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THE EFFECT OF LOWER-SECONDARY CHEMISTRY EDUCATION: STUDENTS' UNDERSTANDING TO THE NATURE OF CHEMISTRY AND THEIR ATTITUDES

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Abstract. *This research follows the previous study examining the effect of chemistry education on students' perception and understanding to the nature of chemistry (NoC) as well as their attitudes towards it as a school subject. Grade 9 students (N = 282) at the end of their compulsory schooling were given a set of open-ended questions focused on their understanding to NoC, perception of chemistry topics' importance, topics the students found interesting and their evaluation of chemistry as a school subject. The answers were analysed using the open coding approach. It is possible to conclude most of the students do not have a clear idea about the nature of chemistry. Students assess chemistry as a school subject in the middle of the 5 point Likert scale. The results of this research offer the background for a more complex analysis of effects influencing students's conception of chemistry and its subject matter.*

Keywords: *chemistry education, education effectiveness, interest in science, students' attitudes.*

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Introduction

The educational concept of chemistry is similar to a wide range of related areas (not only natural sciences) and affects many strata of society from the general public, teachers of the subject, to future professionals in the scientific field. Moreover, the topic is also very actual at the time of curricular change in many countries as it brings evidence for innovative initiatives. Student and teacher *perception and understanding of the education process in relation to conceptual changes* are, according to Teo, Goh, and Yeo's (2014) literature review, one of the most studied areas in Chemistry Education Research – CER.

This paper follows the previously conducted research in the field by Rusek (2011, 2013) focusing on students in their first year in Czech secondary schools (ISCED 3). The researchers found out that the tested sample of students in the cited research (only students in secondary professional vocational training schools) created a limited selection of data (80% of the overall secondary school population in the Czech Republic). The studies published in 2011 and 2013 concluded two comparable results. That is why the sample was changed and this research focused mainly on 9-grade lower-secondary or an according level of grammar school students in order to bring more information from a similar age group (one year younger).

These results offer a valuable source of information in the curricular reform process. Very often the key-word *reduction* is being used when talking about revising the curriculum (Sundberg, Dini, & Li, 1994). There are teachers who feel limited by the number of topics they need to go through in their classes. They usually state that they are not using activating strategies because they find them too time-consuming. There are also teachers who, at the lower-secondary but also at upper-secondary level, feel the need to prepare their students for the following school stage, therefore present them with as much subject matter as possible. As the goal of science education is rather seen by many in developing students' scientific literacy, the latter teachers' opinion needs to be reversed by cogent arguments. Only research

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data can bring these. It is therefore necessary to assess the current attained curriculum (cp. Thijs & van den Akker, 2009) in terms of the quality of particular education topis, i.e. current educational outcomes. Then a debate of revision can be started.

For this reason, the focus of this research adds to the research which brings evidence further usable in the curriculum change debate.

When addressing goals of science education, many researchers regarded student attitudes together with their conception of the nature of chemistry (e.g. Lyakh, Musial, Lotrich, & Bartlett, 2012) as one of the most important aspects in the area of education. Research has shown that interest in science education decreases (Bílek, 2013; Kubiatko, Švandová, Šibor, & Škoda, 2012; Osborne, Simon, & Collins, 2003; Osborne & Collins, 2000; Potvin & Hasni, 2014; Salta & Tzougraki, 2004; Veselský & Hrubišková, 2009). As far as the students' conceptions of the nature of chemistry are concerned, there is only limited number of research done (see e.g. Bunce & Gabel, 2002). Results about a broader concept – the nature of science – showed significant room for improvement (e.g. Lederman, 1992; Moss, Abrams, & Robb, 2001).

Reasons for this state have been frequently addressed by many researchers. Osborne, Collins, Ratcliffe, Millar, and Duschl (2003) stated that "science education is its own enemy as it leaves far too many students with a confused sense of the significance of what they have learned" (p. 694). Osborne and Collins (2000) and Osborne, Driver, and Simon (1996) suggested the main factor is the authoritative and not discursive approach towards science education. Associated with this challenge, difficulty of the language used in science/chemistry education is also an issue. Wellington and Osborne (2001) stated that "language is a major barrier (if not the major barrier) to most students in learning science" (p. 2). This part of science education research was also represented by textbook difficulty analysis (e.g. Biber, Conrad, & Cortes, 2004; Rusek, Stárková, Metelková, & Beneš, 2016; Rusek & Vojíř, 2019) as it significantly influences teachers' instruction. Other researchers gave other reasons for such phenomena: specific themes, methods and organization forms teachers use during science class or during individual natural science classes of biology, chemistry, geography, and physics. Another aspect is the relevance to students' everyday life (e.g. Elmas & Geban, 2016; Stuckey, Hofstein, Mamlok-Naaman, & Eilks, 2013). Potvin and Hasni (2014) indicated school's negative role on students' attitudes, which could also be associated with the course content (Sundberg, Dini, & Li, 1994).

This research was then focused on finding the effect lower-secondary chemistry education has on students' understanding to the nature of chemistry and on their attitudes towards chenistry. The research was conducted under two research questions: *How do senior lower-secondary school students perceive the nature of chemistry before leaving to secondary school?* and *What are the attitudes of senior lower-secondary school students towards chemistry before leaving to secondary school?*

The research was then divided into two areas:

1. Student's understanding the nature of chemistry, e.g. the set of beliefs and ideas of each student about the field, their perception of chemistry knowledge usefulness in everyday life,
2. Student's attitudes towards chemistry, i.e. interest in chemistry topics, evaluation of chemistry as a school subject (see Rusek, 2013).

Based on these factors at the end of compulsory elementary education it is then possible to assess the education effect at this school level.

Research Methodology

General Background

To formulate hypotheses, observed variables need to be identified. In this research, gender was considered a variable in the first and fourth question. It has been a topic of a lot of research, however, the information available is not unified. Klainin and Fensham (1987) pointed out differences in skills and theoretical knowledge increasing with age in favour of girls. On the other hand based on Baker's (2016) conclusions, science is more difficult to understand according to girls, more suitable for boys according to boys. Abungu, Okere and Wachanga (2014), brought the third possible conclusion – there is no significant difference between boys and girls in this respect. From this reason, one may expect boys to prove better understanding to chemistry than girls.

Greenfield (1996) found no differences in achievement and few in attitudes and perceptions – only more stereotypical beliefs held by boys.

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The research question was further concretized with the use of the following hypotheses:

H_1: There is a significant difference between boys' and girls' understanding the nature of chemistry.

The nature of chemistry was considered a set of understanding to the field (what it is, what it deals with) as well as its use (what it is good for in everyday life). Despite there is a lot of research results on this in science education, there is just a few papers published in chemistry education.

H_2: There is a relation between students' understanding the nature of chemistry and the grade they receive in chemistry.

In this research, the grade from the last report cards was taken into account. Students with good school grades were expected to prove understanding to the nature of chemistry. On the other hand, sumative assessment is not consistent and often varies depending on a teacher (Žlábková & Rokos, 2013). Students' grade then does not correspond with their abilities but is given after comparison with the group (Gibbs & Dunbat-Goddet, 2007). For this reason, proving the zero form of this hypothesis (no relation between students understanding of NoC and school grade) was expected.

H_3: There is a relation between students attitude towards chemistry and their grade in chemistry.

There has been a low up to a moderate correlation between attitude and achievement proved (Salta & Tzougraki, 2004). Students with positive attitudes are supposed to study a subject bore, therefore receive better grades. It is therefore possible to infer that students who received a better grade in chemistry have more positive attitudes towards school chemistry than students with worse grade (cp. Neathery, 1997).

H_4: Boys assess school chemistry more positively than girls.

According to Salta and Tzougraki (2004) and later by Baker (2016) girls consider chemistry to be more difficult compared to boys. This is in accordance with Škoda's (2003) result who assessed Czech students attitudes towards chemistry. These results were based on subtle studies, therefore limitations of comparing results of this study need to be taken into account when discussing the results.

Sample

The research sample represented a stratified sample combined with convenient sample (Henry, 1990). In order to ensure absolute response-rate, the questionnaires were distributed to schools the research team has a longer cooperation with via in-school teacher practice. First, the maximum number of grammar school students was chosen. Then the sample was completed with ordinary 9-year basic school students according to the real national ratio of students in 9th grade in lower-secondary schools, i.e. grammar schools and ordinary 9-year basic schools. The data is available online via the statistical yearbook (http://www.msmt.cz/vzdelavani/skolstvi-v-cr/statistika-skolstvi/statisticka-rocenka-skolstvi-vykonove-ukazatele). The basic schools were selected so they represented schools from the capital city and schools from medium and smaller size towns. Altogether 282 students (grade 9 - lower-secondary school, ISCED 2, 14 – 15 years of age) answered the questionnaire. In total there were 138 boys and 139 girls (5 students did not fill the gender item) lower-secondary school students involved in the research.

They were treated with respect to limitations of convenient sampling (see Henry, 1990).

Instrument and Procedures

To assess students' attitudes and understanding the nature of science, the Likert scale is commonly used in a variety of questionnaires (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Prokop, Leskova, Kubiatko, & Diran, 2007; Salta & Tzougraki, 2004; Švandová & Kubiatko, 2012). Respondents usually answer the questions or express their opinion using a 4-or 5 point Likert scale. Possible data processing of such scales has previously been analyzed by Chytrý & Kroufek (2017) who pointed out the deficits in this aspect. Another commonly used instrument is analyzing student attitudes via semantic differential (e.g. Brandriet, Xu, Bretz, & Lewis, 2011; Kubiatko, 2016; Lovelace & Brickman, 2013). Specific advantages and disadvantages of such a method were previously revisited e.g. by Schibeci (1982) leaving researchers with quite clear ideas. In both cases, the results are values (numbers) which are

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then, grouped into specific dimensions such as e.g. students interest, the complexity of the content, teacher factor, significance, meaning, tools (e.g. Prokop, Tuncer, & Chudá, 2007). Some researchers also included questions to detect perceived significance of scientific field and its connection to real-life use (Kubiatko et al., 2012). Such items then already include a connection with the educational content, but they make it impossible to directly observe tendencies in the effects of the concrete theme (content) on attitudes. To measure the nature of science, several questionnares were developed. These instruments combine a scale with interviews (see e.g. Lederman et al., 2002).

Focus on attitudes as well as the understanding the nature of chemistry requires vaster space for respondent expression then just statements used in ordinary scales. This brings a tool based on open-ended questions into play (see Lederman, et al., 2002; Schwartz, Lederman, & Crawford, 2004). To be able to compare and discuss the results, the respondents were given the same set of questions as in the previous two studies (Rusek, 2011, 2013). The research tool's content validity was considered confirmed in the previous research. It included basic demographic questions (grade, gender, school grade from the last period), three open-ended and one semi-open-ended question i) What is chemistry according to you and what is its scientific focus? ii) How useful is chemistry to an ordinary person? iii) What was most interesting in your chemistry class? iv) If you could, what school grade would you give chemistry as a subject? (1-5, where 1 is the highest and 5 the lowest grade).

As mentioned above, aside from these four questions respondents also filled in the grade assessment they received in the last report card for physics, chemistry, math, biology and geography classes, in Czech schools this is the last midterm of the 9th grade school year (each February).

The research tool was distributed by local university pre-service teachers during their teaching practice. This way it was possible to gather more data about individual schools and all the given sheets were also collected. The students overall spent around 20 minutes answering the questions.

Data Analysis

Responses to the open-ended questions were coded using open coding (Strauss & Corbin, 1990) by the first and the second researcher. The codes were assigned to particular student's answer by both coders, in case of disagreement the codes were further discussed (cp. Teo et al., 2014). The first question responses were compared with the official definition of the term chemistry. Two sub-questions are applied inside one analytical question, however the classic definition of chemistry as a scientific field usually includes both parts of the question asked in the research tool. During the data analysis, only one definition was taken into account, but the selection of the frequently used key words was taken from chemistry textbooks for Czech lower-secondary schools (Beneš, Pumpr, & Banýr, 1993, 1999; Škoda & Doulík, 2006). The definition of chemistry as a scientific field included key words such as natural science, substance analysis, change/conversion of substances, substance properties. Students' answers were evaluated mainly in agreement with definitions in the previously mentioned textbooks. Students who gave at least three out of the previously mentioned key words were put into a category of students with a very accurate idea about chemistry; those who gave only two were put into the category of a student who has a general idea about chemistry and finally, those who gave one or any of the key words were put into the category of student who has no idea/conceptualization about chemistry. The authors of this research are aware of the discrepancies which may be created using such an approach. Keeping such discrepancies in mind, however, the data are processed and interpreted so no discrepancies are made.

In the second and third question in the research tool, similar categories were used as in the previously conducted research. In case of new key word occurrence, new categories were created. Less frequently used word categories with similar meaning were merged together. Then the answers in each category were summarized in order to provide data about key word frequency.

The number of respondents allowed us to use quantitative statistical tests to analyze the first and fourth question. Basic descriptive and inductive statistical analysis based on chi-square test was used. Given the nature of the data, nonparametric tests were used to analyse the data. With respect to the particular case, Mann-Whitney test (Mann & Whitney, 1947) was used. This test was used to compare two independent datasets under the condition that we are working with ordinal data (Nachar, 2008). A similar analytical procedure was used to evaluate the subject of a student understanding to NoC. In this case, the Kruskal-Wallis test was used. For a correlation analysis Spearman correlation coefficient was used. This test was used due to the correlation of two ordinal data sets (Hendl, 2012, p. 433). The assessment of the strength of the variables association was made according to Hendl (2012) i.e. zero to very low (0,0); small, low (0.1-0.3); medium (0.3-0.7); large, high (0.7-1.0).

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Research Results

Understanding to the Nature of Chemistry (NoC)

The first question assessed the students understanding of chemistry as a scientific field, or more specifically their conception of NoC. This question was the most related to the chemistry curriculum, the so-called attained curriculum, as the students were supposed to sum up the conceptual knowledge they gained about the school subject here. Student answers are shown in Figure 1.

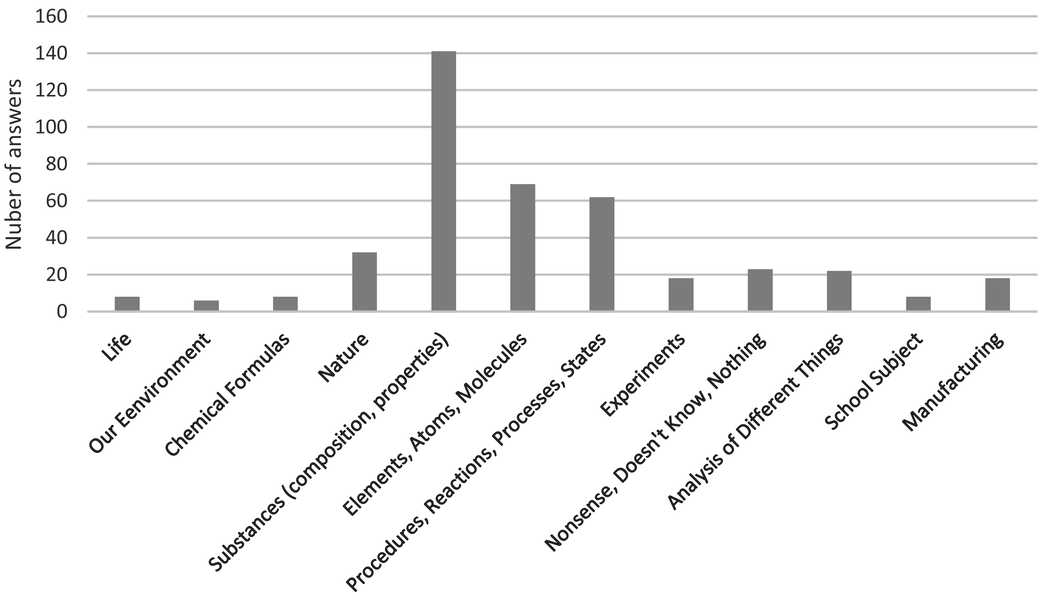

Figure 1. Frequency of words written by students - what is chemistry and what is it concerned with.

The most commonly used terms were substances (their content, properties, and analysis), elements and atoms (structure of substance), reactions and processes. The majority of the students (67%) showed no understanding to NoC. These students wrote no answer, nonsencial answer or statements like "Chemistry is good for nothing" or "It's nonsence.". Another 25% of the respondents showed "general understanding" to nature of chemistry. These students mentioned two key words in their responses. The results showed that only 8% of the students had an exact idea of what chemistry as a scientific field is.

To test H_1^0 about equal ideas of learners about chemistry, the χ^2test was used as an analytical tool. The result was χ^2= 0.97, *df*= 2, *p* = .328 which does not allow the rejection of the hypothesis. This suggested that both boys and girls had comparable ideas about chemistry as a scientific field.

Another hypothesis to this point H_2^0 was related to the zero effect of students' understanding to the NoC on their chemistry school grade. The detected value H (2, N = 278) = 6.33 *p* = .042 it is then possible to reject H_2^0. There was a statistically significant difference between the three groups of students. Performed post-hoc analysis showed that the difference was between the group who did not prove any understanding to NoC and the group who provided good understanding to NoC. The average school grade of the students who showed understanding to NoC was 1.89, and the group with no understanding to NoC 2.24 (1 being the best and 5 the worst school grade).

Based on the following descriptive analysis, a certain trend can be observed. Students who proved good understanding to NoC received better school grades comparing to the students with no understanding to NoC. The results suggested that school assessment is in accordance with the students' understanding of NoC. When analyzed in detail, the respondents' answers (their quality of answers even when no key words were found) did not give any significant change in results. Some interesting answers were spotted, however: "experiments in

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forensic labs", "is related to uncovering the nature of the world through the smallest molecules" or „is concerned with modernizing chemical procedures, such as conservation and preservation" example, one response: "When I hear the word chemistry, all I see is a structure of a formula. It is concerned (chemistry) with something that does not interest me and I am bad at it, because I don't understand it.", "I don't know, I sleep", or "I will never calculate stupid equations in my life", such answers give an insight not only to the range of the students' knowledge but also predict what answers will follow in the next two question items inside the research tool. It is, therefore, possible to say that chemistry education of the tested students did not provide a sufficient picture about the significance of chemistry, not only as a school subject but as a scientific area useful for everyday life, so that students will be able to describe what chemistry is concerned with.

In cases when the results were similar even inside the representative data sample, thus generalization would be possible, there is a danger in the future of science/chemistry as a scientific area. It is impossible to assume and predict that students would choose a career in an area which they do not understand. This idea/concept, as well as any other aspects of NoC, was then tested via the following question items.

Use of Chemistry in Everyday Life

This question, focusing on the target group of students, was designed to find out about another part of NoC – students' view of the practical side of chemistry. In this respect, the link between chemistry subject matter included in the curricular documents for lower-secondary education (grade 6 to 9) and its practical use as seen by students was tested.

Answers were usually quite narrow and short - one or two-word answers. However, their response spectrum was relatively broad. It was, therefore, essential to set such answer categories which would reflect the answers correctly (see Figure 2). Similar categories were used in previous studies as well (Rusek, 2011, 2013). The most frequent category was the practical use of chemistry. Some students used this phrase, whereas others gave specific situations e.g. "chlorine concentration in pool water", "mixing hair-colors in order to become a good barber/hairdresser", "mixing of detergents", etc. One of the frequently used answers for the practical use of chemistry was cooking. The second most frequent category was set to work and health safety. All the answers which related to safety measures were usually based on the knowledge of substance properties such as "understanding the warning signs on bottles", "to know what is dangerous", "I know I shouldn't drink denatured alcohol". Third the most frequent category regarded general knowledge. This category included answers related to the general properties of chemical substances in everyday life e.g. "everything we do is chemistry and some sort of reaction", "general knowledge of chemistry is good for crosswords.". Not very frequent categories were: *pharmacy and medical use* (35 respondents), e.g.: "Chemistry is important for scientists. They develop vaccinations and medication", *manufacturing* (31), *learning about the natural environment* (27), *industry* (19), etc.

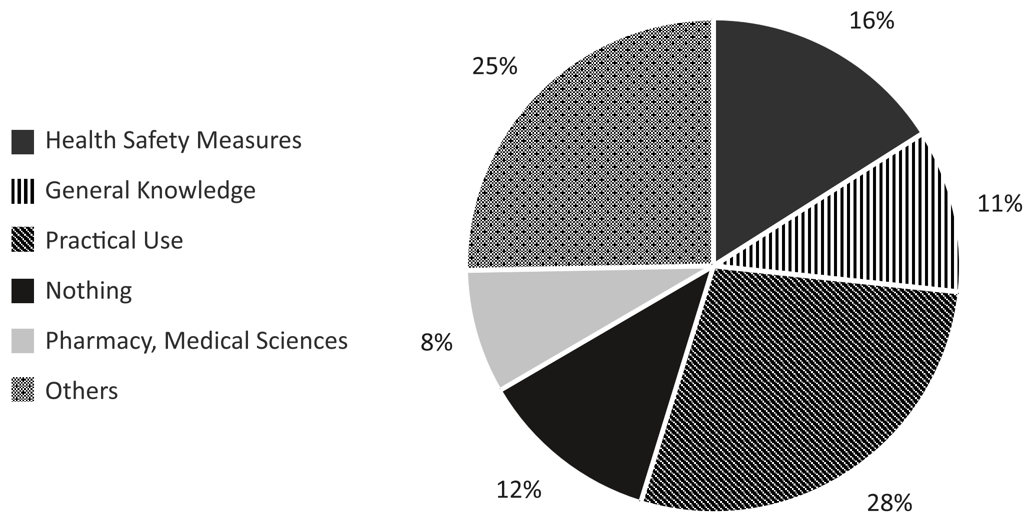

Figure 2. Chemistry use in everyday life according to the students.

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A number of key words written by one respondent gave also a good picture of the results shown in Figure 3.

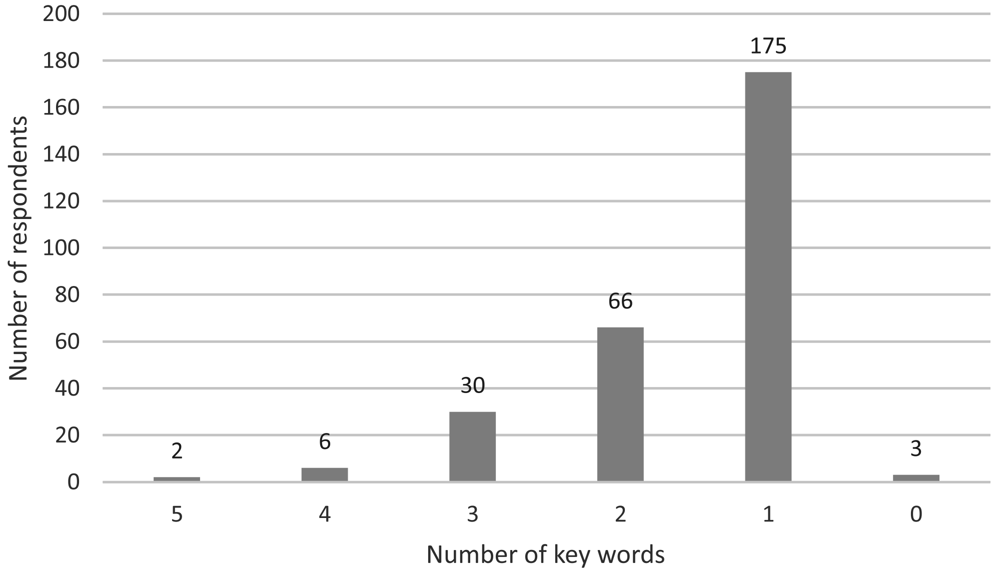

Figure 3. Number of key words given by one respondent to the second question.

Keeping in mind the quite short size of the research tool, it is possible to interpret the number of key words given by students as a demotivation towards answering a question or an inability to think about a particular school subject in a wider context. Another interpretation of this can be the efficiency of information given during chemistry classes. This possibility agrees with previous studies which support the idea that less favorite school subjects are perceived as useless among the student population in primary schools.

Interesting Aspects of Chemistry Teaching – What Attracted Students Attention During Chemistry Classes

This question was focused not only to finding out the lesson content from students, but also offers an overview of learning motivation in chemistry as a science. Almost half of the respondents (129) mentioned experiments to be a very interesting element of the lessons. This then creates the largest category which was an expected and predicted outcome because it frequently occurs in original texts.

The second and third most frequent category included answers from 37 respondents. Out of which the largest group was the group containing answers: hydrocarbons and their derivates. This answer was not surprising either because the 9th graders have been exposed to the theme as learning content in the year the research took place (which was reflected in the collected data). Another category was labeled as "I don't remember, I don't care". Both merged with the category of nonsense (3 respondents) and boring chemical nomenclature substance quantifying (2 respondents), all of these categories altogether are more than 40 responses of a negative nature. Keeping the data collection in mind, it is not possible to generalize the student answers. It is, however, possible to argue that students who do not mention any application for chemistry in everyday life, remember less from the lessons and hold more negative attitudes. Two other categories which altogether represent 6% of all responses were positive. This category was labeled "I like it all", e.g.: "I was quite surprised how complex it is and how much it makes sense at the same time" or "I cannot say what made me interested the most. Chemistry is interesting overall, even though it is hard for me sometimes." Other categories were summed into: "practical for everyday life": "I liked the moment when I found out what are things which I use daily made of (PVC)" or "getting to know the world better." Most frequent categories are shown in Figure 4.

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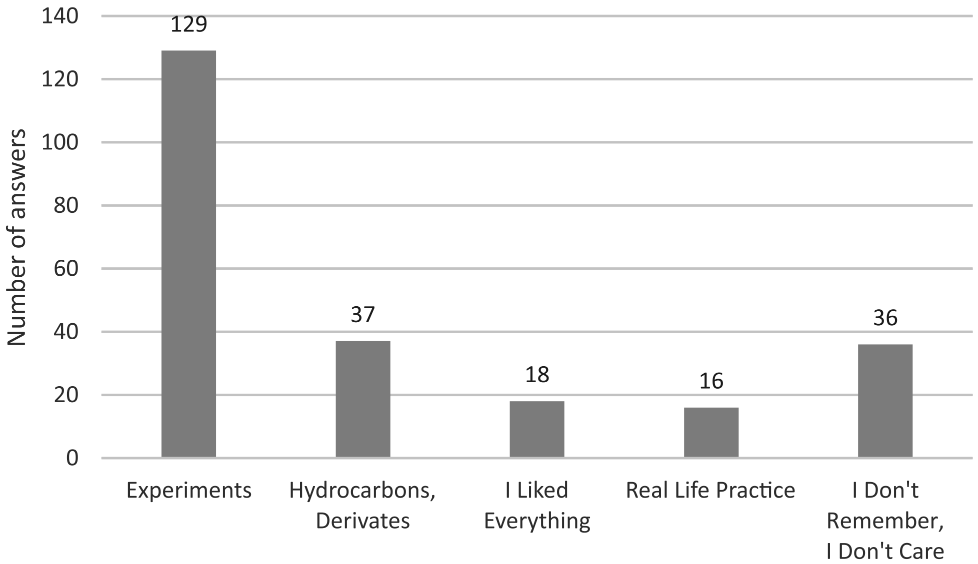

Figure 4. The most frequent answers about what the most interesting topics in chemistry.

As well as in the case of question 2, Figure 5 gives the number of key words answered by one student. In comparison with the perceived use of chemistry, students gave more areas of use in their answers.

The ratio of students who gave more key words was quite high. The higher amount of used key words probably suggests students interest in chemistry, more specifically, a higher number of positive aspects in chemistry teaching, which they can name.

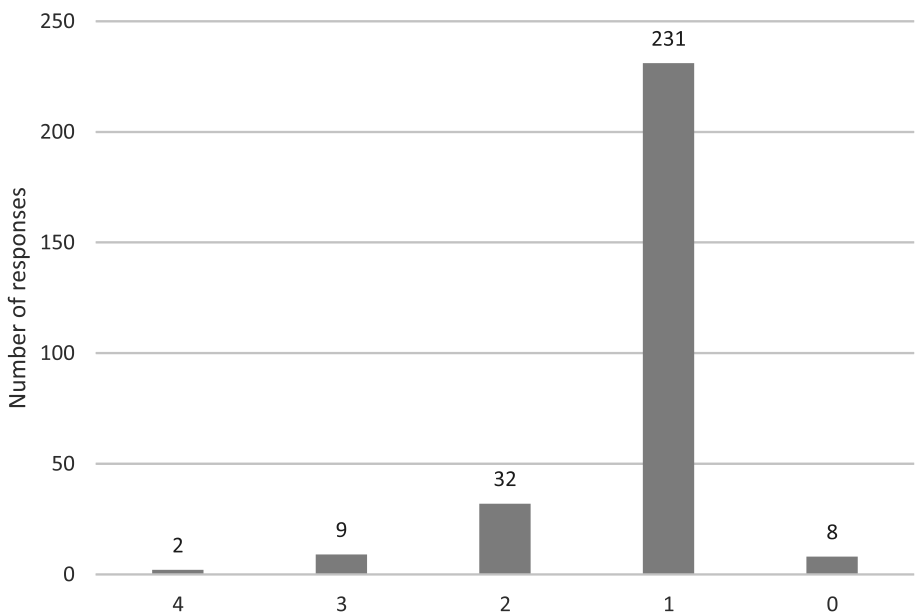

Figure 5. The number of key words answered by one respondent to the third question.

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Student Evaluation of Chemistry as a School Subject

The fourth question, which was related to the students' attitudes towards chemistry, was answered via a simple Czech school-grading scale (1 the best and 5 the worst evaluation). This item was answered by all the respondents. Students also used minuses and half points in their evaluation e.g. 1-, 1/2 etc. In such cases, the evaluation was given the value of 1.5. The results can be seen in Figure 6. Statistical analysis and interpretation of the data are given below.

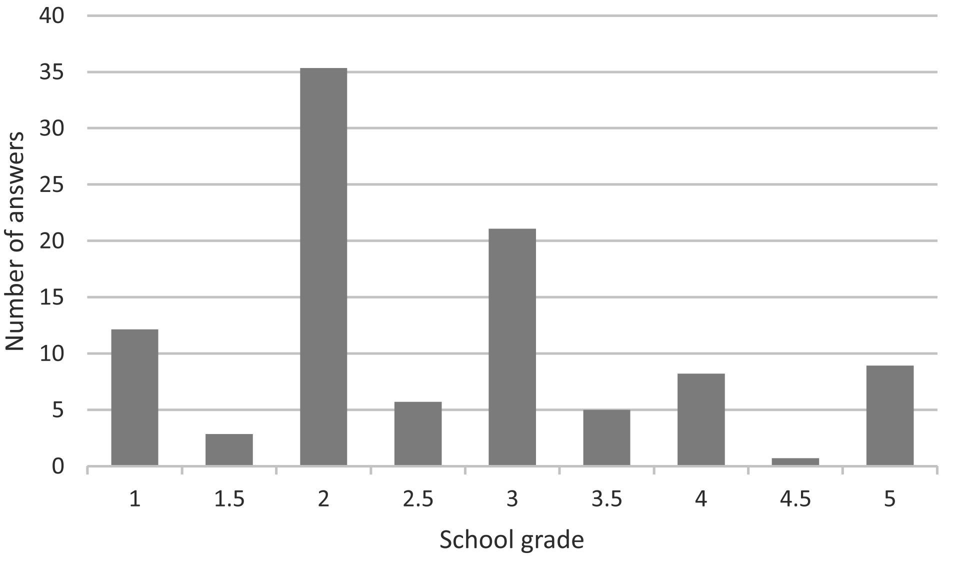

Figure 6. **Student evaluation of chemistry as a school subject.**

The average school grade is shown in Table 1. Researchers are aware of the possible error in calculation. School evaluation creates an ordinal data scale which includes the values of o 1, 1.5, 2 etc. Relating this to school practice in Czech schools, this evaluation and data processing was kept and worked with. With a slight distortion of the data, it is possible to say that grade 3 reflects rather neutral attitudes of students towards chemistry as a school subject.

Table 1. **Students' average evaluation of chemistry.**

Mean	3
Median	2.25
Mode	2

The collected data allowed comparison of student chemistry evaluation with the grade they received in the last half-year. The same grade from the assessment and report cards was found in 37% cases. Only 16% of students gave chemistry a better grade than they received in their report cards. A worse grade was given in 54% of cases. The H_3^0 hypothesis about the zero effect of the report card grade on the student evaluation of chemistry as a school subject was possible to reject. The final *p*-value result ($p < .1$).). The correlation coefficient was then calculated to be $r = .37$, which points to a moderate effect of report card grade on the student evaluation of chemistry as a school subject. The better grade students received in their report cards the worse grade they gave chemistry in the research tool.

Furthermore, in the case of analyze the H_4^0 hypothesis about the equal assessment of chemistry as a school subject by boys and girls, the resulting value of $p = .573$ ($U = 9226$, $Z = 0.546$) does not allow this hypothesis to be rejected. Both girls and boys assessed chemistry similarly, on average that was 2.52 (med 2.5).

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Discussion

Added value of this research dwells in the picking up on previous research in the same area, a spreaded sample and altered questions the respondents were asked. As far as age is concerned, the only diference between the sample of the previous research and this particular one is the summer holiday period as the sample of this research contains lower-secondary school students at the end of the ninth grade (age 15) and the sample of the previous studies contained students at the beginning of their upper-secondary school studies. In the previous research, vocational school students were questioned (the mainstream among upper-secondary school students). In this research, a broader sample was used and grammar school students were included. With the school successfulness of grammar school students in mind (Straková, Greger, & Soukup, 2017), the results of this research were expected to be better than in the previous research. This was not proved, however.

This research was aimed at students' understanding to Nature of Chemistry and their attitudes towards chemistry education. The concept of NoC was simplified to the students' ideas about what chemistry is and what its purpose is. Their attitudes were assessed with the use of a simple scale the students are familiar with – school grade. This enabled the research instrument to be brief enough and short to fill-in without potential risk of the students omitting any item because of their tiredness or boredom (cp. Ben-Nun, 2008).

The results showed majority of the students do not understand NoC. Comparable results were published by Bunce and Gabel (2002), who presented a group of students with particular research content (composition of particles). Compared with the results of the research conducted by Rusek (2011, 2013), the ratio of students who have no idea about NoC is greater. The probability that the status quo has changed in just the last few months (secondary school students tested in the previous research compared to lower-secondary students in this) is very low. A possible interpretation of this data may be in the approach of chemistry teachers in lower-secondary schools towards this field of science. The results may also suggest that students are taught content which is not up to date and the relevance of the content is not highlighted enough either (see Stuckey et al., 2013). Due to the differentiation of the tested respondent groups and data selection, it is not possible to place more judgment on the results. It is interesting, however, to compare students based on their understanding to NoC and opens more room for future research: Do students understand chemistry as a scientific field or is it just a sequence of topics they pass? or What chemistry teachers consider to be the main goal of chemistry education, how is it reflected in their teaching and how is it perceived by their students?

No effect of gender was proved on the students' understanding of NoC which corresponds with Abungu's et al. (2014) results. However, an effect, although small, of school grade on the students' understanding of NoC was proved. Students' understanding to NoC seems to be either assessed by teachers or corresponding with the subject matter the teachers assess. Students with better school grades from chemistry proved better understanding of NoC compared to their peers with worse grades in chemistry. It is possible to infer that understanding to NoC is easier to assess with typical school tests compared to problem tasks (Vojíř, 2017) or inquiry-based tasks (Žlábková & Rokos, 2013) where students with worse school grades show better results than students with good marks. This also offers another room for research.

The results of this research also seem to be affected by students' attitudes towards chemistry. (Salta & Tzougraki, 2014; Veselský & Hrubišková, 2009). The combined results of the the first three questions showed that students not only do not have a very specific understanding to what chemistry is, but also seem to miss significance and usefulness of chemistry for common citizens. This can be caused by the teachers' approach, ideas of what the core subject-matter is (cp. Nationar Research Council, 2012) and also by the conception of chemistry education in general (Škoda & Doulík, 2009).

The fact that students do not mention more than one (or only one) interesting theme from chemistry lessons could be cause by a little interest in filling the questionnaire. However, it could also suggest that current chemistry education does not aim at practical use, or everyday life. This approach correlates with the old-fashioned scientific perception of education (Škoda & Doulík, 2009) still present at Czech schools. Focus on factual knowledge proved eg. by PISA 2006 (Palečková, 2007) is regarded as less motivating than other foci (e.g. DeBoer, 2000). The issue of study content relevance (Elmas & Geban, 2016; Stuckey et al., 2013) has been the main topic of discussion in recent years. As proven by Sundberg et al. (1994), a decrease in course content could be a benefit too.

An important aspect of chemistry education – experiments – was given a special attention in this research. Experiments were mentioned as the most interesting aspect of chemistry eduation. The findings give basis for an additional study focused on the experiment ratio in lessons and their outcomes. Indicators of unsuccessful experi-

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ments or their absence are in accordance with PISA 2015 (Blažek & Příhodová, 2016) results which show that there is not yet an optimal sensible approach seen in contemporary schools towards experimental activities in chemistry. However, the main question still remains about the frequency of experimental activities during lessons and their quality (Blažek & Příhodová, 2016, pp. 34-36). Detailed analysis of students' responses provides more information. Traces of unsuccessful experiments during class occurred in the students' answers "explosion of the burner and half of the desk being set on fire". Other answers pointed to the absence of experiments in classes "I would probably like chemistry more if we had experiments in class, but we don't do them", "We didn't do any experiments, but we have seen them online."

Compared to the previous research, the respondents did not mention the role of a teacher (cp. Prokop, 2007a) as a significant factor of their interest in chemistry. It is possible to assume that the role of a teacher is better perceived by secondary school students than lower-secondary school students. This assumption is, however, in dispute with the classic categories of attitude questionnaires in which the role of the teacher is regarded as an important aspect (e.g. Prokop et al., 2007b; Salta & Tzougraki, 2004).

The last question added to the affective part of the research. The mean value of the students' evaluation of chemistry is 3 (on the scale from 1 to 5). This neutral result is in agreement with the study conducted by Šandová and Kubiatko (2012). Nevertheless, the grade 3 is not considered satisfactory. Considering the values of the students' attitude known from previous research, the result can be regarded as a positive. This value is better than the average level, previously analyzed by Rusek (2011). (In the previous research, the mean value was 3.16.) More detailed information is given in Figure 6. The slightly better result could be explained by the sample selection. Lowersecondary grammar school students were included in the sample, also a certain number of students leaves for upper-secondary grammar school after the ninth grade. As these are considered good, generally motivated students (Šorgo, Lamanauskas, Sasic et al., 2017). Grammar school students' attitudes towards chemistry at the beginning of their upper-secondary studies could then be expected a little more positive comparing to the vocational students. This could be an important impulse for teachers and textbook authors as at least the introduction to the field is supposed to consider the students' motivation.

These results could be used as a support for integrative initiatives. They can be school projects (Bílek & Machková, 2015; Janštová & Rusek, 2015) or movements such as STEM (Science, Technology, Engineering and Mathematics) combine the fields which enables to show the relevance of particular facts. A subject which would be integrated and focused on everyday life questions - as seen in Germany - e.g. Chemie im Kontext (Parchmann, Gräsel, Baer, Nentwig, Demuth, & Ralle, 2006) - throughout better relevance, it is then possible to increase student motivation and interest, which is the most important mission of a general school subject. Another, currently quite widespread factor of improvement could be the use of modern technology. This is, however, limited by the attitude and competence of teachers and their ability to work with technology in education (e.g. Rusek, Stárková, Chytrý & Bílek, 2017). It would also be interesting to see what impact a teacher has on the Culture of Problem Solving (CPS) as introduced by (Eisenmann, Novotná, Přibyl, & Břehovský, 2015). It is obvious that this topic offers more to observe. Also, the outcome of chemistry education ascertained in this research offers information to textbook authors who could utilize the data to design the learning text more with respect to the students' knowledge and expectations (cp. Rusek & Vojíř, 2019).

Conclusions

The students in this research proved only a limited idea about chemistry as a scientific field and were able to mention only few areas in which chemistry knowledge is useful, pointing to a low teaching content relevance to student lives. According to similar student answers from vocational secondary schools or secondary schools with no scientific focus in previous research, it is possible to conclude that chemistry education and teaching as a general science school subject seems not to give students exact idea about NoC, neither seems to provide students with knowledge they would regard as interesting and useful. Only rarely did students mention specific aspects of their chemistry lessons they remembered and found useful or interesting. Because of the fact that students undergo around 120 lessons of chemistry throughout basic school, the overall impact on the affective aspects seems not to be very satisfying. From this point of view, the effect of chemistry education does not seem to be satisfactory. Out of all of the tested student population, only a minority will probably study any natural science subject or even choose chemistry as their primary career choice. Nevertheless, in order to be able to consider the time in school to be well spent, the educational outcomes should be more conclusive.

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There are several limitations of this research. Due to the range of data, such data selection cannot be defined as randomized and stratified. The selected data sample respects, however, the diversity of the tested population. Such research then expands the current knowledge about the area of interest and compared with the previous results, is able to evaluate the study output of school subject chemistry and its efficiency at lower-secondary school level. Another data distortion can be spotted in the use of open-ended questions. Students answer these less willingly. Also, the need to quantify data led to omitting less frequently used answers. The results can have some distortion by the aim to evaluate student-opinion focused questions (question 1). Student understanding the NoC seems to reflect education outputs and thus represents a significant item in the research.

On the other hand, the open questions with quite a narrow focus bring information of a qualitative nature from a larger number of students. This broadens the understanding to the effect of chemistry education usually identified with the use of close-ended questionnaire items.

Individual topics in chemistry education content and factors which affect not only student motivation, but also the result of education in the current environment will be examined in the future. Further attention will be given to integrated educational process from the teachers' and students' perspectives.

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