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THE WATERWORKS: A CONTEXT FOR UNDERSTANDING CHEMISTRY CONCEPTS IN THE SEVENTH GRADE OF PRIMARY SCHOOL

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Abstract. *Industry field trips provide the contexts that enable students to improve their understanding of chemical concepts and processes. The aim of this research study was to explore to what extent students improve their understanding of water, solutions, mixtures, and the methods used for separating mixture components in the context of the waterworks, and what their views towards such an approach are. The sample consisted of 36 students aged 13 to 14 years, equally divided into the experimental and control group. The teaching unit Water and its significance for the living world was realised within the context of the waterworks in the experimental group, while in the control group it was realised using a conventional approach at school. Prior to the elaboration of the teaching unit the students from both groups had been tested using a pre-test, and upon the completion they were tested using a post-test. The views of the experimental group were examined using a questionnaire. The obtained results showed that the activities in the context of waterworks improved the understanding of the studied concepts, that students recognised the relevance of the applied context for their personal and societal life, as well as for their own future professional activities.*

Keywords: *chemistry concepts, context-based approach, waterworks, industry field trip, thirteen-year-old students*

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Introduction

The development of science and technology contributes to continuous progress of the society, which consequently creates a need to constantly reassess young people's education and their preparation for their future personal, professional, and societal life. Science education involves the formation of scientific knowledge, the knowledge of the nature of science and the processes of creating the scientific knowledge, of the significance of that knowledge and the limitations of science (OECD, 2013). It enables the young to apply the knowledge and skills to solve problems, and to logically and critically consider some issues which are relevant to them personally and to their professional activities and societal life (Stuckey et al., 2013).

Research Problem

The results of national research studies have shown that the young consider the subjects from the field of natural sciences, including chemistry, to be irrelevant, and the knowledge and skills acquired to be useless, both in everyday life and in their future professions (Adamov et al., 2009). Young people mention chemistry as one of the hardest school subjects to study, which decreases their motivation for learning (Adamov et al., 2009; Šišović & Bojović, 1999). In this situation the context-based approach to teaching and learning chemistry could contribute to making the teaching contents more relevant to young people, by including an individual, a societal, and a vocational dimension of relevance (Stuckey et al., 2013), which would also contribute to their positive attitude towards science and studying chemistry (Bennett et al., 2007; Mandler et al., 2012).

Context-based learning enables students to relate newly acquired knowledge to their prior knowledge and experience, and to apply the acquired knowledge (Nentwig et al., 2007). Context-based approach to science teaching was developed with the aim of creating a learning environment which would meet various needs of students, society and science (Taconis et al., 2016), develop scientific literacy (Gilbert, 2006), reduce the students' perception that science is difficult to study, that it has little relevance to their

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lives and careers (Osborne & Dillon, 2008). Science introduced in an out-of-school context of the real world is more "authentic" and students can recognise it as more relevant (Braund & Reiss, 2006), which is in line with the didactic model of relevance (Eilks & Hofstein, 2015), goals and importance of chemistry education. Students should be enabled to objectively deal with socio-economic, ethical and ecological problems of modern times (Chowdhury, 2013).

Industry field trips within which students observe the production processes in chemical industry represent one of the contexts which can improve their achievements in studying chemistry (Forest & Rayne, 2009; Hofstein & Kesner, 2006; Hofstein & Kesner, 2015; Jung et al. 2017).

Research Focus

Field trips provide students with an out-of-classroom learning experience in an authentic environment or at interactive sites designed for educational purposes (Kisiel, 2005; Tal & Morag, 2009). The teaching/learning process that occurs during an industry field trip emphasises the contribution of industrial chemistry to the production and processing of useful materials and efficient technologies, without which it would be impossible to imagine responses to many demands of everyday life (Nae et al., 1982), and thus provides the students with opportunities to experience the industrial environment, concrete phenomena and materials directly (Hofstein & Kesner, 2006) and to gain new information in real-life situations (DeWitt & Storksdieck, 2008). Industry field trips are planned within chemistry education in order to demonstrate the application of the previously studied chemistry concepts and principles used within the production processes in chemical industry, to point out the relevance of industrial production processes and the significance of chemical industry for a country's economy (Nae et al., 1982). They can include chemical, technological, ecological and social aspects of production (Hofstein & Kesner, 2006; Nae et al., 1980).

Within some industry field trips students can conduct chemical analyses and experiments as a simulation of industrial production and processing (Orion, 1993; Orion & Hofstein, 1994). They have an opportunity to communicate actively with the environment (Hofstein & Rosenfeld, 1996; Krepel & Duvall, 1981), to reconsider and improve their understanding of the concepts and processes learned during instruction (Forest & Rayne, 2009), and/or from their personal experiences, to increase their interest and motivation (Orion, 1993; Orion & Hofstein, 1994), to develop their critical thinking skills (Chowdhury, 2013) and the analytical skills necessary for problem-solving, to improve their decision-making skills and cooperation and communication skills by working in small groups, and to acquire greater self-confidence and longer-lasting knowledge. The benefits achieved by field trips are various types of academic knowledge, improved communication skills, persistence, diligence, responsibility, keener perception, improved motor skills, adroitness and creativity in finding and using resources, more developed critical thinking, knowledge integration and the generation of the interest in the process of life-long learning (Farmer & Wott, 1995; Forest & Rayne 2009; Storksdieck, 2006).

A proper organisation of a field trip and the role of the teacher who creates the teaching/learning process contribute to making the students' experience gained by the field trip long-term (Rennie, 2007). When planning a field trip, it is important for teachers to previously become familiar with the site to be visited and to coordinate their own and students' activities planned to be done at that site with the curriculum goals (Kisiel, 2005). In addition to this, students should be given some basic information about the aim of the field trip, the time organisation, and the activities which they will do during their field trip (Rennie & McClafferty, 1995; Rudmann, 1994).

Industry field trips in chemistry education establish cooperation between schools and industry (Brunton & Coll, 2005). This partnership provides students with favourable learning opportunities and with an opportunity for problem-based learning. It is recommended to invite experts to explain their profession and work to students during or after the field trips (Harrison, 1998; Hofstein & Kesner, 2006). This enables students to understand the importance of knowledge in decision-making within the social environment in which they live (Sivan et al., 2000; Stuckey et al, 2013). Students obtain an insight into different professions by observing industrial processes (Sanromán et al., 2010), gain valuable experience, teamwork, and problem-solving skills necessary for their future career (Riebe et al., 2013), as well as time management skills and project management skills. Experts from various fields provide students with an opportunity to obtain information about their future school projects (Goldberg et al., 2014), working environment within the industrial facility (Metrejean et al., 2002) and different kinds of professions and jobs available upon finishing a specific school. This can be useful for both parties – the students and the industry.

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Research Aim and Research Questions

The aim of this research study was to explore to what extent students improve their understanding of water, solutions, mixtures, and the methods used for separating mixture components in the context of the waterworks, and what their views towards such an approach are. The following research questions arose from the defined research aims:

1. To what extent does the context of water treatment processes at the waterworks improve the understanding of the curriculum contents about mixtures, the methods used for separating mixture components, solutions and water compared with the conventional instruction?
2. How do students evaluate the relevance of the activities in the context of the production process, the effect of these activities on their understanding of chemical concepts and their motivation for studying chemistry?

Research Methodology

General Background

In this quasi-experimental research study, the effects of the application of the waterworks context within the elaboration of the teaching unit *Water and its significance for the living world* in the seventh grade of primary school (students aged 13 to 14 years; in our educational system, it is the second cycle of primary school education) were examined. This teaching unit was chosen because it includes the contents and activities which are relevant to an individual and the society, and which are important for the development of the young into responsible citizens who take care of the environment in their everyday activities and have a potential to improve their chemical literacy. In addition to this, it presents a suitable framework for illustrating the connection between the knowledge and skills developed by studying chemistry and their practical application within the professional activities. The research study was conducted in May 2018.

Sample

The sample in this research study consisted of 36 seventh grade students from two primary schools in the territory of Belgrade divided into two groups – the experimental group and the control group, each with 18 students. The number of the students included in the research study was determined based on the limitations on the maximum number of students who could be present at the waterworks due to the safety of the students and the effective realization of the activities. The experimental group and the control group were fairly equal in terms of gender (there were nine boys and nine girls in the control group, and ten boys and eight girls in the experimental group). There was not a statistically significant difference between the groups regarding the average grade in chemistry at the end of the first term of the seventh grade of primary school (the average chemistry grade of the students in the control group on a scale of 1 to 5 was 4.2, while in the experimental group it was 4.0).

Before commencing the research, talks had been conducted with the management and with the chemistry teachers in both schools regarding the subject, aims and methodology of the research being planned, as well as the participation of students. After the consent to start with the research study had been obtained, a contract of cooperation was concluded between the Faculty of Chemistry and both schools, signed by the Dean of the Faculty and the principals of both schools. At the beginning of the research, the students were explained the aims of the research study and in what kind of activities they were expected to participate. The same teacher worked with the students from both the experimental group and the control group (the first author of the paper). All students who participated in the research study had voluntarily agreed to participate in it. They were informed that they were allowed to withdraw from the planned activities at any moment, that the results achieved would be used only for the purpose of the research study and that they would not influence their chemistry marks and their final mark. They were offered an opportunity to be informed about the results achieved through their participation in this research study if they wanted.

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Instruments and Procedures

For the purpose of this research study, two instruments were designed – a test for pre- and post-testing and a questionnaire. The test items were based on the curriculum and the contents of general chemistry in the approved and current chemistry textbooks for the seventh grade of primary school. This enabled each student to answer the test items. The test contains six sets of items of open and closed type, with a total of 17 items (Appendix 1). The items related to two topics of the curriculum: *Chemistry as an experimental science and chemistry in the world around us* (the first set of items - the examples of elements, compounds and mixtures) and *Homogeneous and heterogeneous mixtures* (sets of items 2, 3, 4, 5 and 6 - solutions, mixtures and the methods used for separating mixture components). Within their previous chemistry education, the students had gained experience of answering the types of items which were used in the test and the prior knowledge necessary to understand the test items.

The questionnaire used in the research study had five open-ended items and six items which involved expressing one's attitude on a 5-point Likert scale of assessment (Appendix 2).

The validity of the test and the questionnaire based on the defined aims and research questions was examined by the members of the Department of Chemical Education, the University of Belgrade – the Faculty of Chemistry, two pedagogues and five chemistry teachers who were not included in the research planning. In addition to this, they examined if the test items were in line with the chemistry curriculum, if they were clearly formulated and if all students had had equal opportunities to acquire the prior knowledge necessary for formulating the answers within the instruction at school. Both instruments were improved upon receiving the feedback from them.

The test reliability was assessed through internal consistency, i.e., the Cronbach alpha coefficient was determined. The Cronbach alpha coefficient of internal consistency of the test was .72 for the pre-test, and .74 for the post-test. The questionnaire reliability was determined for the items which included the Likert scale, and the value of the Cronbach alpha coefficient was .77. Since the values of the Cronbach alpha coefficient of the internal consistency are higher than the lowest value allowed – .70, the test and the questionnaire can be considered to have sufficient internal consistency (Nunnally, 1978).

The plan of the activities during the research study is shown in Table 1.

Table 1
The Activities of the Control and Experimental Group During the Research Study

Classroom period	Control group	Experimental group
1 (45 minutes)	Pre-test	Pre-test
2 and 3 (90 minutes)	Elaboration of the teaching unit *Water and its significance for the living world* using the conventional approach at school: 1. a conversation about the properties of water and its significance for the living world; 2. looking at and analysing photographs about water production technologies and water treatment processes.	Elaboration of the teaching unit *Water and its significance for the living world* during a field trip to the waterworks: 1. an introductory conversation conducted by a technologist and the teacher with the students about water in nature and its significance for the living world; 2. a tour of the waterworks, observation and a conversation conducted by the technologist and the teacher with the students about water production technologies and water treatment processes; 3. career guidance conversation with the staff working at the waterworks (a technologist, a sanitation technician, a laboratory technician) and providing answers to the questions about the drinking water quality control.
4 (45 minutes)	Post-test	Post-test and questionnaire completion

At the beginning of the research study both groups did a pre-test in order to establish the similarity of the groups regarding their previous knowledge of substances, mixtures, the methods used for the separation of mixture components, solutions and water. In the next two classroom periods, students from the control group were taught about water and its significance using the conventional approach at school, while the students from the

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experimental group were taught in the context of the waterworks. The students' activities planned to be realised during the field trip to the waterworks were guided by the technologist employed at the waterworks and the teacher (Table 1).

A post-test was conducted in the first subsequent chemistry classroom period after the activities in the control and experimental groups (i.e., seven days after the pre-test) in order to examine the effects of the context-based approach within the field trip to the waterworks and the effects of the conventional approach on understanding the contents of chemistry. A questionnaire was used to investigate the views of the students from the experimental group on the relevance and effects of the activities during the field trip to the waterworks on their understanding of the chemical concepts and motivation to learn chemistry.

Data Analysis

The collected data were processed using the statistical program for social science (SPSS 19). The *t*-test was conducted to determine whether there were any statistically significant differences among the groups' mean scores in the pre- and post-test, as well as to explore the statistical significance of the difference in the percentage of correct answers for each item between groups. The students' responses to open-ended items in the questionnaire were coded and the frequency of the responses within each category was determined.

Research Results

The Characteristics of the Distribution of the Pre- and Post-test Scores

Table 2 shows the characteristics of the distribution of the scores achieved by both groups in the pre- and post-test: the number of participants (*N*), the minimum (*Min*) and maximum (*Max*) number of achieved points in the test, the mean (*M*), the standard deviation (*SD*), the *skewness* and *kurtosis* values.

Table 2
The Characteristics of the Distribution of the Pre- and Post-test Scores for Both Groups of Participants (the Maximum Number of Points was 17)

	Group	*N*	Min	Max	*M*	*SD*	Skewness	Kurtosis
Pre-test	Control group	18	4	16	10.1	3.3	0.087	-0.756
	Experimental group	18	3	15	9.2	3.5	0.115	-0.789
Post-test	Control group	18	4	15	9.6	3.2	0.030	-0.985
	Experimental group	18	8	17	12.7	2.9	0.075	-0.958

As can be seen in Table 2, the skewness and kurtosis values are within the acceptable range (±1), so the distribution of the results can be considered normal. The normality of the distribution of the obtained results was additionally examined using the *Shapiro-Wilk* test, suitable for testing the characteristics of the distribution of scores in a small sample (Table 3).

Table 3
The Evaluation of the Normality of the Score Distribution Using the Shapiro-Wilk Test

Pre-test Control group			Pre-test Experimental group			Post-test Control group			Post-test Experimental group		
W	*df*	*p*	*W*	*df*	*p*	*W*	*df*	*p*	*W*	*df*	*p*
0.975	18	.883	0.963	18	.660	0.956	18	.532	0.927	18	.173

Based on the results presented in Table 3 it was concluded that the distribution of the scores in the pre-test and the post-test in the control and experimental group could be considered normal.

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By employing the independent sample *t*-test (Table 4), it was established that there was not a statistically significant difference between the groups regarding their achievements in the pre-test, i.e., that the students from the experimental and control group had similar prior knowledge. However, the mean scores achieved by the experimental group in the post-test were statistically significantly higher than the mean scores achieved by the control group.

Table 4
The Statistical Significance of the Differences in the Means of the Independent Samples in the Pre- and Post-test

	t	*df*	*p*
Pre-test	0.778	34	.442
Post-test	-3.050	34	.004

The Scores for the Individual Items of the Pre- and Post-test

Table 5 presents the number and percentage of students in both groups who correctly and incorrectly answered the pre-test items, as well as the values of the *t*-test, which was used to examine the statistical significance of the difference in the percentages of correct answers in the groups. The difference in the percentages of correct answers in the two groups of participants was not statistically significant for any of the items of the pre-test, with the control group having a higher percentage of correct answers to 13 out of 17 items. Thus, it was established that the students from both groups had similar prior knowledge of the tested contents.

Table 5
The Frequency of Correct and Incorrect Answers in the Control and Experimental Group in the Pre-test (the Maximum Number of Points was 17)

Item	Control group (*N* =18)				Experimental group (*N* =18)				t_{C-E}
	Correct answers		Incorrect answers		Correct answers		Incorrect answers		
	N	%	*N*	%	*N*	%	*N*	%	
1a	6	33.3	12	66.7	10	55.6	8	44.4	-1.338
1b	6	33.3	12	66.7	9	50.0	9	50.0	-1.000
1c	7	38.9	11	61.1	6	33.3	12	66.7	0.338
1d	13	72.2	5	27.8	11	61.1	7	38.9	0.692
1e	15	83.3	3	16.7	12	66.7	6	33.3	1.144
1f	15	83.3	3	16.7	13	72.2	5	27.8	0.786
2	9	50.0	9	50.0	8	44.4	10	55.6	0.325
3a	13	72.2	5	27.8	10	55.6	8	44.4	1.027
3b	14	77.8	4	22.2	10	55.6	8	44.4	1.414
3c	14	77.8	4	22.2	13	72.2	5	27.8	0.375
3d	11	61.1	7	38.9	9	50.0	9	50.0	0.656
3e	15	83.3	3	16.7	11	61.1	7	38.9	1.493
4	2	11.1	16	88.9	4	22.2	14	77.8	-0.879
5	12	66.7	6	33.3	11	61.1	7	38.9	0.338
6a	11	61.1	7	38.9	8	44.4	10	55.6	0.987
6b	8	44.4	10	55.6	11	61.1	7	38.9	-0.987
6c	10	55.6	8	44.4	9	50.0	9	50.0	0.325

Table 6 presents the number and percentage of students in both groups who correctly and incorrectly an-

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swered the post-test items, and the values of the *t*-test, which was used to examine the statistical significance of the difference in the percentages of correct answers in the groups.

Table 6
The Frequency of Correct and Incorrect Answers in the Control and Experimental Group in the Post-test (the Maximum Number of Points was 17)

Item	Control group (*N* =18)				Experimental group (*N* =18)				t_{C-E}
	Correct answers		Incorrect answers		Correct answers		Incorrect answers		
	N	%	*N*	%	*N*	%	*N*	%	
1a	6	33.3	12	66.7	13	72.2	5	27.8	-2.466*
1b	8	44.4	10	55.6	11	61.1	7	38.9	-0.987
1c	8	44.4	10	55.6	11	61.1	7	38.9	-0.987
1d	14	77.8	4	22.2	17	94.4	1	5.6	-1.448
1e	14	77.8	4	22.2	13	72.2	5	27.8	0.375
1f	13	72.2	5	27.8	13	72.2	5	27.8	0.000
2	10	55.6	8	44.4	11	61.1	7	38.9	-0.329
3a	13	72.2	5	27.8	14	77.8	4	22.2	-0.375
3b	10	55.6	8	44.4	16	88.9	2	11.1	-2.338*
3c	13	72.2	5	27.8	17	94.4	1	5.6	-1.821
3d	8	44.4	10	55.6	16	88.9	2	11.1	-3.117*
3e	16	88.9	2	11.1	14	77.8	4	22.2	0.879
4	5	27.8	13	72.2	9	50.0	9	50.0	-1.365
5	9	50.0	9	50.0	12	66.7	6	33.3	-1.000
6a	8	44.4	10	55.6	13	72.2	5	27.8	-1.712
6b	9	50.0	9	50.0	14	78.8	4	22.2	-1.761
6c	8	44.4	10	55.6	14	78.8	4	22.2	-2.121*

*The difference in the percentages of correct answers is statistically significant at the .05 level.

The statistical significance of the difference in the percentages of correct answers in the pre- and post-test in each group of participants was examined using the *t*-test (Table 7). The ordinal numbers of the activities (as listed in Table 1) conducted at the waterworks which could have influenced the results achieved in the test are also given in Table 7.

Table 7
The Significance of the Difference between the Percentages of Correct Answers in the Pre- and Post-test in Each Group, and in the Post-test between the Groups

Item	$t_{pre\text{-}test - post\text{-}test}$ Control group	$t_{pre\text{-}test - post\text{-}test}$ Experimental group	$t_{C(post\text{-}test) - E(post\text{-}test)}$	Activities of the experimental group (Table 1) #
1a	0.000	-1.374	-2.466*	(1)
1b	-1.458	-1.458	-0.987	(1)
1c	-0.566	-2.557*	-0.987	(1)
1d	-1.000	-2.915*	-1.448	(1)
1e	1.000	-0.437	0.375	(1)
1f	1.458	0.000	0.000	(1)
2	-0.566	-1.844	-0.329	(1), (2), (3)

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Item	$t_{pre-test – post-test}$ Control group	$t_{pre-test – post-test}$ Experimental group	$t_{C(post-test) - E(post-test)}$	Activities of the experimental group (Table 1) #
3a	0.000	-2.204*	-0.375	(1)
3b	1.288	-2.062	-2.338*	(1)
3c	0.369	-2.204*	-1.821	(1)
3d	1.374	-2.715*	-3.117*	(1)
3e	-0.566	-1.844	0.879	(1)
4	-1.844	-2.557*	-1.365	(2), (3)
5	1.844	-0.566	-1.000	(2), (3)
6a	1.844	-2.557*	-1.712	(2), (3)
6b	-0.369	-1.000	-1.761	(2), (3)
6c	0.697	-2.051	-2.121*	(2), (3)

*The difference in the percentages of correct answers is statistically significant at the .05 level.

Results of the Questionnaire

Table 8 shows the frequencies of students' responses in the experimental group regarding their liking of studying chemistry, their interest in studying school subjects in the context of industrial production processes, the effects of field trips on understanding chemistry, and the relevance of the knowledge acquired during the field trip to the waterworks.

Table 8
The Frequencies of Students' Responses Regarding Their Liking of Studying Chemistry, and Regarding the Contribution and Relevance of Field Trips, N=18

Questions \ Answers	Yes		No	
	N	%	*N*	%
Do you like studying chemistry?	12	66.7	6	33.3
Would the context of industrial production processes increase you interest in studying chemistry?	16	88.9	2	11.1
Can chemistry be understood better if the instruction is carried out within the field trips similar to the field trip to the waterworks?	17	94.4	1	5.6
Do you consider the knowledge gained by the field trip to the waterworks relevant to your life in the society?	15	83.3	3	16.7

Table 9 contains the students' explanations as to why they would be more interested in studying chemistry in the context of field trips.

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Table 9
Students' Explanations as to Why They are Interested in Studying in the Context of Field Trips, N=18

Explanations	*N*	%
Learning outside the classroom is more interesting.	5	27.8
By learning outside the classroom, we experience the real processes in our environment.	4	22.2
We will remember the teaching material more easily.	3	16.7
We develop new sills and learning potentials.	2	11.1
Because we learn by investigating.	1	5.6
We are better informed about various water treatment technologies.	1	5.6
No response.	2	11.1

The explanations provided by the students from the experimental group as to why they believe that chemistry can be understood better in the context of field trips are listed in Table 10.

Table 10
Students' Explanations as to Why Chemistry can be Understood Better in the Context of Field Trips, N=18

Explanations	N	%
It will be more interesting if we learn chemistry outside the classroom.	4	22.2
We do different activities.	3	16.7
We have a conversation with people who are employed in factories.	3	16.7
The questions posed are answered with a demonstration on the spot.	2	11.1
We become familiar with various learning environments, of which we have not been aware before.	2	11.1
We can learn about some other factories.	1	5.6
We can conduct chemical experiments during a field trip.	1	5.6
We will remember the chemistry teaching material more easily if we observe chemical processes.	1	5.6
I do not like travelling, I have other interests.	1	5.6

Table 11 shows the students' explanations as to why the knowledge acquired during the field trip is relevant to them.

Table 11
Students' Explanations Regarding the Relevance of the Knowledge Acquired During the Field Trip, N=18

Explanations	*N*	%
We acquire general knowledge which is useful for the future.	5	27.8
We acquire wider general knowledge.	4	22.2
We learn how to be socially responsible.	3	16.7
We get to know more about people's professions and their roles in everyday life.	2	11.1
We learn the meaning of some new terms and in this way, we improve our vocabulary.	1	5.6
No response	3	16.7

Table 12 presents the number and percentage of students who have expressed their attitudes towards studying chemistry in the context of the waterworks on a 5-point Likert scale of assessment.

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Table 12
Students' Views on Learning Chemistry in the Context of the Waterworks, N=18

Statements	1*		2*		3*		4*		5*	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*
The field trip to the waterworks was interesting.	-	-	1	5.6	2	11.1	5	27.8	10	55.6
The activities we had during the field trip to the waterworks were too demanding.	-	-	8	44.4	7	38.9	1	5.6	2	11.1
During the field trip to the waterworks, I broadened my knowledge of water.	-	-	-	-	2	11.1	3	16.7	13	72.2
During the field trip to the waterworks, I broadened my knowledge of water treatment.	-	-	-	-	2	11.1	2	11.1	14	77.8
In the future, there should be more field trips to the waterworks conducted in a similar manner.	-	-	2	11.1	-	-	6	33.3	10	55.6
This kind of field trip increases my motivation for learning chemistry.	-	-	-	-	2	11.1	4	22.2	12	66.7

*1 – I strongly disagree; 2 – I mostly disagree; 3 – I both agree and disagree; 4 – I mostly agree; 5 – I strongly agree

Table 13 presents students' responses regarding the advantages and disadvantages of the field trip.

Table 13
Students' Views on the Advantages and Disadvantages of the Field Trip to the Waterworks, N=18

Advantages	*N*	%	Disadvantages	*N*	%
We learn in an interesting way.	5	27.8	There are no disadvantages.	9	50.0
The instruction includes practical experience.	4	22.2	There were some unpleasant odours during our field trip to the waterworks.	4	22.2
We learn something more, we complete our knowledge, and we leave the classroom.	4	22.2	The field trip was noisy.	3	16.7
We do not use formulae and chemical calculations.	3	16.7	We have less time to study other school subjects.	2	11.1
We meet experts who work at the waterworks – technologists, laboratory and sanitation technicians with whom we talk about things, which we find interesting about water treatment and water quality.	2	11.1			

Discussion

The Results for the Individual Items of the Pre- and Post-test

In the first set of items of the pre-test, in which students were expected to classify the given examples into elements, compounds and mixtures, students from both groups were more successful at identifying the examples of chemical elements than the examples of chemical compounds and mixtures (water as a pure substance and waters in nature and in households). Four students from the control group and two students from the experimental group stated that they had not had a dilemma about this.

The most common dilemma in both groups related to rainwater (seven students in the control group, i.e., 38.9 %, and nine students in the experimental group, i.e., 50.0 %, stated this), and to deionised water (based on the answers, this was difficult for four students in each group, 22.2 %). One student from the control group and two students from the experimental group had a dilemma about the example of tap water. One student from the

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control group had a dilemma about seawater, while one student from the experimental group had a dilemma about oxygen. Some other research studies indicate students' problems in identifying the examples of chemical elements, compounds, and mixtures (Stains & Talanquer, 2007). Bearing in mind the percentage of incorrect answers in the pre-test and the above-mentioned dilemmas, it can be concluded that the students in this research study had difficulties in differentiating between water as a pure substance and waters found in nature, which are mixtures.

The second item related to the students' assessment was whether drinking water was a saturated, unsaturated, or supersaturated solution. The percentage of correct answers for this item in the pre-test has shown that, in comparison to the number of students from both groups who know that tap water is a mixture, a smaller number of them identify it as an unsaturated solution, which could be a consequence of a decontextualized approach to teaching (Pınarbaşı & Canpolati, 2003).

In the third set of items students matched waters in nature with the phases in which they are found in nature. The most frequent correct answer in the control group referred to the glacier, while in the experimental group it referred to lake water. The smallest number of correct answers in both groups of students in the pre-test referred to the phase of groundwaters. The percentage of correct answers to the items within this set also points out the problem of decontextualized approach in chemistry education, as well as the fact that students fail to find a connection between the contents of chemistry and the contents of other school subjects (primarily geography).

In the fourth set of items, an experiment setup was described, the result of which was supposed to indicate that the mass fractions of the dissolved solid components were different in the following mixtures: mineral water, rainwater and tap water. In comparison to the other test items, the smallest number of correct answers was achieved for this item in both groups in the pre-test, which additionally indicates the students' problem with understanding the composition of waters found in nature and tap water.

The fifth question tested students' knowledge of the methods used for obtaining soft water. Approximately two thirds of the students from both groups in the pre-test correctly chose the appropriate method among the options given.

The first item in the sixth set of items was related to water treatment processes, and students were expected to decide in which order the given processes should be performed based on their description. In the second item students were expected to transfer their knowledge of the percolation method to a specific context and the role of the gravel and sand layer in water treatment by the percolation method which is used to remove impurities. The third item referred to the explanation of why the methods of water ozonation or prechlorination are applied. The responses of the students from both groups in the pre-test point out the need to use different contexts when teaching about the methods used to separate mixture components in order to form more functional knowledge, i.e., knowledge which could be applied to the examples which relate to real-life situations.

The number of correct answers in the control group in the post-test compared to the results achieved in the pre-test increased for seven items, it stayed the same for two items, while it decreased for eight items. Even though it was established that there was not a statistically significant difference between the percentages of correct answers of the students from the control group in the pre- and post-test (Table 7), it should be examined why the conventional approach caused confusion among some students. Compared to the number of correct answers in the pre-test, students from the experimental group gave more correct answers to 16 out of 17 questions of the post-test. The students from the experimental group statistically significantly improved their achievements in the post-test compared to the pre-test for seven items, 1c, 1d, 3a, 3c, 3d, 4 and 6a (Table 7). The percentage of correct answers in the post-test in the experimental group was higher for 14 out of 17 items compared to the control group, while this difference was statistically significant for four items (1a, 3b, 3d and 6c). The sixth set of items refers mostly to the practical application of the studied concepts, and it can be said that activities 2 and 3 within the field trip to the waterworks (Table 1) contributed to the fact that the students from the experimental group statistically significantly improved their achievement in the post-test regarding water treatment processes compared to the pre-test, as well as that they provided statistically significantly higher number of correct explanations why the methods of water ozonation or prechlorination are applied than the students from the control group (Table 7). In the light of the experience which the experimental group had at the waterworks, it can be concluded that it had the greatest influence on the better differentiating between the examples of elements, compounds and mixtures, the identification of the phases of waters in nature and the understanding of the water treatment processes.

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Results of the Questionnaire

Students from the experimental group who stated that they liked studying chemistry provided the following explanations: they found chemistry to be an interesting science (three students; 16.7 %), it was their favourite subject (three students; 16.7 %), it was more interesting than physics (one student; 5.6 %), their chemistry teacher was a good educator (two students; 11.1 %), their chemistry teacher motivated students to study chemistry using various teaching methods (one student; 5.6 %) and learning chemistry was fun when students conducted experiments (one student; 5.6 %). These students' responses are in line with the previously identified factors which influence the popularity of a school subject (Vaino et al., 2012). Students who did not like studying chemistry explained their dislike by writing that they found chemical formulae and equations difficult to understand (four students; 22.2 %) and that the contents of chemistry were difficult and too extensive (two students; 11.1 %). This is in line with the results obtained within previous research studies conducted in our education system (Adamov et al., 2009; Šišović & Bojović, 1999).

Based on the most frequent answers to the second item in the questionnaire, out-of-classroom instruction is more interesting to students, and they believe that in that way they experience real processes from their environment. This and the other explanations provided by the students (Table 9) are in line with the positive effects of field trips determined by other research studies (Hofstein & Kesner, 2006).

With the exception of one student, other students from the experimental group believe that chemistry can be understood better in the context of field trips and their explanations (Table 10) show that they realise some of the important characteristics of learning during field trips (Chowdhury, 2013; Hofstein & Kesner, 2006).

Most students consider the field trip relevant because it has enabled them to acquire general knowledge which they will need in the future (in line with the results obtained by Holbrook, 2005; Höper & Köller, 2018; Stuckey et al., 2013) and to broaden their general knowledge. Some students have recognised the relevance of learning about social responsibility, finding out about professions and enriching their vocabulary by learning new terms (Table 11).

The majority of the students strongly agree that they have broadened their knowledge of water and water treatment during their filed trip. Two thirds of the students strongly agree that the field trip has increased their motivation for chemistry learning, which is in line with the results of some other research studies (Itzek et al., 2016; Lantada et al., 2013). Slightly more than half of the students strongly agree that the field trip was interesting to them and that there should be more field trips of this kind in the future. As far as the assessment of the difficulty of the activities is concerned, the majority of the students mostly disagree that the activities were demanding or do not have a formed view on this.

Based on the students' most frequent answer, the main advantage of learning chemistry in the context of waterworks is the fact that it makes learning more interesting. The next most frequently mentioned advantages relate to out-of-the-classroom learning, which enables learning new things, completing previously acquired knowledge and practical work. A number of students have recognised the absence of the symbolic language of chemistry and calculations as an advantage. The responses of the students who have pointed out an opportunity to talk with professionals about the issues which they found interesting as an advantage are in line with some authors' recommendations to invite experts who can describe their professional activities to students during field trips (Harrison, 1998; Hofstein & Kesner, 2006). The context of industry field trips thus enables the identification of initial competences necessary for the future professional orientation of the young (González-Peña et al., 2021).

Half of the students in the sample have stated that the conducted field trip had no disadvantages. Some of the disadvantages mentioned are the unpleasant odours and the noise, while several students have said that this approach did not leave them enough time to study for their other school subjects.

Conclusions and Implications

The research study was performed with two groups of students, one of which learned the lesson about *Water and its significance for the living world* in the context of waterworks (the experimental group), and the other one learned the lesson through the traditional approach at school (the control group). According to the results of the pre-test, the groups had similar prior knowledge. Based on the statistically significantly greater overall achievements of the students from the experimental groups in the post-test in comparison with the control group, the first research question can be answered affirmatively, i.e., the context of the water treatment processes at the waterworks significantly improves the understanding of the chemical concepts in comparison with the conventional instruction.

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Students' responses to the questionnaire items indicate that the applied context increases their interest in learning chemistry and that this approach makes learning more interesting, that they want more field trips of this kind and that they enable them to experience real processes from their environment and to develop new skills, abilities, and motivation for learning.

Students assess that the industry field trip is important to them since in this way they gain general knowledge necessary in the future, learn about social responsibility and various professional fields and activities, improve their general knowledge with the knowledge of water and its significance for the living world, of water treatment processes, and enrich their vocabulary by learning new terms. These advantages can provide an important support for future decision-making in personal, professional and social life, and for the identification of the competences necessary for professional orientation.

The results of this research study have pointed out the potential of the waterworks as a context for learning and improving the understanding of the basic chemical concepts. The significance of this research study lies in the fact that, based on the literature review, the effects of industry field trips on the motivation of thirteen-year-olds to learn chemistry have not been studied yet. However, for students of that age it is important to start thinking about their future professional orientation and to gain insights into different professional activities, since they will soon have to choose their future secondary school.

The limitations of the conducted research study relate to the fact that it is not possible to make generalizations due to the sample size. The number of students in the experimental group was limited by the number of visitors allowed to the waterworks and by the conditions necessary to provide each visitor with an opportunity to observe the processes and participate in the activities. However, the research study has provided an insight into the potentials of such instruction and enabled the identification of the advantages and disadvantages, which is very useful for planning more effective field trips in the future.

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Declaration of Interest

The authors declare no competing interest.

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Appendix 1: Test

(1) Classify the examples given in the first row as elements, compounds and mixtures by writing the + sign in the right place in the table.

	a) Seawater	b) Deionised water	c) Rainwater	d) Tap water	e) Hydrogen	f) Oxygen
Element						
Compound						
Mixture						

What examples were most difficulty to classify?

(2) Circle the letter next to the correct answer. Tap water is:
a) a saturated solution б) an unsaturated solution в) a supersaturated solution

(3) Match the examples of waters in nature with their phase in nature by writing a letter on the corresponding line.

a) water vapour in the atmosphere ________ gas phase
b) spring water
c) lake water ________ liquid phase
d) groundwater
e) a glacier ________ solid phase

(4) Several drops of mineral water were added onto the first metal plate, several drops of rainwater were added onto the second metal plate and several drops of tap water were added onto the third metal plate. The plates were then heated up until the water evaporated from them. Explain how you can determine on which plate rainwater drops had been before heating.

(5) Circle the letter next to the correct answer. Which of the following methods can be used to obtain soft water from hard water?
a) crystallisation b) distillation c) filtration d) decantation

(6) Drinking water is obtained by treating water found in nature. This method consists of several processes. These processes are described below.

A) Order the described processes of water treatment from the first to the last one by writing the smallest number on the line next to the first process, and the largest number on a line next to the last process.

___ Passing water through grids and sieving – keeping larger impurities (which float) and small impurities (waste).
___ Flocculation and clarification (decantation) of water – adding substances with which some components present in water form insoluble substances which settle out in the water treatment basins.
___ Percolation through sand – keeping the solid substances, water becomes clearer.
___ Ozonation or prechlorination – destroying most of the viruses and bacteria, decomposition of the substances which cause water to have unpleasant smell and taste.
___ Percolation through activated charcoal – removing the last impurities – microorganisms and dissolved substances.

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____ Chlorination – destroying the cells of the remaining microorganisms and ensuring good quality of water.

B) Percolation of water through a layer of gravel and sand is one of the processes used in water treatment at waterworks. CROSS OUT THE INCORRECT WORD in order to get a true statement.
By percolating water through a layer of gravel and sand dissolved/undissolved impurities are removed.

C) Explain why the process of ozonation or prechlorination is used in water treatment.

Appendix 2: Questionnaire

Answer the following questions by circling the answer with which you agree and by writing an explanation for your choice on the line.

1. Do you like studying chemistry? YES NO
Explanation:

2. Would the context of an industrial production process increase your interest in studying chemistry? YES NO
Explanation:

3. Can chemistry be understood better if the instruction is carried out within the field trips similar to the field trip to the waterworks? YES NO
Explanation:

4. Do you consider the knowledge gained by the field trip to the waterworks relevant to your life in the society? YES NO
Explanation:

5. Express the degree of your agreement with the given statements about the conducted field trip to the Waterworks. (Descriptions of the agreement with the statements are the following: 1 – I strongly disagree; 2 – I mostly disagree; 3 – I both agree and disagree; 4 – I mostly agree; 5 – I strongly agree.)

Statement	1	2	3	4	5
The field trip to the waterworks was interesting.					
The activities we had during the field trip to the waterworks were too demanding.					
During the field trip to the waterworks, I broadened my knowledge of water.					
During the field trip to the waterworks, I broadened my knowledge of water treatment.					
In the future, there should be more field trips to the waterworks conducted in a similar manner.					
This kind of field trip increases my motivation for learning chemistry.					

6. What would you point out as the advantages and disadvantages of the conducted field trip?
a) Advantages:
b) Disadvantages:

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