvian students' right answers is 158.3 (Mann-Witney test U=9312.0, p<.001). The lasts two propositions are evaluated of statistically significant differences in comparative country aspect. The right answers to the questions *Oil pollution in the sea is problem, because ...* and *When it rains the oxides which are in the air (CO2, SO2, SO3) forms ...* were chosen differently in both countries and this enclose that Latvians know better about these mentioned phenomena that Lithuanians.

**Short Research Summary**

Students from Latvia very well know that *Heterogeneous mixture is petrol with water* and *Chemically the cleanest water is in spring*. Also, they are competent to answer why Oil pollution in the sea is problem and what are "E" substances, and what oxides are forming. These statements were chosen by dominant part of students in Latvia (more than 70%) but the results in comparative country aspect are of statistically significant difference. More than half part of Latvian respondents more than Lithuanians know that *During photosynthesis such substances are formed in plants glucose and oxygen* and that *A chemical transformation is rusting of iron* also, as *The colorfully effects of fireworks result from burning of metals*. The Lithuanians more than Latvians know that *The slow oxidation is rotting* and that *Sodium chloride in water exists in a form of ions*. These results are of statistically significant differences.

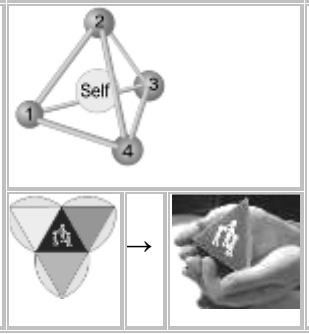
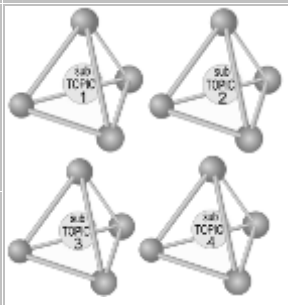
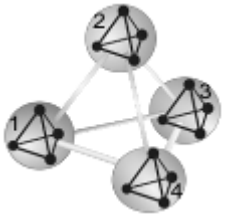
## Teaching and Learning Method

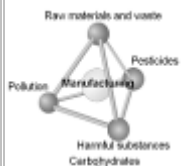
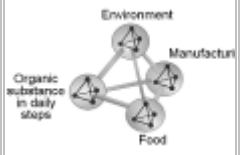
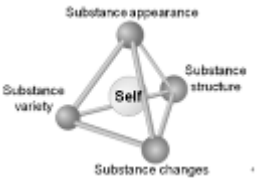
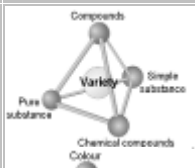
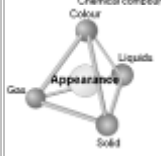
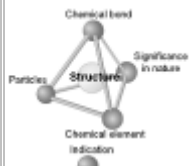
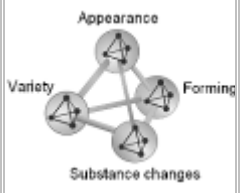
### Method Description

Knowledge is one of the basic components of scientific literacy. It is suggested to supplement knowledge of facts with contextual knowledge in order that interest of learning chemistry and a formation of scientific literacy would arise for students. Interconnections can be formed by connecting existing and adding new information; therefore connected knowledge forms (Siemens, 2006). Importance to find and understand connections as soon as possible is valuable for students, few of R. Fisher's (2005, 85) recommendations was taken into account in the method - to systematize and organize content of the taught subject in schemes or models. The new teaching and learning method, called *TETRA*-method, is oriented on creation of connective knowledge. For the creation of the connective knowledge we offer to use the spatial mind model – tetrahedron - the simplest polyhedron which would be visually easier to perceive for students and would associate with nature in general.

The action of the spatial mind model is oriented to find, to understand and to use the connections of phenomena among various topics or idea and information exactly from student's point of view and experience. The interactions between nature and human are shown completely. It makes a sense that everything is interconnected in nature. The spatial mind model is evoking students` interest to learn which is indicated by incorporation of human factor in learning process by using the so called „Self-perception" phenomenon. The basis of the method is a four step system, see Table 1.

***Table 1: Examples for the learning various topics by the using of the spatial mind model in chemistry***

| | **Step 1** | **Step 2** | **Step 3** | **Step 4** |
|---|---|---|---|---|
| **General example** | Actualization of main topic and subtopics | Activation of student's learning | Characterization of connected subtopics | Summarizing of the main topic |
| |  |  |  |  |

| | | | | |
|---|---|---|---|---|
| **"Organic substance"** (Introduction lesson) |  |  |  <br>  <br>  <br>  |  |
| **"Substances"** (Topic for repeating) |  |  |  <br>  <br>  <br>  |  |

The spatial mind model is used in all steps by the using different methodical activity in each of them. It is mainly foreseen to use for the forming of connected knowledge at the beginning of the learning a topic and at the end. It is recommended to use information technologies when using this model. It is advisable to make each node of the model in different colour to make it visually more likeable, presentable and interesting for students.

**The Pilot Approbation of the *TETRA*-method**

The pilot approbation of teaching and learning method took place at two schools of Latvia, 2009 year spring time. Totally two teachers, 63 students of grade 8 and 31 students of grade 9 were involved in the method testing.

Both chemistry teachers used the *TETRA*-method for teaching different topics. Teacher A used the example on topic *Substances* in grade 8. Teacher B used a general form of model for the topic *Organic substances* made by teacher thematic system in grade 9. See in previous section for examples in table 1. There were prepared two kinds of Microsoft PowerPoint presentations: introductory and repetition **for various learnable topics. These topics are interconnected and at the same time independent.**

Students' achievements in the learning process of chemistry are evaluated in 10 point scale according to the evaluation criteria – knowledge level and quality; acquired skills and abilities where ten points are the highest level, but one point is the lowest level. The mean value ($1 \leq M \leq 10$) expresses students' achievements according the ten point scale during the learning chemistry. Students' evaluation is carried out in correspondence with the national regulation documents. Examination works were formed in the system of evaluation points to display more completely students' achievements by learning chemistry.

**Results of the Pilot Approbation**

**Grade 8.** All parallel grades took part in the approbation process of the *TETRA*-method. The thematic system *Substances* were used in learning of chemistry. Results shows that students' achievement of all grades have higher knowledge level (*M>7.5; t=3.101, df=62; p<.05*) in learning with the *TETRA*-method. The results are very similar in all grades, see Figure 2.

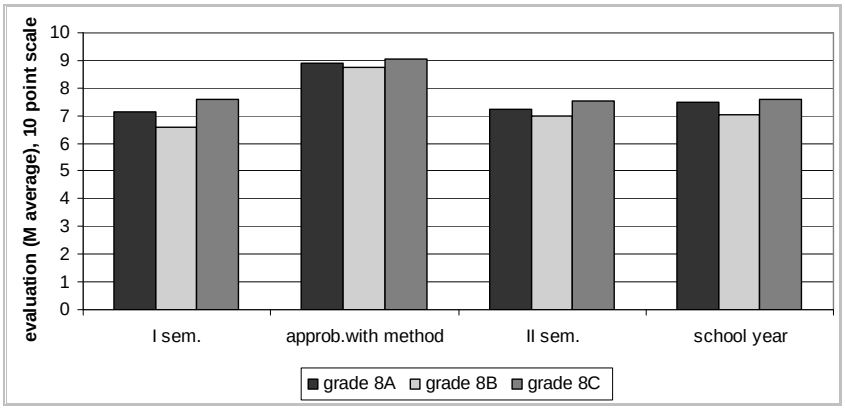



Figure 2. Evaluation of students' acquirement during the methods` approbation

The level of students` knowledge average rise up to 21 – 29 % as good and very good knowledge if compare first semester level. These changes are observed at all grades and all schools where approbation was done.

**Grade 9.** Within the framework of pedagogical experiment there were choose control group 9B and experimental group 9A of parallel grades 9. The choice of previous grouping was following – rating (*M=4.63*) of grade 9A in the first semester of school year is less then of the grade 9B (*M=6.17*). It was our aim to improve the students` interest and to get the better achievements in learning chemistry on topic *Organic substances* by using the method. As the results shows variety of different methods used in education process promotes students` successes in chemistry, see Figure 3.

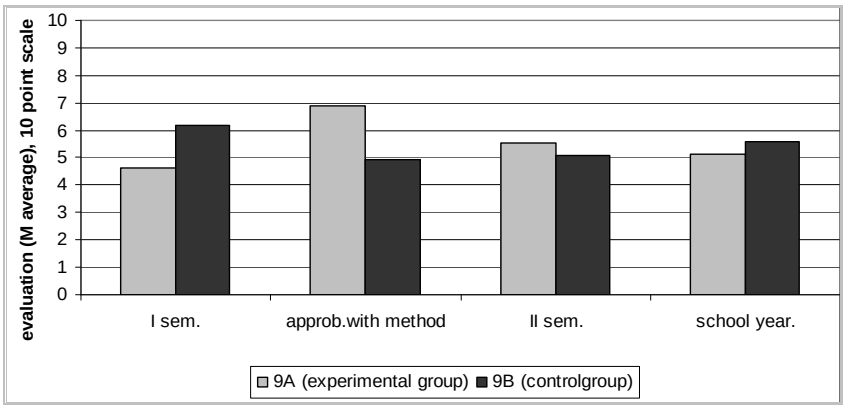



Figure 3. The changes of students` knowledge level by using the *TETRA*-method in learning

The level of students knowledge in experimental group 9A on topic organic substances is comparatively higher (*M=6.9*; good knowledge) then control group (*M=4.9;* average knowledge; *t=2.756, df=30, p<.05)*. The comparative results in first semester and school year for experimental group (*M=5.5)* and control group (*M=5.1*) are the factor on progressive method capacity in chemistry education process. Positive tendencies are similar in all grades that means teacher factor is exclude.

**Discussion**

Mostly part of students acknowledged that studies become more interesting for them, but at the same time it becomes a little bit difficult, because it was necessary to think widely. After understanding the system of *TETRA*-method students were excited of learning process. Students are showing interest in chemistry lessons on learnable topic by using examples from daily life based on practice.

Dispose of spatial mind model by searching connections between various topics (Step 3) students focus their thoughts on different things and processes around. **Students start to think connectively, they do not concentrate only on mechanical remembering of chemical facts but start to learn about processes in nature. It stimulates for students the forming of connective and on the understanding based knowledge, see** Figure 4.

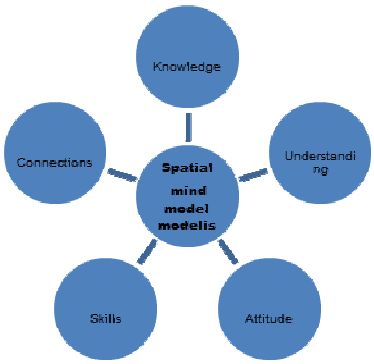



Figure 4. The action of the model's using for the forming **connective knowledge**

**It should be mentioned that „information filtration" or selection and accepting of the most significant information is taking place in the method.** The development of argumentation skills is important because reason why incoming information is more important than other turn students` attention to various facts in practical life.

Teachers find out the *TETRA*-method as an alternative methodical solution in chemistry for interesting and different teaching and learning process. The system of steps can enhance students` thoughts organization in systemic way linked with surrounding environment and daily life.

## Conclusion

Significant differences between Latvian and Lithuanian students` level of knowledge are on topics *Chemically the cleanest water; Heterogeneous mixtures; Physical and chemical transformations; "E" substances*. The level of students` knowledge is comparatively low on average scale, 52% correct answers.

The developed *TETRA*-method which is based on the results of previous pedagogical research and used in the learning of chemistry enhances students` knowledge level. The spatial mind model which is used in the realization of the *TETRA*-method gives a chance for students to build connective knowledge in systemic way coordinated with surrounding world. The model is suitable for enhance students' interest and fixing the knowledge.

Students are actively involved in the learning; also positive attitude towards chemistry is evoked. The significance of chemistry as a subject in the context of securing sustainable education grows by developing students' competences that create scientific literacy.

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## Appendix

***Table 2: Students' opinion about natural science phenomena***

| **Proposition** | **Latvia** | | | **Lithuania** | | | Mann-Whitney U | Z | p |
|---|---|---|---|---|---|---|---|---|---|
| | N | Sum of Ranks | Mean Rank | N | Sum of Ranks | Mean Rank | | | |
| What is formed in a complete burning of natural gas … | 177 | 25638.0 | 144.8 | 122 | 19212.0 | 157.4 | 9885.0 | -1.438 | >.05 |
| The colorfully effects of fireworks result from burning of ... | 177 | 28839.5 | 162.9 | 122 | 16010.5 | 131.2 | 8507.5 | -3.935 | <.001 |
| Chemically the cleanest water is... | 177 | 33009.0 | 186.4 | 122 | 11841.0 | 97.0 | 4338.0 | -10.151 | <.001 |
| Oxygen solubility in water increases with... | 177 | 26942.5 | 152.2 | 122 | 17907.5 | 146.7 | 10404.5 | -0.808 | >.05 |
| Glaciers melt because... | 177 | 25873.5 | 146.1 | 122 | 18976.5 | 155.51 | 10120.5 | -1.104 | >.05 |
| A chemical transformation is ... | 177 | 30821.5 | 174.1 | 122 | 14028.5 | 114.9 | 6525.5 | -6.715 | <.001 |
| "E" substances are ... | 177 | 28975.0 | 164.6 | 122 | 15576.0 | 127.6 | 8073.0 | -4.286 | <.001 |
| The slow oxidation is ... | 177 | 23734.5 | 135.6 | 122 | 20518.5 | 168.1 | 8334.5 | -3.810 | <.001 |
| The chemical formula of ozone is... | 177 | 26952.5 | 152.2 | 122 | 17897.5 | 146.7 | 10394.5 | -.634 | >.05 |
| Physical transformations are ... | 177 | 28310.0 | 162.7 | 122 | 15646.0 | 128.2 | 8143.0 | -3.994 | <.001 |
| Sodium chloride in water exists in a form of ... | 177 | 24553.5 | 140.3 | 122 | 19699.5 | 161.4 | 9153.5 | -2.842 | <.001 |
| Heterogeneous mixture is ... | 177 | 31156.5 | 176.0 | 122 | 13693.3 | 112.2 | 6190.5 | -7.356 | <.001 |
| During photosynthesis such substances are formed in plants... | 177 | 28035.0 | 158.3 | 122 | 16815.0 | 137.8 | 9312.0 | -2.429 | <.001 |
| Oil pollution in the sea is problem, because ... | 177 | 28230.0 | 159.4 | 122 | 16620.0 | 136.2 | 9117.0 | -2.835 | <.05 |
| When it rains the oxides which are in the air (CO2, SO2, SO3) are forming... | 177 | 28890.0 | 163.2 | 122 | 15960.0 | 130.8 | 8457.0 | -3.681 | <.001 |

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