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# Constructivist Practices in Teaching Chemistry: A Cross-National Study

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# Constructivist Practices in Teaching Chemistry: A Cross-National Study

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**Abstract**

This report shows the plan, methodology and results of the study over a very crucial problem, in science education related to development of interest of students to chemistry lessons by constructivist teaching approach. A cross national study entitled "In the past and now: Constructivist practices in teaching chemistry - Bulgaria, Balkans and Europe" has been conducted. During the research the author was trying to find answers to the following questions: "What are the current trends in the application of constructivist approach in Bulgarian schools, the Balkans and in Europe?" and "What are the attitudes of teachers towards the usage of constructivist methods in teaching chemistry in the surveyed countries?" The purpose of the research was to assess science secondary classroom environment in terms of constructivist approach, to explore the high school science classroom of a constructivist teacher and examine how constructivist-based teaching influences students and their learning of chemistry not only in Bulgarian schools but also in neighboring countries.

The data collection methods for students were three surveys – What is happening in this class? (WIHIC), Constructivist Learning Environment Survey (CLES) and Modified Attitude Scale Modeled on Test of Science Related Attitudes (TOSRA) and for teachers: Teacher Pedagogical Philosophy Interview (TPPI). The study has been conducted in international schools and state schools in Tirana (Albania), Pristina (Kosovo), Bucharest (Romania), Bielsko-Biala and Warsaw (Poland) and Vienna (Austria). Till now the questionnaires have been given to 788 secondary school students and 17 teachers.

**Keywords:** Constructivist teaching approach, chemistry education, cross-national study

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## Introduction

We live in a world where there are always changes, transitions, development and construction. These cases are the fastest and most effective when they are about children or students. Recent years significant reforms in education have taken place. National Program for Development of School Education and Pre-school Education (2006-2015)[1] is based on the understanding that the main value of the educational system is the child (student). These reforms are the result of joining the European Union and the requirements to be competitive in the labor market in a dynamic global economy (the Lisbon Strategy). Becoming a global village helped us to refine and explore better and more modern teaching methods. To be competitive, you need to keep in touch with the world.

One of the most important principles in the psychology of learning is that students should construct their own knowledge in mind (Hollenbeck, 2009).The teacher becomes a mediator (mediator) to assist this process, allows students to discover and implement their ideas independently, processes the data so that it is understandable for them.

Learners have difficulty in understanding most of the concepts in chemistry and have incorrect notions that hinder consistent train (Garnet, 1992; Hesse, 1992; Pardo & Solez – Patolez, 1995; Renstorm, 1990; Staver, 1995). This fact leads to the problem of developing students' interest in chemistry as a school subject. The application of the constructivist approach is a method that can be beneficial in overcoming this case. Constructivist approaches in teaching and learning of science are applied in order to enable students to make meaningful connections between significant new knowledge and transient (Hollenbeck, 2009). Thus it can be expected that it will increase the attractiveness of teaching as the subject chemistry and the study content.

This report shows the plan and methodology of the study over a very crucial problem in science education related to the constructivist teaching approach which is in agenda in modern education nowadays.

Declining popularity of science among students, including chemistry is a global trend (Toshev, 2007). The application of the constructivist approach is supposed to be a better and more interesting way of teaching that can help students to understand the abstract concepts in chemistry.

Over the past twenty years the interest in student thinking and in the relationship between teaching and learning has increased in school education research. In higher education, teachers have introduced alternatives to traditional teaching methods in order to address these interests in thinking and student learning (Theall, 1999).

According to Savery & Duffy (1996) problem-based learning assignments are one of the best strategies for putting constructivist theory into practice. Discovery learning and problem-based learning are two investigative learning

[1]Ministry of Education and Science, School and pre-school education development national programme. http://www.mon.bg/opencms/export/sites/mon/en/left_menu/acts/programme_ministry-of-education_2006-2015.pdf

strategies that involve students in the learning process. These strategies can constitute constructivist learning and can be effective strategies in higher education.

Since constructivist methods encourage students to learn content and process information through discovery and reflection, these might bring about this desired depth of learning.

*Some of the most Important and Well-known Constructivist Theorists*

Constructivist approach is one of the leading trends in modern psychology and pedagogy. It is not associated with an aspect of training as methods or curriculum, but a comprehensive approach based on the understanding that the process of cognition is the new knowledge associated with previous experience of the learner. Student learning in a constructivist learning environment is one of the modern trends of continuous reforming education and science (Tafrova-Grigorova, 2012).

Jean Piaget (1929, 1950, and 1952) introduced the constructivist concepts of assimilation and accommodation, which describe the way students construct their own meaning as they experience the world. Jerome Bruner (1966, 1971, 1986, 1990, and 1996) built upon the constructivist philosophies of Dewey, Vygotsky, and Piaget as he explored the process and the culture of education (Wagner, 2008).

## Methodology of Research

*Aim, Research Questions and Tasks*

**The aim** of the study is to investigate science classroom environment in Bulgarian and other European schools. For this purpose it is necessary to seek teachers' and students' views on the application of constructivist-based teaching and learning practices and thus to explore the high school science classroom environment.

**The research questions are:**

1. What are the students' perceptions of science classroom?
2. What is the teachers' pedagogical philosophy of secondary science teachers?
3. Do the science teachers apply a constructivist inquiry approach in classroom?
4. What are the current tendencies of the application of constructivist approach in Bulgarian schools, the Balkans and Europe?

**The tasks** which come out from these questions are as follows:

1. To conduct a survey of samples of science teachers and their students in some European countries including some schools from the Balkans.
2. To explore patterns that emerged after close observations and careful documentation.

3. To analyze the survey results and to draw conclusions about constructivist-based teaching in high school science classroom environment.
4. To propose and recommendations for future projects, initiatives and studies.

*Instruments*

Different instruments have been used (QTI, SLEI, CLES, WIHIC, TPPI) by educational researches to identify the characteristics of constructivist learning environment (Tafrova-Grigorova, 2012a). The instruments used in the present study are: *What is happening in this class? (WIHIC), Constructivist Learning Environment Survey (CLES) and Modified Attitude Scale Modeled on Test of Science Related Attitudes (TOSRA) for students and for teachers: Teacher Pedagogical Philosophy Interview (TPPI).* These instruments have been chosen among many other of the kind because they have been used by other researches and their validity has been proven.

The WIHIC questionnaire is the most-frequently used classroom instrument around the world today (Fraser, 2012). The original WIHIC includes 90 questions in nine categories. This version is processed by statistical analysis of the responses of 355 students on what is happening in their classes in science (Fraser et. al., 1995). Analysis of the 1081 Australian students gives final version of the questionnaire (Aldridge et. al., 2000). It contains seven categories containing eight statements (Student Assistance, Support from teacher Involvement, Research Orientation in tasks Cooperation, and Reciprocity). The answers can be from "almost never" to "very often." "I discuss ideas in class" and "I work with classmates on projects in class" are examples of statements in categories Commitment and Cooperation. WIHIC tool has been translated into several Asian languages and is often used for research in Asian countries like China, Singapore, Indonesia, South Korea, Brunei and others.

CLES is a survey to explore the views of teachers for students' learning environment in which they learn and adjust their learning environment into they would like to have. This tool enables you to seek answers to the questions: (1) how teachers and students perceive the learning environment in which they work and (2) what the learning environment they want to work is. The original version consists of 36 statements, but then undergoes processing and development based on critical constructivism, to take account of socio-cultural constraints of the individual learner, which affect his cognitive constructivist activity (Fraser, 1991). The new version consists of a series of claims, structured around five key elements of constructivist learning environments: Benefits for students (Personal Relevance), Scientific Uncertainty, Critical Voice, Interaction student - teacher (Shared Control), Interaction student - student (Student Negotiation). Allegations of Personal Relevance Category aim to establish whether there is a link between what is taught in school science and extracurricular life experiences of students, Scientific Uncertainty - how students understand that science does not only have the simple answer that it

develops and changes; Critical Voice - whether and how students can freely express their opinions about their training methods; Shared Control - how the training is centered around the students so that they can manage and control their own learning; Student Negotiation - the extent to which students share another learning experience and activities can be mutually appreciated.

National specificities of school education are considered in the translation of CLES to the corresponding language - the questionnaire is adapted so as to be well understood by the respondents. In Bulgaria, the first research was conducted with CLES, which examines views of Bulgarian students and their science teachers, differentiated by age, location, type of school and gender, for real and desirable learning environment (Boiadjieva et. al., 2009; Boiadjieva et. al., 2011; Hollenbeck, 2009). The views of students and teachers are reported at point Likert scale with ratings of "This is almost never the case." to "This is almost always the case."

The Bulgarian version of the CLES consists of 23 statements arranged in two series, each of which refers to the current and preferred learning environment. Statements are grouped into five categories listed above.

CLES is a tool that has at least two advantages. First of them is that the researcher can analyze the research problem through the relationship between perceptions of the teacher and his students, and the second - that allows for expression of their personal opinions of teachers and students in a short time and with little preparation or training. Discriminative validity - the ability to discriminate on various grounds, such as gender and class, and the reliability of CLES has been proven repeatedly.

Test of Science-Related Attitude, (TOSRA) (Fraser, 1981), is the most widely-used attitude instrument in science education research today (Fraser et.al, 2009). TOSRA clearly defines each of the constructs to be measured by providing distinct subscales based on Klopfer's (1971) classification of students' attitudinal aims: attitude to science and scientists, attitude to inquiry, adoption of scientific attitudes, enjoyment of science learning experiences, interest in science, and interest in a career in science. These six constructs are clearly defined and each represents a different 'object' about which students are likely to form opinions (Fraser et.al, 2009).

In order to investigate the relationships between the learning environment and students' attitudes in the investigated countries the TOSRA tool was selected. The final version of TOSRA measures seven distinct science-related attitudes among secondary school students: Social Implications of Science; Normality of Scientists; Attitude to Scientific Inquiry; Adoption of Scientific Attitudes; Enjoyment of Science Lessons; Leisure Interest in Science; and Career Interest in Science (Fraser 1978, 1981). This instrument is composed of seven scales and each scale is composed of 10 items. The response scale is a five - point Likert scale and has response categories ranging from Strongly Agree to Strongly Disagree. Teachers and researchers have found TOSRA useful and easy to use for measuring and monitoring progress of science-related attitudes of individual students or whole classes of students. In particular, TOSRA also makes it possible for researchers and teachers to obtain

a 'profile' of attitude scores for a particular group of students (Fraser et.al, 2009). In the present study "Enjoyment of Science Lessons" scale with 10 items has been administered to students. The responses were given by on a three – level Likert scale: 1- Disagree, 2- Not sure, 3- Agree. Maximum score per item is 3 and total maximum score is 30.

TPPI - Teachers Pedagogical Philosophy Interview is a questionnaire which is designed and developed by Richardson and Simmons (Richardson & Simmons, 1994). It consists of two sets of questions.

The first group of questions is related to the way of teaching. Respondents have to describe themselves as teachers and to highlight their professional qualities. The answers of the second group questions require information how both teachers and students learn.

*Background of Research*

The basic parameters of the study are the following:

Period of carrying out: October 2012 - April 2013.

Target group: high school students, science teachers (chemistry, biology and physics).

Volume and composition of the sample: *The study has been conducted at international schools and state schools in Tirana (Albania), Pristina (Kosovo), Bucharest (Romania), Bielsko-Biala and Warsaw (Poland) and Vienna (Austria). Till now the questionnaires have been given to 788 secondary school students and 17 teachers. In our previous research 30 teachers were surveyed from 28 schools from 9 areas of Bulgaria.*

*Procedure:* The TOSRA tool were first given to 15 students in $10^{th}$ grade and 13 students in $11^{th}$ grade at an international school in Tirana, Albania. A chemistry teacher was interviewed by TPPI. On the same day the questionnaires were given to 123 students in $11^{th}$ grade and 55 students in $12^{th}$ grade at a private school in Tirana, Albania. Seven teachers were interviewed at this school.

Secondly, the same questionnaires were given to 98 students in $11^{th}$ grade at a private school in Pristina, Kosovo and to one teacher.

Later 43 students in $10^{th}$ grade, 16 students in $11^{th}$ grade and 18 students in $12^{th}$ grade at a computer school in Bucharest, Romania answered the TOSRA questionnaire. TPPI was applied to three teachers at this school. On the same day the questionnaires were given to 14 students in $11^{th}$ grade, 10 students in $12^{th}$ grade and 3 students in $13^{th}$ grade and one chemistry teacher at an international school in Bucharest, Romania.

In Poland the survey was conducted in two cities: Bielsko-Biala and Warsaw. The school in Bielsko-Biala was a public school and the one in Warsaw an international school. In Bielsko-Biala the TOSRA questionnaire was given to 115 students in $2^{nd}$ grade (high school) and 80 students in $3^{rd}$ grade (high school). One teacher answered the TPPI questions. In Warsaw 14 students participated from $1^{st}$ grade (junior high school), 12 students from $2^{nd}$grade (junior high school), 16 students from $3^{rd}$ grade (junior high school), 11students from $1^{st}$ grade (high school), 23 students from $2^{nd}$ grade (high

school) and 15 students from 3rd grade (high school) from the international school. TPPI was administered to three teachers there.

Finally, in Wien, Austria totally 94 students participated in the survey. 25 students were from 1st grade (high school), 12 students were from 2nd grade (high school), 17 students were from physics biology class, 19 students were from technology class and 21 students were from 12th grade. One chemistry teacher answered the questions. The distribution of the students and teachers are given in Table 1.

**Table 1.** *Number of surveyed students and teachers – distribution by countries*

| Country | Students | Teachers |
|---|---|---|
| Albania | 206 | 8 |
| Austria | 94 | 1 |
| Kosovo | 98 | 1 |
| Poland | 286 | 3 |
| Romania | 104 | 4 |
| Total | 788 | 17 |

Data on the composition of the teachers' sample is given in Table 2. The distribution of the teachers by age, pedagogical internship and sex has been done in this way to comply with the total for the countries.

**Table 2.** *Teachers' sample composition*

| Characteristics | | Al | A | Ks | Pl | Ro | Total |
|---|---|---|---|---|---|---|---|
| Age | up to 30 years | 4 | | 1 | 2 | 3 | 10 |
| | 31 – 40 years | 3 | | | | 1 | 4 |
| | 41 – 50 years | | 1 | | | | 1 |
| | over 50 years | | | | 1 | | 1 |
| Pedagogical internship | up to 10 years | 7 | | 1 | 3 | 4 | 15 |
| | 11- 20 years | | 1 | | | | 1 |
| | 21- 30 years | | | | | | |
| | over 30 years | | | | | | |
| Sex | women | 6 | 1 | | 2 | 1 | 10 |
| | men | 1 | | 1 | 1 | 3 | 6 |

Legend: Albania: Al, Austria: A, Kosovo: Ks, Poland: Pl, Romania: Ro

In the formerly mentioned previous research on "Science Teacher`s attitudes towards constructivist environment: a Bulgarian case" a survey was conducted as a part of our research activities on the constructivist science teaching practices in the Bulgarian schools. Teacher Pedagogical Philosophy Interview (TPPI) was applied as a research instrument by adapting and reducing it up to six questions. The sample of research consisted of 30 secondary science teachers at 28 schools from 9 areas of Bulgaria.

*General Results of the Present Survey*

In the present study the data resulted by TPPI which is administered to the teachers and TOSRA tool which is administered to their students will be discussed. From total 788 surveyed students with TOSRA questionnaire 710 are the valid results see (Fig.1). The measures of the central tendency: mean score, median, mode and the standard deviation for the total of 10 items of all 710 are calculated by Statistical Package for the Social Sciences (SPSS). The reliability is 0,860 according to Cronbach's Alpha.

TOSRA mean score and standard deviation of the sample of 711 students are shown in Table 3.

**Table 3.** *TOSRA mean score ($\bar{x}$) and standard deviation (s) of the sample of 710 students***.**

| | $\bar{x}$ | | | | | | s | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Al | A | Ks | Pl | Ro | All | Al | A | Ks | Pl | Ro | All |
| Q1 | 2,40 | 2,46 | 2,77 | 1,91 | 2,42 | 2,27 | 0,72 | 0,73 | 0,52 | 0,69 | 0,74 | 0,76 |
| Q2 | 2,15 | 2,45 | 2,47 | 1,95 | 2,29 | 2,17 | 0,75 | 0,67 | 0,69 | 0,78 | 0,73 | 0,77 |
| Q3 | 2,28 | 2,48 | 2,66 | 2,11 | 2,46 | 2,31 | 0,80 | 0,66 | 0,56 | 0,77 | 0,72 | 0,76 |
| Q4 | 2,19 | 2,38 | 2,47 | 2,06 | 2,36 | 2,22 | 0,81 | 0,82 | 0,75 | 0,88 | 0,79 | 0,84 |
| Q5 | 2,82 | 2,63 | 2,88 | 2,66 | 2,70 | 2,73 | 0,41 | 0,63 | 0,36 | 0,60 | 0,59 | 0,55 |
| Q6 | 2,91 | 2,83 | 2,90 | 2,81 | 2,80 | 2,85 | 0,33 | 0,41 | 0,30 | 0,48 | 0,51 | 0,43 |
| Q7 | 1,21 | 2,53 | 2,59 | 2,10 | 2,28 | 2,26 | 0,74 | 0,69 | 0,62 | 0,76 | 0,73 | 0,74 |
| Q8 | 2,01 | 2,24 | 2,53 | 1,83 | 2,10 | 2,05 | 0,75 | 0,77 | 0,69 | 0,78 | 0,80 | 0,80 |
| Q9 | 1,66 | 1,76 | 1,94 | 1,65 | 1,84 | 1,73 | 0,74 | 0,80 | 0,81 | 0,79 | 0,77 | 0,78 |
| Q10 | 2,18 | 2,31 | 2,42 | 2,05 | 2,25 | 2,19 | 0,72 | 0,65 | 0,75 | 0,74 | 0,74 | 0,74 |
| $\bar{x}$ | 2,18 | 2,41 | 2,56 | 2,11 | 2,35 | 2,28 | | | | | | |

**Figure 1.** *The distribution of the total score for the ten TOSRA items*

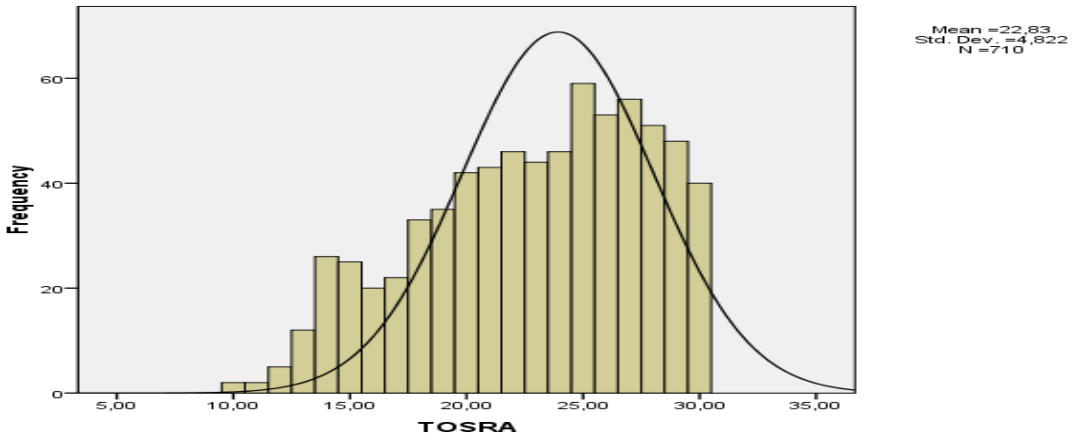
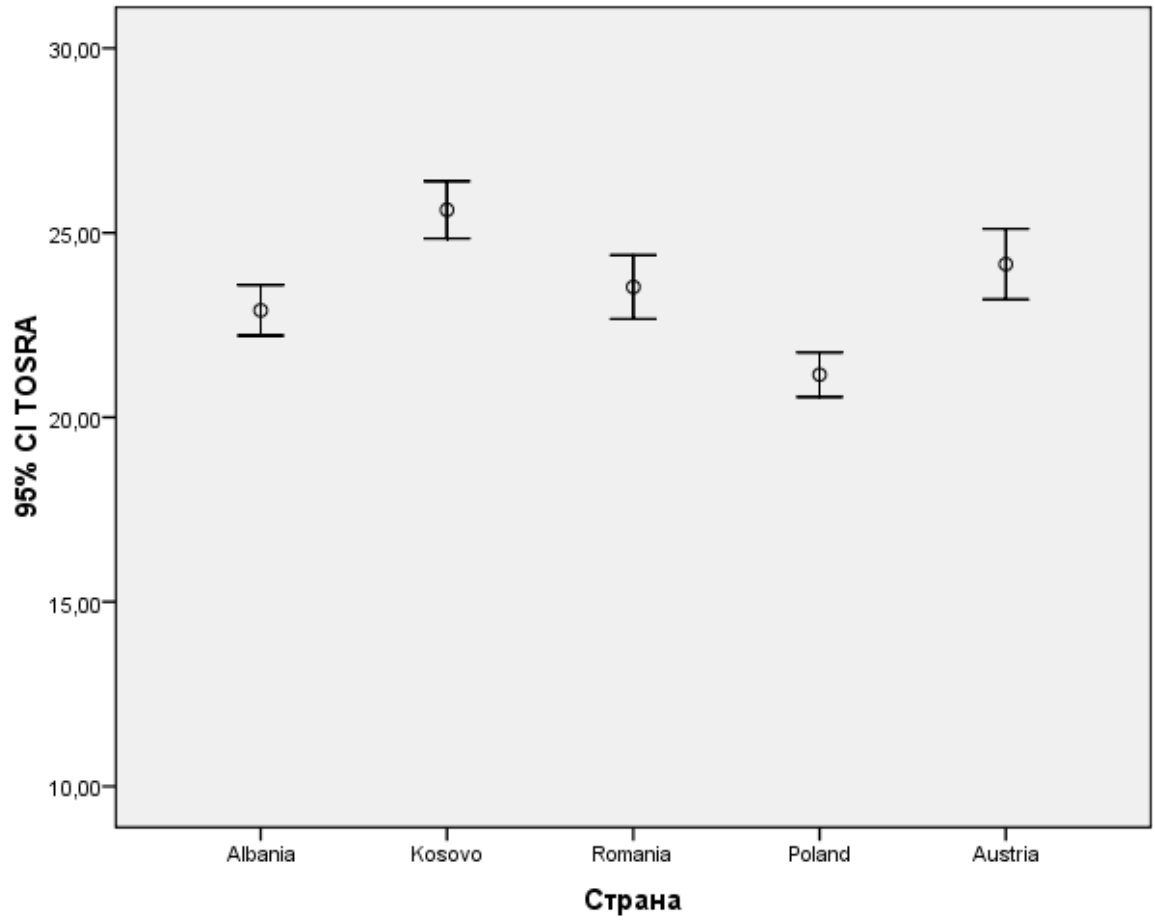


**Figure 2.** *Mean total score by countries for a confidence interval of 95%*




*Limitations and Factors that may affect the Results*

One of the main challenges of the cross-national studies is getting the authority permissions to be able to carry out the research at schools. Besides, the research schools should be picked out accurately to sample the whole country. As this research was conducted at restricted number of schools in each country, the results cannot be accepted as modeling the whole country.

Some countries have a test-oriented educational system. As student-oriented and inquiry-based learning is more challenging and necessitate more time, classroom activities are mostly based on problem solving and test techniques. Another factor is that the curriculum in some countries is exposed to changes very often which makes teachers adapt their annual plans. As a result of these adaptations, mostly the number of the experimental practices and activities in the lessons are reduced. Moreover, in some countries, because of the vocational tendencies and popularity of some departments at universities, the number of science lessons in the curriculum is decreased.

**Discussion and Conclusion**

According to the mean score of the data from TOSRA the students from all the countries have given nearly maximum scores to the question number six which is: "Finding out about new things is important." The standard deviation is the lowest for all the countries. This result shows that the great majority of the students from all the countries unanimously wish to discover, to acquire new scientific knowledge.

On the other hand the students from all the countries have given low scores to the question number 9 which states: "We should have more science lessons each week." The students do not wish to have more lessons, but they would be happy if their present lessons are more interactive, attractive and interesting.

The highest value of the standard deviation for question number four which states: "Science is one of the most interesting school subjects." shows that in the sample of investigated 788 students are heterogeneous in their preferences and attitudes towards science.

The Kosovar and Austrian students have the highest mean scores for all the questions. The Polish and Albanian students have pointed the lowest mean scores for these 10 questions (see Table 3 and Fig. 2).

According to the teachers' answers to the first question (Q1) 35% of all 17 teachers give priority to the interaction with students, 29% of them describe themselves as professionals and 18% of them put emphasis on personal qualities. On the other hand 12% of the teachers did not comment on this question and 6% percent answered that this question should be asked to the head master. There is a tendency to have a student – centered science classroom. One of the Albanian describes herself as "Opened with students with their problems; trying to be their friend more than their teacher". Whereas another teacher from Poland describes himself as "I am a teacher full of passion and commitment, I am professional and well prepared to teach." In the constructivist classroom the students are active. The teacher is a mediator.

58 % of the teachers rely on the class inclusion of their students by making experiments, participating in projects, experience and games according to the responses to the second question (Q2). 30 % of the teachers give priority to their professional and personal qualities. 6 % of the teachers did not answer this question and the same percent of them responded that we should ask their students.

Questions number 3, 4, 5 and 6 seek responses to how teachers and their students learn. 35 % of the teachers who responded to the third question (Q3) think that their students learn best by interactive lessons, pair work, group work, discussions, doing experiments and participating in projects. 65 % of the teachers think that their students learn by taking notes, writing, doing their homework and testing.

41 % of the teachers learn by practising new technologies, discoveries and meeting chemistry in everyday life. To the question number four (Q4), one of these teachers says "Analyzing my previous experience and adapting them to

match the case in the time being and updating myself to new experiences". On the other hand 59 % of the teachers learn by taking notes, reading, watching video clips or movies and solving problems.

For the main features of a good learner which is asked in the fifth question (Q5) most of the teachers consider that a good learner should be patient, good listener, open-minded for new ideas, striving to discover new things, analytical, logical and explorer.

Almost all of the teachers who responded the question number six (Q6) evaluate that their students have understood the curriculum content by asking questions, giving quizzes and tests. One of the teachers says "By testing them with questions, lab reports grading, and feedback verbal or written". Some of the teachers check students' progress during the lesson and some of them at the end of the lesson. Four of the teachers give small projects or experiments to check the students' achievements.

With 58 % result of the question number two, the teachers reveal themselves as constructivist teachers. On the other hand the results from question number three show that the teachers in fact do not apply the constructivist approach in their lessons.

The highest scores from TOSRA tool are achieved by the students from Kosovo and Austria. These results are not unexpected. During the visit of Kosovo it turned out that the school had an assistant teacher (lab assistant) who prepares the laboratory equipment and helps both the teacher and students in their lab activities. In Austria the constructivist teaching approach was particularly required by the curriculum of the school surveyed.

The mean scores of questions 2, 4 and 7 which manifest average enjoyment, fun and interest of students show that the students have close perceptions of science classroom.

Based on the interviews with the teachers it can be concluded that there is a tendency of the European teachers to apply constructivist teaching approach and the students are ready to initiate and collaborate a constructivist science classroom environment. However the results show that although some of the teachers apply constructivist teaching approach in science classroom while some do not.

The study is expected to contribute to create a basis for the development of worldwide partnership in the field of science education and to the officially declared "European year (2013) of citizens" by EU.

The necessity for continuing of the research on the development of understanding and interest in chemistry by implementation of modern teaching methods and strategies is crucial. In this context this study will be useful for universities, schools, and other educational and cultural organizations in realization and development of partnership and international cooperation as a theory and practice.

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