Chemistry Education Research and Practice

PAPER

Cite this: *Chem. Educ. Res. Pract.*, 2014, **15**, 239

Creativity in teaching chemistry: how much support does the curriculum provide?

Biljana Tomasevic and Dragica Trivic*

Received 13th September 2013,
Accepted 17th March 2014

DOI: 10.1039/c3rp00116d

www.rsc.org/cerp

In this study, the views of Serbian chemistry teachers (N = 334) on the ways in which contemporary chemistry curricula stimulate the creativity of students were surveyed. The majority of the teachers have a positive attitude towards promoting creativity through teaching chemistry. Most of them also stated that their teaching practice contained activities that are conducive to stimulating creativity (85.7%). Some of the teachers stated that the potential for stimulating creativity is to be found in laboratory work (34.1%). Among the activities that they believe could be organised based on the curricula, the solution of mathematical problems by divergent approaches (78.8%) and the presentation of specific topics by students (68.2%) were particularly emphasised. To stimulate creativity among students, most teachers indicated that examples of laboratory tasks and criteria to evaluate students' work would be helpful. In order to stimulate creativity, the teachers require additional information related to the set up of laboratory work and criteria for the evaluation of students' activities and products. The contribution of the present study is that it could guide future curriculum development to make it more usable for teachers and to enable creative thinking among students.

Introduction

Today education must fulfil a number of requirements. Among the most important ones are equipping students for lifelong learning and for contemporary society, which is continuously confronting people with new tasks and situations (Sternberg, 2007). The stimulation of and support to the development of divergent thinking and creativity throughout the education process, in all the subjects taught within the framework of the curriculum, could contribute to being equipped for this situation. A prerequisite to attain this is teaching that constitutes a good balance between the acquisition of knowledge and skills, on the one hand, and promoting and providing freedom to innovate, create and propose, on the other. Educators must strive to integrate into chemistry teaching the connection between knowledge and everyday life, its industrial, technological, economic, social and other aspects (Pilling and Waddington, 2005). Contemporary chemistry teaching requires active methods of learning, wherein emphasis is laid on the process of knowledge assimilation that requires and favours higher levels of cognitive thinking, and analytical, critical and creative approaches through problem solving (Cardellini, 2006; Overton and Potter, 2008; Stamovlasis *et al.*, 2010; Christiana and Talanquer, 2012; Avramiotis and Tsaparlis, 2013). These approaches should be incorporated into the assessment of knowledge (Lewis *et al.*, 2011).

University of Belgrade Faculty of Chemistry, Department for Chemistry Education, Serbia. E-mail: dtrivic@chem.bg.ac.rs

Regular teaching enables the creativity and creative potential that every person possesses, irrespective of sex and age, to be influenced. This kind of creativity in the literature is called ordinary, "democratic" creativity (Craft, 2001). It is clear that creativity with "a smaller *c*" differs from creativity with "a Larger C" (Big-C), which designates exceptionally creative and gifted persons, the achievements of whom are undoubtedly significant for civilisation (Kozbelt *et al.*, 2010).

Each educational system decides what kind of model of support and stimulation of creativity it wishes to employ, in keeping with the possibilities and trends of social changes and developments (Welle-Strand and Tjeldvoll, 2003).

In this study, a survey was conducted aimed at gaining insight into the following: the views of chemistry teachers on the possibilities and ways of stimulating and cultivating divergent thinking and creativity, what support for this is given in the curriculum and what instructions should be dispensed through the curriculum to facilitate the realisation of such a way of teaching. The survey was conducted on a sample of 334 teachers working in primary, vocational and grammar schools in Serbia. Insight into the views of chemistry teachers on stimulating creativity among their students could influence future policy decisions on the chemistry curriculum.

Creativity in the teaching of natural sciences and chemistry

The concept of creativity can be explained by means of the Sternberg triarchic theory of human intelligence (Sternberg, 1997). Creative intelligence, which is the ability to create a succession of new ideas, ensures a connection between analytical and practical intelligence. In other words, creativity enables that which is usually considered to be intelligence is realised in real life. Furthermore, according to Sternberg (2003), the abilities necessary for continual advancement and future achievements, participation in and contribution to public and social life, are the result of a symbiosis, *i.e.*, the unification of intelligence, creativity and wisdom, referred to as Wisdom, Intelligence, Creativity, Synthesised (WICS). The abilities necessary for making various choices are controlled by individual elements of the WICS model or their combinations. Creativity is necessary, among others, for the manifestation of initiative, imagination and originality, to connect scientific achievements and practice, for the manifestation of the potential for the organisation and realisation of innovative research, for dedication to creative solutions, achievements and the visionary spirit. Therefore, creativity is the result of the simultaneous and joint functioning of all skills, *i.e.*, without creativity, there is no promotion of good and useful ideas.

In order to describe and define creativity, it is usually associated with unique, talented people from very diverse spheres of life and their achievements. Numerous authors have provided a large number of different definitions of creativity, mainly following the postulates and views of their areas of study. From a very broad scope of definitions, some of those collected and presented by Taylor (2007) are quoted here:

– creativity as the formation and linking of mutually very distant elements in a new combination (Mednick);

– the ability to bring something new into existence (Barron and May);

– the possibility of gaining insight into something, being aware of it and responding to it (Fromm);

– the art of observing and completely acquainting oneself with ones limitless being (Schachtel), *etc.*

Furthermore, Taylor (2007) states that, when defining creativity, one can point to the existence of the products of creativity. For this reason, a great number of definitions include the development of something new and unique. These products can be both mental and material in character. Such products are the result of very persevering and motivated work on ideas and problems that were initially not even quite clearly and understandably reviewed and defined. Consequently, by application and combination of that which already exists, something new may be produced, including new relations and contents. Thus, the definition of creativity as a process of thinking, always accompanied by explicit and deductive reasoning in the verification of a new idea, is approached. A creative process is a mental activity aimed at defining a problem and its resolution. It is accompanied by a corresponding invention, be it artistic or technical, while special emphasis is placed on defining the problem and finding a solution as elements of the creative process. As a complex cognitive activity, creativity is also influenced by motivation, personal factors, environmental conditions and circumstances (Feldhusen, 2002).

Still, definitions, ways of identification, theoretical formulations and research results are very diverse and heterogeneous. In fact, no universally accepted definition of creativity exists (Getzels, 1985). If some generalisations are required, they could be as follows (Sternberg, 2006): creativity always creates a (relatively) new product, and in doing so combines knowledge from various domains; to a certain degree it can be measured and developed, and it is not particularly well rewarded, although everyone proclaims it desirable.

The main arguments enabling the promotion of creative approaches and requirements through the teaching of natural sciences are dynamism, multidisciplinarity and changeability of ideas and solutions (Schmidt, 2011). Education in the realm of natural sciences should be the key and play an essential role in training students for not only the compilation and recognition of evidence and facts, but also in the development of analytical thinking to approach the enormous existing corpus of knowledge and scientific explanations. Education should further train students in the understanding of processes in nature and the laws regulating them, and in performing practical and theoretical research. Finally, education should promote high standards of scientific literacy (NACCCE, 1999). All of the above is necessary in order to understand how science shapes the contemporary world, the achievements and ideas of changes, the importance and limitations of science, so that new, upcoming situations can be approached wisely and responsibly. The most convenient consideration of creativity in chemistry teaching connects it with the experimental nature of chemistry. Experimental and theoretical work will be more successful if students are placed in a position where they can discover facts, define problems, present ideas, propose solutions and decide on the most acceptable ones as often as possible (Taylor, 2007). In doing so, it is important to note that a problem in chemistry is not an exercise that can be completed by working through a simple, familiar algorithm (Wood, 2006; Bennett, 2008; Avramiotis and Tsaparlis, 2013). When it comes to problem solving, which engages higher levels of thinking, the process unfolds as follows: (a) recognise the existence of a problem; (b) define the nature of the problem; (c) explore resources to solve the problem; (d) formulate strategies to solve the problem; (e) brainstorm various solutions; (f) evaluate solutions, and (g) choose the best solution (Kong, 2007). Creativity could be associated with the process of formulating and testing hypotheses in the course of solving a set or a discovered problem, as well as with a process which requires the ability to adjust or find new connections between facts and data. That which Torrance presents as a model of creativity in teaching is an accurate description of a well set (experimental) task or problem entailing the following phases: sensing problems or difficulties, making guesses or hypotheses about the problem, evaluating the hypotheses and possibly revising them, and communicating the results (Torrance, 1988). Particularly, the open-ended problems, which require an unfamiliar approach to obtain a solution and use a real life context with insufficient data (Overton *et al.*, 2013), have great potential to stimulate the creativity of students as one of the important life skills.

When teachers of natural sciences/chemistry are confronted with all these requirements, the question arises as to what extent they are capable of fulfilling them. Although they acknowledge that they could achieve the centrally defined objectives by experimenting with their teaching, they are nervous of the reactions of managers or parents if pupils fail to make a good impression at examinations (Tanggaard, 2011). As a result, teachers quite often decide against such changes. They are especially prone to rejecting them if they do not find themselves equal to this or if they have insufficient understanding of the concept of creativity in teaching chemistry. For these reasons, creativity, as a phenomenon, should be brought closer to teachers and they should be given an explanation which teaching situations and achievements of students are connected with creativity.

One of the easiest ways of introducing creativity in the classroom is by posing questions which, apart from knowledge of facts, require analytical and divergent thinking, building self-efficiency, defining and redefining problems, encouraging idea generation and allowing for making mistakes (Sternberg and Williams, 1996). Besides, creativity could be stimulated in practice by encouraging students to ask more questions in the course of acquiring new scientific notions, or questions arising out of personal interests. Students should also be encouraged to investigate the reasons for their personal observations, to propose solutions to situations and problems from everyday personal or social life, to experiment and try things in safe surroundings (Barrow, 2010).

According to a survey conducted by Rutland and Barlex (2008), there are very few teachers who are interested in and capable of stimulating the creativity of their students. The survey showed that the majority of teachers require additional training in order to overcome their resistance to changes and insistence on applying solely traditional teaching methods that is based on knowledge transfer. For change to be achieved, teachers should primarily explain to students that being creative means stepping out of the prearranged framework, and that benefits of this change can be manifold (Sternberg and Williams, 1996).

An analysis of the existing curricula showed that the word creativity and its synonyms featured a very small degree in the curricula of science (Heilmann and Korte, 2010). Then again, even though a given curriculum may possess the potential for realising teaching that favours exploratory approaches and problem solving, it does not necessarily mean that all teachers will realise it in such a way if there are no explicit instructions and binding, prescribed activities. This indicates that despite good intentions aimed at modernising education, teachers may end up without sufficient support to realise such teaching.

The purpose of the study

Teaching that will motivate students through a demonstration of the applicability of the acquired knowledge and skills, and by stimulating their creativity, cannot be based solely on the competencies and personal enthusiasm of teachers, but should have clear support and guidelines provided through the curriculum. The aim of this survey was to examine how chemistry teachers use the curriculum in order to stimulate the creativity of their students.

The polling of chemistry teachers was conducted with the aim to:

(1) Review the ways in which teachers use the curriculum, and the curriculum components that constitute sources of information for particular segments of their preparations.

(2) Review the attitudes of chemistry teachers:

– towards chemistry as a teaching subject through which creativity can be stimulated and developed;

– towards teaching the contents and scientific methods of chemistry as a basis for the kind of teaching that stimulates creativity;

(3) Analyse the extent to which teachers, in their own view, realise the teaching situations in chemistry classes through which they stimulate and support the creativity of their students, as well as the examples offered by teachers in order to illustrate such situations.

(4) Collect the views of teachers on missing components of the curriculum that would be necessary to help them in planning and realising the kind of teaching that will enable the cultivation of support to and development of creativity.

Research questions

The following research questions were formulated:

(1) What are chemistry teachers' perceptions of the possibilities of creativity development within chemistry teaching?

(2) Which teaching situations for promoting divergent thinking and creativity could be planned and realised based on the instructions contained in the curriculum?

(3) Which of the curriculum components and associated information represent good forms of support for divergent thinking and creativity?

Methodology

Sample

The survey was conducted during the regular annual meeting of chemistry teachers. The meeting was held on 29–30 April 2013 in Belgrade. The participants were from 85 different towns in Serbia. In this way, data gathering enabled direct contact with a large number of chemistry teachers from very different parts of the country. Furthermore, this approach avoids the usual problems associated with a low response rate (Taber, 2013). All participants received the questionnaire on the first day of the annual meeting with the request to complete it before the end of the meeting. On the second day, the questionnaires with the participants' data were collected. The sample comprised 334 chemistry teachers. Out of the total number of participants, 193 (57.9%) worked in a primary school, only 41 (12.3%) worked in grammar schools, while 78 (23.3%) worked in secondary vocational schools. The remaining teachers worked in more than one type of school. Since no reliable data concerning the total number of chemistry teachers in Serbia could be obtained, the response rate was calculated based on the number of schools in the sample (Drechsler and Van Driel, 2009). According to official data (Statistical Office of the Republic of Serbia, 2013), there are 3455 primary schools and 494 secondary schools in Serbia. Teachers in the sample came from 187 primary schools (5.4% of the primary schools in Serbia), 25 from grammar schools and 44 vocational schools (14.0% of the total number of secondary schools in Serbia).

Instrument

The questionnaire used for the purpose of conducting this survey contained four main parts: (I) questions related to the personal data of teachers (Q1–Q5); (II) questions pertaining to the use of the curriculum in everyday practice (Q6–Q9); (III) questions related to the views of the teachers on the possibilities for creativity development in education generally, as well as in chemistry teaching specifically (Q10–Q14); (IV) questions pertaining to the use of curriculum and the information mediated through its various components associated with the development of creativity during the teaching/learning process (Q15–Q20).

The questionnaire comprised different types of questions:

– closed-type questions (two-option responses, multiple choice questions where the respondents may choose one or more answers, and those with a Likert scale);

– open-type questions, requiring the respondents to give appropriate information, examples or proposals.

The question Q18, besides asking the respondents to express their degree of agreement, was also asked to underline the important points in the text, allowing respondents to express their view of a certain text which represented an example of a part of a curriculum. It is through such questions that the most direct insight can be gained into what teachers are guided by when transforming parts of a curriculum into the real teaching situations.

A preliminary questionnaire had already been presented in a seminar in which twenty chemistry teachers participated. Based on their responses, the clarity of formulations of items was improved, as well as the order of the items in the questionnaire. Following this, the final version of the present questionnaire was constructed (see Appendix).

Data analysis

Descriptive statistics were performed to determine the composition of the respondents in terms of age, sex, level of education and years of working experience. Furthermore, the percentages, mean scores and standard deviations were computed for all the questions. To further explore the relationships between some of the answers in the questionnaire, a Principal Component Analysis (PCA) was conducted.

Results

Respondents

The results pertaining to the personal data of the chemistry teachers in the sample (Q1–Q5) are presented in Table 1. A total of 14.1% of respondents had less than 5 years of working experience as teachers, which means that the sample was mostly composed of teachers who have acquired a certain degree of working experience, especially those who had worked for more than 10 or 20 years as teachers. 88.6% of the sample were female.

A total of 29% of the respondents possessed initial education required for teaching (chemistry teacher, biology and chemistry teacher, physics and chemistry teacher). A total of 63% of the respondents were educated in the domain of chemistry or related disciplines. Around 7% of the respondents attended some form of postgraduate studies (specialisation, Master's Degree studies), but only half of them obtained teaching related (postgraduate) education. The structure of the survey sample indicates the diversity of the respondents in terms of initial education, age, years of teaching experience, showing the heterogeneity of the sample diverse in terms of competency as teachers. The majority of the chemistry teachers from the sample obtained the requisite academic-level education pertaining to the chemistry curricula by graduating from faculties that provide education in the sphere of chemistry or related disciplines, but only one-third of them, those who graduated from teacher-training faculties, obtained the pedagogical knowledge necessary for teaching through their initial education. The legal regulations previously in effect, which regulated the work of the majority of the respondents in this sample, prescribed that those teachers whose initial education did not include psychological–pedagogical–methodological training would have to pass an additional examination within the framework of their professional competence. The examination would be taken after one year of teaching practice. The legal regulations currently in effect require practising teachers to have earned 36 ECTS credits based on subjects belonging to the above-mentioned areas of education, and a Master's Degree certificate in academic education.

Teachers' perceptions for creativity development

To research the need for including instructions concerning creativity in the curriculum, it was first necessary to investigate the function of the curriculum in the teachers' work in general terms,

Table 1 Background data of the sample (N = 334)

Years of work as teachers	Percentage	Age	Percentage	Initial level of teachers' education	Percentage
Less than 5	14.1	25–30	5.1	Teacher-training faculties	29.0
5–10	15.0	31–40	26.9	Non-teacher-training faculties	63.0
10–20	38.0	41–50	32.4	Postgraduate education in teaching	3.5
20–30	21.3	51–60	28.1	Postgraduate education in other areas	3.5
More than 30	11.1	>60	2.7		
No data	0.6	No data	4.8		

Table 2 The respondents' answers to questions pertaining to the ways in which they implement the curriculum and employ textbooks (in %)

	Percentage
Q6: In which phases of planning do you use the chemistry curriculum?	
When preparing the annual work plan	74.8
When preparing a monthly work plan	49.7
When preparing a class scenario in writing	40.0
Q7: Has your need to use the curriculum (during periods when there were no changes to it) changed as your working experience increased?	
I have used the curriculum to an equal degree all the time	61.8
I use the curriculum less now than when I started working	22.7
I use the curriculum more now than I did when I started working	11.6
Q8: What kind of information contained in the curriculum is the most important to you for the realisation of your teaching plan?	
The goals and tasks of chemistry	55.7
Operative tasks/outcomes	48.6
The contents of themes	36.1
Demonstration experiments	29.3
Practice classes	22.0
Instructions for the realisation of a topic	20.0
The manner of realising the curriculum	21.8
Additional work	11.2
Q9: To what extent do you rely on the contents of textbooks during the realisation of your teaching plan?	
Not at all	0.0
Very little	14.1
Very much	68.2
Completely	14.4

The statistical analysis was performed using SPSS version 17.0.

to what extent they use it and in what phases of their preparation. In addition, it was necessary to estimate to what extent teachers use chemistry textbooks in panning a lesson (Table 2).

Less than two-thirds of the teachers used the curriculum equally throughout their years of teaching. The majority of the respondents (74.8%) use the curriculum a lot when preparing their annual work plan, *i.e.*, for planning the number of classes required for particular topics (contents). When it comes to preparing a lesson plan, only 40% of the teachers use the curriculum. Among the different curriculum components, the *goals* and *outcomes* are most frequently recognized by the teachers as a support for this activity. About half of the teachers indicated these two components. According to the same criteria, the *contents of the themes* of the curriculum were selected by about one third of the teachers. The information from other curriculum components was less important for many of the respondents. When preparing for teaching, teachers evidently rely on the framework provided by the textbook for the students (*very much* and *completely* 82.6%).

The answers of the teachers related to the possibilities of creativity development in education in general, as well as in chemistry teaching particularly, are presented in Table 3.

The results show that 65.0% of the total sample was of the opinion that all persons, irrespective of their sex and age, possess creative potential. A total of 85.0% of the respondents were of the opinion that creativity could be developed through teaching chemistry. A high percentage of the respondents (79.4%) believe that *all contents* or the *majority of the contents* of the chemistry curriculum are appropriate for and conducive to developing creativity, and that the actual scientific method of chemistry is suitable for this (*very much* and *completely* 74.9%). According to the above-mentioned percentages, most chemistry teachers in this sample have a positive attitude towards the issue of creativity in teaching chemistry.

The majority of the teachers stated that they were realising situations conducive to stimulating creativity (85.7%) and about half of them offered examples to testify this (Table 3). These answers were grouped and coded. Teachers mainly mentioned laboratory work (34.1%), without stating any particular topics, providing concrete descriptions of situations or detailing ways of achieving creativity. The others mentioned students' presentations dealing with specific topics (3.9%) and independent research work (3.0%). Only a few teachers mentioned other ways of stimulating creativity, which included working on projects, dealing with topics from everyday life (environmental protection), dealing with problem-type situations, solving tasks in various ways, using models, organising group work and providing quizzes. The fact that a large number of the respondents claimed that situations exist in their teaching practice that enable students to be creative, but only about half of them confirmed this by providing examples may be a consequence of their wish to express a socially desirable view, their awareness that creativity in teaching is a very topical issue and that their own practice should keep pace with this trend. Then again, it may be that teachers are generally of the opinion that they do practice such a form of teaching, but not at the level of real and deliberate planning.

Teaching situations for promoting creativity based on curriculum instructions

More than half of the respondents stated that the curriculum, *mostly* or *completely*, enabled them to accomplish situations in

Table 3 The answers of the respondents to questions pertaining to the possibility of promoting creativity through teaching chemistry (in %)

	Percentage
Q10: Are you of the opinion that all persons, irrespective of sex and age, possess creative potential that could be developed through education?	
Yes	65.0
No	27.2
I don't know	4.8
Q11: Are you of the opinion that education through teaching chemistry provides opportunities for creative approaches and support the development of creativity?	
Yes	85.0
No	5.1
I don't know	6.6
Q12: Are you of the opinion that the contents of chemistry are conducive to stimulating creativity?	
All contents are equally conducive	5.4
The majority of the contents are conducive	74.0
Only a few of the contents are conducive	16.5
The contents are not conducive at all	0.6
No answer	0.0
Q13: Are you of the opinion that the scientific methodology of chemistry is conducive to stimulating creativity?	
Not at all	1.2
To a negligible degree	2.7
A little	18.3
Very much so	59.6
Completely	15.3
No answer	3.0
Q14: Does your teaching practice contain situations whereby you stimulate the creativity of students?	
Yes	85.7
No	6.1
No answer	8.2
Name the situations in which you stimulate students' creativity.	
Laboratory practice	34.1
Students' presentations	3.9
Students' independent research work	3.0
Working on projects	2.1
Everyday life	2.1
Organising group work	1.8
Resolving problem-type situations	1.5
Use of models	1.5
Protection of the environment	0.9
Quizzes, games (of association)	0.6
The Internet	0.6
Solving tasks in different ways	0.3
Total	52.4

The statistical analysis was performed using SPSS version 17.0.

which students could manifest their creativity and divergent thinking. This overall attitude slightly varied depending on the specific teaching situations (Table 4).

According to the teachers, the curriculum guided them a lot in supporting students in preparing and giving presentations on topical issues and solving mathematical problems through divergent approaches. The planning of situations in which students independently prepare and conduct experiments is the least guided by the information contained in the curriculum.

Curriculum components and associated information as support for divergent thinking and creativity

Considering that various educational documents, strategies, the national curriculum, and to a lesser extent, the curriculum of individual subjects speak in favour of creativity, the teachers were asked which components of the educational documents, in their opinion, should have the most information supporting creativity. The fewest respondents opted for defining the notion through general educational goals and outcomes (20.7% and 22.8% respectively). The current situation shows that it is precisely through these segments that creativity is most often promoted, in the sense of the strategy of the entire educational system. These documents are of crucial importance for drafting the other documents, but the responses of the teachers show that these postulates of the educational policy must be concretised and operationalised in the curricula (Heilmann and Korte, 2010). When assessing the curriculum components through which teachers should obtain the most information required for the realisation of teaching situations that stimulate creativity, the respondents mostly declared themselves to be in favour of defining the skills, knowledge, recommendations/instructions for the realisation in the chemistry curriculum and the standards (Table 5).

For the purpose of gaining insight into the information from the curriculum that inspires teachers to create teaching situations, the respondents were asked for their views on particular segments of various curricula (Table 6). Among the offered segments, there were various components of the curricula: general educational goals, competence for lifelong learning that could be developed through chemistry, instructions on how to realise teaching chemistry through research and structured wholes of the curricula in the form of content/standard/goal/indicator, or content/goal/description/outcomes. Both examples of the operationalisation and concretisation of goals pertained to the topic *Solutions*.

The results showed that teachers consider concretely defined indicators the most convenient, *e.g.*, those suggesting that students should prepare and perform experiments in order to determine how certain factors (mixing, particle size and temperature) influence the dissolving of a substance, or that students should understand that different substances are characterised by different levels of solubility in water, and that solubility depends on temperature. Besides different kinds of information which the respondents assessed from the point of view of its usefulness, a large number of the respondents did not find the information they required, as evidenced by the fact that as many as 38.4% and no less than 59.1% of the respondents had nothing to say about the first example and second example of the operationalisation of goals, respectively.

The question about obtaining necessary support from the curriculum for creating situations that stimulate creativity was also posed from the perspective of specific segments of the curriculum that would be necessary or very useful for teachers (Table 7). The respondents require additional information pertaining to all statements provided in Table 7. Among them, the examples of laboratory tasks would be important (*mostly* and *completely*) for 86.5% of teachers, while the criteria for evaluating the work of students would be useful for 84.1%.

Table 4 The respondents' answers concerning the realisation of teaching situations based on the curriculum (in %)

	1-Not at all	2-To a negligible degree	3-A little	4-Mostly	5-Completely	No answer	Mean	SD
Q15: To what extent does the chemistry curriculum offer you possibilities to realise situations in which you are able to stimulate creativity and accept divergent solutions?	0.9	4.5	**34.7**	**53.0**	2.7	4.2	3.54	0.68
Q16: To what extent are you guided by information contained in the curriculum in the realisation of following teaching situations?								
Organising situations in which students prepare and realise presentations dealing with topical issues	1.5	6.6	**25.4**	**42.8**	16.8	6.9	3.72	0.90
Solving mathematical problems through divergent approaches	0.3	6.3	**23.4**	**55.4**	8.1	6.6	3.69	0.74
Students independently produce essays, projects, notice boards...	1.8	9.3	**24.3**	**41.0**	17.4	6.3	3.67	0.95
Evaluation of achievements based on creativity and the originality of solutions	1.2	7.8	**26.3**	**47.9**	9.0	7.8	3.60	0.83
Considering arguments for and against some decision	1.5	10.5	**31.7**	**37.1**	11.7	7.5	3.51	0.91
Experimental solving of problem-type situations	3.3	11.7	**31.7**	**35.9**	9.3	8.1	3.39	0.95
Organising work with divergent solutions in laboratory practice	4.2	9.6	**34.1**	**38.6**	5.1	8.4	3.29	0.91
Students independently prepare and conduct experiments	6.9	10.8	**38.0**	**30.2**	7.2	6.9	3.22	1.0

Table 5 The respondents' answers to the question about which components of the curriculum should offer information for developing students' creativity

	Percentage
Q17: Mark the curriculum components through which you should obtain the most information needed for the realisation of teaching situations that stimulate creativity.	
General educational goals	20.7
General educational outcomes	22.8
General educational goals realised through teaching chemistry	45.2
General educational outcomes realised through teaching chemistry	43.1
The importance of natural sciences/the importance of chemistry/introduction to the subject	49.7
The goals of teaching chemistry	35.0
The outcomes/achievements of teaching chemistry	36.5
Outcomes – knowledge	61.1
Outcomes – skills	68.3
Outcomes – views	48.5
Standards	53.6
Recommendations/instructions for realising the curriculum	54.5
Evaluation	45.2

Less than half of the respondents offered proposals for additions to and changes in the curriculum that would improve instructions for teaching situations (Table 8). According to received proposals, the groups of answers were extracted and coded. Most of them pertained to laboratory work, in the sense of having more practice classes or providing instructions for independent research work by students, instructions for the realisation of practical tasks, *etc.* There were other suggestions as well, offered by a considerably lower number of the respondents. As in the case of the preceding question, a large number of the respondents (52.8%) did not offer any suggestion, which also points to the fact that teachers have not yet sufficiently reviewed and considered the issue of creativity, and consequently do not have very concrete ideas on how they could deal with this issue in their teaching practice. Thus, only a very small number of the respondents offered their suggestions.

In order to find the correlation among the teachers' answers related to curriculum support for creativity development, the results (Q16, Q18 and Q19 – Likert-type scale) were first assessed for their suitability for factor analysis. The Kaiser–Meyer–Olkin (KMO) measure of sampling (KMO 0.826, $p = 0.000$) supported the factorability of the matrix (Tabachnick and Fidell, 2001). Principal component analysis (PCA) revealed five eigenvalues exceeding 1, explaining 25.9%, 13.7%, 7.3%, 6.6% and 5.7% of the variance, respectively. These five factors explain 59.3% of the variance. Loadings smaller than 0.30 were omitted. Following an Oblimin rotation, the five factors showed small intercorrelations; the structure matrix indicated good discrimination between the factors, which is supported by factors that exceeded the criterion value obtained from parallel analysis (Watkins, 2000).

The next step was to look at the content of questions that load into the same factor to attempt to identify common teaching situations (Table 9).

The questions that load highly on factors 1–5 seem to relate to:

– Information associated with the accomplishment of experimental and mathematical problems with divergent approaches to the solution.

– Necessary examples of experimental and mathematical tasks.

– Operationalisation of goals.

– Information for the consideration of certain themes with incorporated divergent approaches.

The results indicate a need for further improvement of the curriculum with examples of teaching situations and teaching/learning methods, an appropriate method for the monitoring of the progress of students and the criteria for evaluating the results of the work of students (Lewis *et al.*, 2011). Moreover, information related to the set up of experimental and mathematical problems, appropriate examples and topics with the potential for divergent approaches to the solutions could be useful for chemistry teachers (Wood, 2006). Teachers need the concretization of the curriculum goals in order to ensure their achievement in regular teaching practice.

Table 6 The answers of the respondents to the question: which of the segments available give them information for the realisation of teaching situations that stimulate creativity (in %)

Segments		Percentage	1-Not at all	2-To a negligible degree	3-A little	4-Mostly	5-Completely	No answer	Mean	SD
Q18: To what extent are you guided by information contained in the segments of curricula in realising teaching situations that stimulate creativity?										
A	Science as research		0.0	0.9	5.1	**50.9**	**28.4**	14.7	4.25	0.61
	Example 1		0.3	0.0	5.4	**48.2**	**31.4**	14.7	4.29	0.64
B	Content	9.3								
C	Standard	11.4								
D	Goal	12.3								
E	Indicators	26.0								
	Example 2		0.3	1.2	6.9	**47.6**	**26.0**	18.0	4.19	0.69
F	Content	8.7								
G	Goal	1.5								
H	Description	6.9								
I	Outcomes	20.0								

Table 7 The answers of the respondents concerning their expected support from the curriculum (in %)

	1-Not at all	2-To a negligible degree	3-A little	4-Mostly	5-Completely	No answer	Mean	SD
Q19: To what extent would it be useful for you if parts of the curriculum contained specific information on the realisation of teaching situations that are conducive to creativity as help and support during your preparation?								
Criteria for evaluating students' work	0.6	0.3	6.9	**40.7**	**43.4**	8.1	4.37	0.70
Examples of laboratory tasks	0.0	0.9	4.2	**53.3**	**33.2**	8.4	4.30	0.60
Examples of workbook tasks, tests	0.6	0.9	9.3	**40.4**	**39.5**	9.0	4.29	0.75
Compulsory laboratory tasks	0.0	0.9	6.9	**49.7**	**32.9**	9.6	4.27	0.64
Descriptions of teaching situations	0.6	1.5	8.1	**44.3**	**34.4**	11.1	4.24	0.77
Topics for independent student papers	0.0	1.2	13.8	**39.0**	**37.1**	8.7	4.23	0.75
Specific contents	0.0	2.4	6.3	**51.2**	**30.8**	9.3	4.22	0.68
Specific mathematical problems	0.0	1.2	11.4	**44.6**	**33.2**	9.3	4.22	0.71
A list of questions	0.3	1.5	12.6	**46.4**	**30.5**	8.7	4.15	0.74
Compulsory teaching methods for certain teaching units	1.2	1.8	12.9	**47.6**	**26.9**	9.6	4.08	0.80

Table 8 The proposals of the respondents for changes in the curriculum (in %)

	Percentage
Q20: State what you consider to be a necessary part of the curriculum for the purpose of providing guidelines for the development and stimulation of creativity through teaching chemistry.	
More laboratory work, practice classes and instructions for independent work of students	12.0
More demonstration-type experiments	2.4
More specific contents, goals, outcomes and standards	4.2
Specific instructions for realising textbook contents, examples of teaching situations	5.1
Connections with other subjects, sciences, multidisciplinarity	1.8
Examples from everyday life, practical application	7.8
Examples of problem-type situations and tasks	1.5
Topics and instructions for students' work, projects, presentations, independent research work	6.9
Proposals concerning teaching methods	2.7
Examples of tests, workbook tasks	7.2
Decreasing the burden of the curriculum	5.4
Proposals that do not pertain to the curriculum (school equipment, textbooks, changes in the teaching plans, professional training of teachers, visits to laboratories…)	17.2
Others	1.2
No proposals	52.8

Discussion

The positive attitude toward the possibility of creativity development in the domain of chemistry education is shown by the large number of chemistry teachers in the sample. The teachers' beliefs strongly influence their teaching of chemistry and they act as a filter through which a number of decisions about the

Table 9 The rotated component matrix for the results of questions Q16, Q18 and Q19

Questions		Component 1	2	3	4	5
Q19	9	0.768				
Q19	8	0.766				
Q19	10	0.741				
Q19	7	0.630				
Q19	5	0.537	−0.373			
Q19	6	0.456				
Q16	3		−0.826			
Q16	2		−0.788			
Q16	5		−0.674			
Q16	1		−0.624			
Q19	3			−0.819		
Q19	2			−0.801		
Q19	4			−0.622		
Q19	1			−0.595		
Q18	2				0.841	
Q18	3				0.728	
Q18	1				0.633	
Q16	7					−0.880
Q16	8					−0.762
Q16	4					−0.706
Q16	6		−0.370			−0.569

Extraction method: principal component analysis. Loadings less than 0.30 are omitted. Rotation method: Oblimin with Kaiser normalization.

curriculum and instructional tasks are made (Park *et al.*, 2006). However, for some teachers, it may be a consequence of their wish to express a socially desirable view.

More than half of the teachers stated that the curriculum generally led them in planning teaching/learning situations in which students had an opportunity to develop creativity. They connected this kind of support in the curriculum mostly with situations in which students prepare and realise presentations on topical issues and when they solve mathematical problems through divergent approaches. Even though there are no examples and direct instructions for solving such problems in the present curriculum, teachers recognised these situations as reflecting their regular teaching practice, while they receive from the curriculum teaching topics and contents within which problems are solved. However, it is not known whether teachers conduct such activities deliberately, with the view of indicating the possibility of divergent solutions to the problem at hand. Solving stoichiometric problems, which is a very prominent segment of the respondents' teaching practice, is most often possible in a variety of ways owing to their logic and structure. These situations are not examples of divergence if each student, without knowing how other students solve the given problem, resorts to the same algorithm each time, *i.e.*, if such situations are not used as a stimulus for confronting different approaches, for analysing the simplest, shortest, clearest approach, or for reviewing the solutions in other ways. If these situations are only used for solving stoichiometric problems, they can in no way be a challenge or represent an example of cultivating and recognising divergent solutions in practice.

For more than two-thirds of the respondents the curriculum *mostly* or *completely* provides the possibility for students to prepare and present papers on specific topics, by providing teachers information through their contents. Still, these contents contain no instructions on evaluating the results, which means that teachers must develop their own criteria. Thus, different criteria do not necessarily provide students with valid feedback associated with their originality and creativity in the preparation and presentation of their work.

When assessing the curriculum components through which they should get the most information needed for the realisation of teaching situations that stimulate creativity, most of the respondents declared to be in favour of defining the skills, knowledge, recommendations/instructions for the realisation of the curriculum and the standards. It is clear that knowledge plays a crucial role in all thinking processes, be it convergent, divergent, creative thinking or problem solving (Feldhusen, 2002). Even though the goals and outcomes constitute the most important information in the curriculum for teachers, they agree that they need specific instructions, topics, laboratory tasks and evaluation criteria. Generally, the stressing of goals and outcomes concerning the development of creativity has no effect whatsoever unless it is supported by specific situations.

The teachers need additional instructions for organising students' work and criteria for evaluating the activities and products of their students. Laboratory work, which teachers refer to as an example, does not necessarily stimulate creativity if it is not organised with this in mind, especially if it is not research based. Teaching practice shows that such work requires a lot of training and experience (Ahtee *et al.*, 2011). Teachers require additional guidelines in order to organise their work so that they can use the potential of certain teaching situations (Newton and Newton, 2010). If this information is to be useful to the majority of teachers, it is necessary to examine certain situations in terms of conducting a discussion, developing abilities and providing support for strengthening desirable competencies (Wood, 2006).

Conclusions and implications

The society of today and of the future requires educated, enterprising and creative persons. Changes in society are faster and more complex than ever before, and require skilful and quick reactions, flexibility and adaptability. Thus, the most desirable characteristics of future generations are individuality, self-reliance, independence, tolerance, readiness to take risks and readiness for lifelong learning. The above-mentioned are precisely the elements of creativity that are increasingly required every day (Welle-Strand and Tjeldvoll, 2003).

Creativity is certainly something that can be stimulated through chemistry teaching. It is therefore important to emphasize the need to improve the curriculum for encouraging students' creativity (Mohd Daud *et al.*, 2012). Divergent thinking and original answers could be associated with the process of finding solutions to the problems of different levels of difficulty, and could appear when students face the challenge of connecting knowledge from various domains in order to solve problems that are of importance to them (Schmidt, 2011).

If creativity is posited as an imperative in today's educational process, the following question arises: what should be the guidelines, help and task for teachers of science/chemistry to enable these requirements to be fulfilled in their teaching practice? Individual examples from practice constantly demonstrate that a creative teacher will find ways of organising his/her teaching in such a manner. However, just as teachers are confronted with requisite contents/outcomes that they are expected to realise, it is also necessary to provide support in other ways, through their initial education, professional training and curriculum, with the aim of realising creative teaching, which would stimulate the creativity of their students.

The basic guidelines for this aim should be presented in documents regulating and organising the teaching process, namely, the curriculum. The results of the presented survey conducted on a sample of 334 teachers working in primary, secondary and grammar schools in Serbia show that most teachers have a positive attitude towards the development and stimulation of creativity through teaching chemistry and most of them claim that their teaching practice contains activities that are conducive to this. These findings are, with respect to the first research question of the study, related to teachers' perceptions for creativity development within chemistry teaching.

Also, this study responds to the question related to teaching situations for promoting divergent thinking and creativity that could be planned and realised based on the instructions contained in the curriculum. According to the opinion of the teachers, the curriculum offers different types of support for the planning and realisation of theoretical situations (organisation of discussions among students or their preparation of essays) and experimental/mathematical situations for creativity development. Among the given situations that could be realised based on the curriculum, the ones that stand out are solving problems through divergent solutions and students' presentations, which, if realised in a manner that does not involve evaluation that stresses and rewards the importance of an analytical, critical and creative approach, does not necessarily mean support to creativity. It is clear that specific descriptions of teaching situations and criteria for evaluating students' work are what teachers require in their curriculum.

Recognising laboratory work as the key way of stimulating creativity, more than half of the respondents are of the opinion that the curriculum does not contain enough instructions for supporting students to independently prepare and conduct experiments.

The answer to the third research question shows that concrete recommendations related to teaching situations, tests, tasks, teaching methods and instruction for the realisation of experimental work are essential information to be obtainable from the curriculum. Such instructions and additional suggestions should be included in various components of the curriculum, through definitions of knowledge, skills and views, recommendations for the realisation and evaluation and through explanations of the importance of chemistry as a natural science. They should be presented by means of concrete examples, which teachers would be able to realise and use as a model for planning other teaching situations. Placing emphasis on the development of creativity through goals and outcomes, be it within the framework of strategies or the curriculum, is of no importance to either teachers or students unless it is supported by specific suggestions. Chemistry teaching and teachers could enable students to perform independent research, solve problems and make assessments in prepared teaching situations through well thought out and planned work.

Table 10 The future curriculum components and associated information

Information	Contents of curriculum components	Curriculum components
Recommendation necessary for the planning and realisation of different parts of the teaching process (teaching situations, teaching/learning methods, evaluation)	– Descriptions of teaching situations – Examples of workbook tasks, tests – Criteria for evaluating students' work – A list of questions – Compulsory teaching methods for certain teaching units – Topics for independent student papers	– Recommendations/instructions for realising the curriculum – Formative and summative assessment
Information associated with accomplishment of experimental and mathematical problems with divergent approaches to solution	– Experimental solving of problem-type situations – Solving mathematical problems through divergent approaches – Students independently prepare and conduct experiments – Organise work with divergent solutions in laboratory practice	– Recommendations/instructions for realising the curriculum – Formative and summative assessment – Outcomes – Skills
Necessary examples of experimental and mathematical tasks	– Compulsory laboratory tasks – Examples of laboratory tasks – Specific mathematical problems – Specific contents	– Recommendations/instructions for realising the curriculum
Operationalisation of goals	– Indicators – Outcomes – Science as research	– The outcomes/achievements of teaching chemistry – Outcomes – Knowledge – Outcomes – Skills
Information for the consideration of certain themes with incorporated divergent approaches	– Organising situations in which students prepare and realise presentations dealing with topical issues – Considering arguments for and against some decisions – Students independently produce essays, projects, and notice boards – Evaluation of achievements based on creativity and the originality of solution	– Recommendations/instructions for realising the curriculum – Formative and summative assessment

Precisely this is where additional support in the curriculum is a necessity. The contribution of this study is that it could guide future development of the curriculum by making it more usable for teachers and thus enable creative thinking amongst students.

Based on the results of the factor analysis, connections could be made between the possible future components of the curriculum and associated information that would support development of divergent thinking and creativity in chemistry teaching (Table 10). Furthermore, Table 10 presents the possible contents of the future curriculum components.

The contents in Table 10 could be a useful base for future discussions related to curriculum reform between different partners: the Association of Chemistry Teachers, the members of the Serbian Chemical Society, the Institute for the Improvement of Education, the Ministry of Education and the National Education Council of the Republic of Serbia.

It should be noted that self-reported data are associated with a number of limitations of the study, such as the ability of the teachers to accurately estimate their activities and their subjectivity based on an understanding of creativity. This leads to another limitation of this study that concerns the familiarity rate of teachers with the concept of creativity. In addition, for the open-ended questions, which were asked to obtain the most concrete answers, the fit was less than half of the teachers. This is something we hope to explore in our future work, which would have several implications for future research.

First, more quantitative and qualitative studies are recommended for further exploration of the indicators of creativity support in different teaching/learning situations in the classroom, as well as of indicators of the progress of students in divergent thinking and creation of original answers or products. Furthermore, the results of these studies could provide the base for the development of the criteria for evaluating the activities and products of students. Interviews could provide much more depth and explore more complex beliefs, understandings and experiences of teachers associated with the concept of creativity.

Appendix

The questionnaire

Part I (Q1–Q5)

(1) In which type of school do you teach? (a) Primary school (b) Grammar school (c) Secondary vocational school	(2) How many years have you taught? (a) Less than 5 (b) 5–10 (c) 10–20 (d) 20–30 (e) More than 30	(3) Sex: (a) Male (b) Female
(4) How old are you? (a) 25–30 (b) 31–40 (c) 41–50 (d) 51–60 (e) Above 60	(5) What are your academic qualifications?	

Part II (Q6–Q9)

(6) In which phases of planning do you use the chemistry curriculum? (a) When preparing the annual work plan (b) When preparing a monthly work plan (c) When preparing a class scenario in writing	(7) Has your need to use the curriculum (during periods when there were no changes to it) changed as your working experience increased? (a) I have used the curriculum to an equal degree all the time (b) I use the curriculum less now than when I started working (c) I use the curriculum more now than when I started working
(8) What kind of information contained in the curriculum is the most important to you for the realisation of your teaching plan? (a) The goals and tasks of chemistry (b) Operative tasks/outcomes (c) The contents of themes (d) Demonstration experiments (e) Practice classes (f) Instructions for the realisation of a topic (g) The manner of realising the curriculum (h) Additional work	(9) To what extent do you rely on the contents of textbooks during the realisation of your teaching plan? (1) Not at all (2) Very little (3) Very much (4) Completely

Part III (Q10–Q14)

(10) Are you of the opinion that all persons, irrespective of sex and age, possess creative potential that could be developed through education? (a) Yes (b) No (c) I don't know	(11) Are you of the opinion that education through teaching chemistry provides opportunities for creative approaches and support to the development of creativity? (a) Yes (b) No (c) I don't know

Table (*continued*)

Part III (Q10–Q14)

(12) Are you of the opinion that the contents of chemistry are conducive to stimulating creativity?
(a) All contents are equally conducive
(b) The majority of the contents are conducive
(c) Only a few of the contents are conducive
(d) The contents are not conducive at all

(13) Are you of the opinion that the scientific methodology of chemistry is conducive to stimulating creativity?
(1) Not at all
(2) To a negligible degree
(3) A little
(4) Very much so
(5) Completely

(14) Does your teaching practice contain situations in which you stimulate students' creativity?
(a) Yes
(b) No
Name the situations in which you stimulate students' creativity?

Part IV (Q15–Q20)

(15) To what extent does the chemistry curriculum offer you possibilities to realise situations in which you are able to stimulate creativity and accept divergent solutions?
(1) Not at all
(2) To a negligible degree
(3) A little
(4) Mostly
(5) Completely

(16) To what extent are you guided by information contained in the curriculum in realising the following teaching situations? (1-Not at all; 2-To a negligible degree; 3-A little; 4-Mostly; 5-Completely)
(1) Organising work with divergent solutions in laboratory practice
(2) Solving mathematical problems through divergent approaches
(3) Experimental solving of problem-type situations
(4) Students independently produce essays, projects, notice boards...
(5) Students independently prepare and conduct experiments
(6) Evaluation of achievements based on creativity, originality of solution
(7) Organising situations in which students prepare and realise presentations dealing with topical issues
(8) Considering arguments for and against some decision

(17) Mark the curriculum components through which you should obtain the most information needed for the realisation of teaching situations that stimulate creativity.
- General educational goals
- General educational outcomes
- General educational goals realised through teaching chemistry
- General educational outcomes realised through teaching chemistry
- The importance of natural sciences/the importance of chemistry/introduction to the subject
- The goals of teaching chemistry
- The outcomes/achievements of teaching chemistry
- Outcomes – knowledge
- Outcomes – skills
- Outcomes – views
- Standards
- Recommendations/instructions for realising the curriculum
- Evaluation

(18) To what extent are you guided by information contained in the segments of the curriculum in the realisation of teaching situations that stimulate creativity?
(1-Not at all; 2-To a negligible degree; 3-A little; 4-Mostly; 5-Completely)
Underline the parts of the text that you refer the most.

Science as research
A ...Creative thinking in new and unknown situations can be achieved in various ways, but those that will prove especially productive are the situations that require very diverse occurrences and those that stimulate students' intuition...
...Experiments such as those dealing with the determination of physical characteristics, the dissolution of compounds and the examination of gaseous reactions should be an introduction to open-type research wherein students are entrusted with the task of posing questions, planning experiments, gathering and presenting data and communication. For example, after determining their physical properties, students may examine the connection between the density of certain liquids and their boiling temperatures.

An example of the operationalisation and concretisation of goals
B Content framework
In everyday life, one is confronted with a large number of substances that are used for making solutions. The ratio of the solute and the solvent determines the concentration level and the physical properties of the solution.
C Standard
Students understand the terms concentration, solute and solvent, and apply them when describing a solution.

Table (continued)

Part IV (Q15–Q20)
D Goal Students should: – Describe the factors that influence the process of dissolution and assess the influence of changes on the concentration of a solution. E Indicators Students: – Describe a solution using the terms solute and solvent; – Draw a representation of a solution at the level of particles; – Describe the solute–solvent ratios in concentrated and dilute solutions, expressing the concentration of a solution through molarity and molality; – Prepare and conduct an experiment with the view of determining how certain factors (*e.g.*, mixing, particle size, temperature) influence the dissolution of the solute; – Connect the ppm value with significant issues pertaining to research into environmental protection. An example of the operationalisation and concretisation of goals F Content: Water as a solvent. Solutions and solubility. G Goal: describing the effect of water as a solvent and other properties pertaining to solubility. H Description – studying the terms: solvent, solute and solution; – The rule of solubility; – The saturation of a solution, and interpreting the solubility curve. I Outcome Students will: – Know and use the terms solvent, solute, solution and saturated solution; – Know the general rules explaining the solubility of the most widely known types of salts in water; – Understand that different substances are characterised by different levels of solubility in water, and that solubility depends on temperature; – Know that the solubility of gases decreases with increasing temperature; – Predict the level of solubility of some types of salts in water; – Understand and interpret simple solubility curves. (19) To what extent would it be useful for you if parts of the curriculum contained specific information on the realisation of teaching situations that are conducive to creativity as help and support during your preparation? (1-Not at all; 2-To a negligible degree; 3-A little; 4-Mostly; 5-Completely) (1) Specific contents (2) Examples of laboratory tasks (3) Compulsory laboratory tasks (4) Specific mathematical problems (5) Compulsory teaching methods for certain teaching units (6) Topics for independent student papers (7) A list of questions (8) Examples of workbook tasks, tests (9) Descriptions of teaching situations (10) Criteria for evaluating students' work (20) State what you consider to be a necessary part of the curriculum for the purpose of providing guidelines for the development and stimulation of creativity through teaching chemistry.

Acknowledgements

This paper represents the result of working on the project "Scientific Theory and Practice in Society: Multidisciplinary, Educational and Inter-generational Perspectives", Reg. No. 179048, the realisation of which is financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

Ahtee M., Juuti K., Lavonen J. and Suomela L., (2011), Questions asked by primary student teachers about observations of a science demonstration, *Eur. J. Teach. Educ.*, **34**, 347–361.

Avramiotis S. and Tsaparlis G., (2013), Using computer simulations in chemistry problem solving, *Chem. Educ. Res. Pract.*, **14**, 297–311.

Barrow L. H., (2010), Encouraging Creativity with Scientific Inquiry, *Creat. Educ.*, **1**, 1–6.

Bennett S.W., (2008), Problem solving: can anybody do it? *Chem. Educ. Res. Pract.*, **9**, 60–64.

Cardellini L., (2006), Fostering creative problem solving in chemistry through group work, *Chem. Educ. Res. Pract.*, **7**, 131–140.

Christiana K. and Talanquer V., (2012), Modes of reasoning in self-initiated study groups in chemistry, *Chem. Educ. Res. Pract.*, **13**, 286–295.

Craft A., (2001), An analysis of research and literature on Creativity in education, Report prepared for the Qualifications and Curriculum Authority.

Drechsler M. and Van Driel J., (2009), Teachers' perceptions of the teaching of acids and bases in Swedish upper secondary schools, *Chem. Educ. Res. Pract.*, **10**, 86–96.

Feldhusen J. F., (2002), Creativity: the knowledge base and children, *High Abil. Stud.*, **13**, 179–183.

Getzels J. W., (1985), *Creativity and Human Development*, The International Encyclopaedia.

Heilmann G. and Korte W. B., (2010), *The Role of Creativity and Innovation in School Curricula in the EU27, A content analysis of curricula documents*, European Commission Joint Research Centre Institute for Prospective Technological Studies.

Kong S. L., (2007), Cultivating Critical and Creative Thinking Skills, in Tan A. G. (ed.), *Creativity a Handbook for Teachers*, Singapore: World Scientific Publishing, pp. 303–326.

Kozbelt A., Beghetto P. A. and Runco M. A., (2010), Theories of Creativity, in Kaufman J. C. and Sternberg R. J. (ed.), *The Cambridge Handbook of Creativity*, Cambridge University Press, pp. 20–47.

Lewis S. E., Shaw J. L. and Freeman K. A., (2011), Establishing open-ended assessments: investigating the validity of creative exercises, *Chem. Educ. Res. Pract.*, **12**, 158–166.

Mohd Daud A., Omar J., Turiman P. and Osman K., (2012), Creativity in Science Education, Procedia Soc. Behav. Sci., **59**, 467–474.

National Advisory Committee on Creative and Cultural Education (NACCCE), (1999), All our futures: creativity, culture and education, London: Department for Education and Employment.

Newton L. D. and Newton D. P., (2010), What Teachers See as Creative Incidents in Elementary Science Lessons, *Int. J. Sci. Educ.*, **32**, 1989–2005.

Overton T. and Potter N., (2008), Solving open-ended problems, and the influence of cognitive factors on student success, *Chem. Educ. Res. Pract.*, **9**, 65–69.

Overton T., Potter N. and Leng C., (2013), A study of approaches to solving open-ended problems in chemistry, *Chem. Educ. Res. Pract.*, **14**, 468–475.

Park S., Lee S. Y., Oliver J. S. and Cramond B., (2006), Changes in Korean Science Teachers' Perceptions of Creativity and Science Teaching After Participating in an Overseas Professional Development Program, *J. Sci. Teach. Educ.*, **17**, 37–64.

Pilling G. M. and Waddington D. J., (2005), Implementation of Large-Scale Science Curricula: A Study in Seven European Countries, *J. Sci. Educ. Technol.*, **4**, 393–407.

Rutland M. and Barlex D., (2008), Perspectives on pupil creativity in design and technology in the lower secondary curriculum in England, *Int. J. Technol. Des. Educ.*, **18**, 139–165.

Schmidt A. L., (2011), Creativity in Science: Tensions between Perception and Practice, *Creat. Educ.*, **2**, 435–445.

Stamovlasis D., Tsitsipis G. and Papageorgiou G., (2010), The effect of logical thinking and two cognitive styles on understanding the structure of matter: an analysis with the random walk method, *Chem. Educ. Res. Pract.*, **11**, 173–181.

Statistical Office of the Republic of Serbia, (2013), URL:http://webrzs.stat.gov.rs/WebSite/.

Sternberg R. J., (1997), A Triarchic View of Giftedness: Theory and Practice, in Coleangelo N. and Davis G. A. (ed.), *Handbook of Gifted Education*, Boston, MA: Allyn and Bacon, pp. 43–53.

Sternberg R. J., (2003), WICS as a Model of Giftedness, *High Abil. Stud.*, **14**, 109–137.

Sternberg R. J., (2006), Introduction, in Kaufman. J. C. and Sternberg R. J. (ed.), *The International Handbook of Creativity*, Cambridge: Cambridge University Press, pp. 1–10.

Sternberg R. J., (2007), Creativity as a Habit, in Tan A. G. (ed.), *Creativity a Handbook for Teachers*, Singapore: World Scientific Publishing, pp. 3–26.

Sternberg R. J. and Williams W. M., (1996), *How to Develop Student Creativity*, Alexandria, VA, USA: Association for Supervision & Curriculum Development.

Tabachnick B. G. and Fidell L. S., (2001), *Using multivariate statistics*, Needlam Heights, MA, USA: Allyn and Bacon.

Taber K. S., (2013), Non-random thoughts about research, *Chem. Educ. Res. Pract.*, **14**, 359–362.

Tanggaard L., (2011), Stories about creative teaching and productive learning, *Eur. J. Teach. Educ.*, **34**, 219–232.

Taylor I. A., (2007), A Retrospective View of Creativity Investigation, in Irving T. A. and Getzels J. W. (ed.), *Perspectives in Creativity*, Piscataway, NJ, USA: Transaction Publishers.

Torrance E. P., (1988), The Nature of Creativity as manifest in its testing, in Sternberg R. J. (ed.), *The Nature of Creativity*, New York: Cambridge University Press, pp. 43–75.

Watkins M. W., (2000), *Monte Carlo PCA for parallel analysis (computer software)*, State College, PA: Ed & Psych Associates.

Welle-Strand A. and Tjeldvoll A., (2003), Creativity, Curricula and Paradigms, *Scand*, *J. Educ. Res.*, **47**, 359–372.

Wood C., (2006), The development of creative problem solving in chemistry, *Chem. Educ. Res. Pract.*, **7**, 96–113.

