C·E·P·S Journal

Center for Educational Policy Studies Journal
Revija Centra za študij edukacijskih strategij

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The CEPS Journal is an open-access, peer-reviewed journal devoted to publishing research papers in different fields of education, including scientific.

Aims & Scope

The CEPS Journal is an international peer-reviewed journal with an international board. It publishes original empirical and theoretical studies from a wide variety of academic disciplines related to the field of Teacher Education and Educational Sciences; in particular, it will support comparative studies in the field. Regional context is stressed but the journal remains open to researchers and contributors across all European countries and worldwide. There are four issues per year. Issues are focused on specific areas but there is also space for non-focused articles and book reviews.

About the Publisher

The University of Ljubljana is one of the largest universities in the region (see www.uni-lj.si) and its Faculty of Education (see www.pef.uni-lj.si), established in 1947, has the leading role in teacher education and education sciences in Slovenia. It is well positioned in regional and European cooperation programmes in teaching and research. A publishing unit oversees the dissemination of research results and informs the interested public about new trends in the broad area of teacher education and education sciences; to date, numerous monographs and publications have been published, not just in Slovenian but also in English.

In 2001, the Centre for Educational Policy Studies (CEPS; see http://ceps.pef.uni-lj.si) was established within the Faculty of Education to build upon experience acquired in the broad reform of the national educational system during the period of social transition in the 1990s, to upgrade expertise and to strengthen international cooperation. CEPS has established a number of fruitful contacts, both in the region – particularly with similar institutions in the countries of the Western Balkans – and with interested partners in EU member states and worldwide.

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Revija Centra za študij edukacijskih strategij je mednarodno recenzirana revija z mednarodnim uredniškim odborom in s prostim dostopom. Namenjena je objavljanju člankov s področja izobraževanja učiteljev in edukacijskih ved.

Cilji in namen

Revija je namenjena obravnavanju naslednjih področij: poučevanje, učenje, vzgoja in izobraževanje, socialna pedagogika, specialna in rehabilitacijska pedagogika, predšolska pedagogika, edukacijske politike, supervizija, poučevanje slovenskega jezika in književnosti, poučevanje matematike, računalništva, naravoslovja in tehnike, poučevanje družboslovja in humanistike, poučevanje na področju umetnosti, visokošolsko izobraževanje in izobraževanje odraslih. Poseben poudarek bo namenjen izobraževanju učiteljev in spodbujanju njihovega profesionalnega razvoja.

V reviji so objavljeni znanstveni prispevki, in sicer teoretični prispevki in prispevki, v katerih so predstavljeni rezultati kvantitavnih in kvalitativnih empiričnih raziskav. Še posebej poudarjen je pomen komparativnih raziskav.

Revija izide štirikrat letno. Številke so tematsko opredeljene, v njih pa je prostor tudi za netematske prispevke in predstavitve ter recenzije novih publikacij.

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215 Rachel Mamlok-Naaman, Ingo Eilks, George Bonner and Avi Hofstein, *Professional Development of Chemistry Teachers: Theory and Practice*, Advance in chemistry education series (vol. 1), Royal Society of Chemistry: London, UK, 2018; 203 pp.: ISBN: 978-1-78262-706-7
— Silvija Markic

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Editorial

Chemistry Education in the Countries of the Former Yugoslavia

Why is a woman and chemistry education researcher from Germany interested in the development and the situation of chemistry education in the seven new countries of the former Yugoslavia?

Well, Yugoslavia was the country where I grew up. When I think about my childhood and the name Yugoslavia, I have memories of a place where different people lived together in an attractive geographic region where it was possible – in such a small region – to go skiing during the winter, but also spend the whole warm summer at the beach. For me, the country was characterised by a diversity of languages, ethnicities, cultures and religions. These were similar in many ways, but some differences were also noticeable. For me, it made us a "little Germany", where everybody lives together. Germany is the country where I live now.

I went to school in the former Yugoslavia for nine years, starting in 1984, and experienced how chemistry was taught and learned. The differences between my chemistry lessons in German classes and those in the former Yugoslavia were enormous. I cannot say what was better or what was not, but I can say that it was different.

Yugoslavia was made up of six constituent socialist republics: SR Bosnia and Herzegovina, SR Croatia, SR Macedonia, SR Montenegro, SR Serbia and SR Slovenia. In addition, two Socialist Autonomous Provinces, Vojvodina and Kosovo, were members of the federation. The country existed in Southeast and Central Europe for the majority of the twentieth century. Yugoslavia was established after the First World War in 1918 and broke up in the early 1990s.

After the end of the Socialist Federal Republic of Yugoslavia, in summer 1991, Slovenia and Croatia declared independence and were recognised by most European countries in January 1992. In April of the same year, Bosnia and Herzegovina's independence was also recognised. In autumn 1991, the Republic of Macedonia declared independence and, in April 1992, the Federal Republic of Yugoslavia was formed, which was a union of Serbia, Montenegro, Vojvodina and Kosovo. In the following years, Kosovo and Montenegro became independent states. The former SR Serbia and the province of Vojvodina are now the Republic of Serbia.

Thus, from a starting point of one country with the same system in all of the republics and both provinces, seven different new countries now exist.

As a chemistry education researcher interested in the development of chemistry education, but also as somebody who knew only the one system and one way of chemistry education shared by seven countries, I have a strong interest in and curiosity about the possibilities for the development of chemistry education when starting from one system. Since the fall of socialist politics in those countries, some changes can be seen. I never experienced those changes myself, which is why I am so interested in them. I wanted to see whether the countries are focusing on similar issues or have different foci. Since my roots are in one of these new countries, I have always observed and been interested in the development of chemistry education in the countries of the former Yugoslavia.

The submissions in this focus issue are different in nature, but present a bright picture of good research and development in the countries of the former Yugoslavia.

The paper entitled *Chemical Education Research in Slovenia after 1991: A Systematic Review* by Iztok Devetak and Vesna Ferk Savec from the University of Ljubljana gives a systematic review of chemistry education research in Slovenia after 1991. Two main research groups exist, in Ljubljana and Maribor, and four main research fields are identified: submicrorepresentations, models and animations; chemistry teacher education; experimental work; and conceptions of basic chemical concepts. This shows a wide range of research.

Croatia is represented in this issue by two papers, both focusing on the research on preservice chemistry teachers. The paper entitled *Initial Beliefs of Preservice Chemistry Teachers in Croatia* by Lana Šojat examines the beliefs about teaching and learning that preservice chemistry teachers possess prior to commencing their chemistry education courses. The study shows that the beliefs are traditional in nature and, in some cases, are in line with the old Yugoslavian system. The second paper, *Evidence of the Development of Pedagogical Content Knowledge Related to Chemical Bonding during a Course for Preservice Chemistry Teachers* by Roko Vladušić, Robert Bucat and Mia Ožić, addresses the development of preservice chemistry teachers' pedagogical content knowledge (PCK) related to chemical bonding. A university course on the topic was changed and evaluated. The findings show evidence of the growth of an individual preservice teacher's PCK about chemical bonding. The particular characteristics of the change described by the authors indicate that their source is almost certainly the revised Chemistry Education 2 curriculum.

The paper entitled *Chemistry Education in Bosnia and Herzegovina* by Meliha Zejnilagić-Hajrić and Ines Nuić from the University of Sarajevo in Bosnia and Herzegovina presents the development of chemistry education in this country. Bosnia and Herzegovina is different to the other countries presented in this special issue, as it is characterised by linguistic, religious and cultural diversity. The authors present the education system in their country, as well as the education system for future chemistry teachers.

Mirjana D. Segedinac, Dušica D. Rodić, Tamara N. Rončević, Saša Horvat and Jasna Adamov from the University of Novi Sad present the development of research in the field of chemistry education at their university since the breakup of the Socialist Federal Republic of Yugoslavia. Novi Sad is a city in Vojvodina, which is part of Serbia. The authors take us on a tour of chemistry education research, starting with the integration of the computer in chemistry teaching and learning in the 1990s, through the possibility of including eco-chemical content in chemistry curricula, to an investigation of the effectiveness of instructional strategies based on a systemic approach and a triplet model of content representation, using combined measures of students' performance and mental effort.

Fatlume Berisha is the author of the paper *Chemistry Education in Kosovo: Issues, Challenges and Time for Action*. The contribution from Kosovo is a study based on a multidimensional analysis of the issues and challenges of chemistry education in this country. The author describes the curricula for pre-university education, with a focus on the challenging field of natural science. She presents conclusions regarding action based on the results.

The paper entitled *Challenges and Recommendations for Improving Chemistry Education and Teaching in the Republic of North Macedonia*, written by Marina Stojanovska, Ivanka Mijić and Vladimir M. Petruševski from North Macedonia, discusses challenges and recommendations for improving chemistry education and teaching on the primary, secondary and tertiary level in the authors' country. One of the greatest challenges identified is the lack of investment in education and the absence of notable improvements in the conditions for teaching chemistry. The authors give recommendations at different levels, from the need for appropriately educated, qualified and motivated teaching staff, well-equipped laboratories and teaching resources, through the Continuous Professional Development (CPD) of chemistry teachers and the mutual cooperation of all stakeholders in the educational process, to continuous support from the authorities and policy-makers for gifted pupils and chemistry teachers.

This focus issue is completed with two VARIA papers from the wider field of education.

The paper entitled *Business School Teachers' Experiences with a Student with Autism Spectrum Disorder* by Jaka Vadnjal and Darinka Radoja focuses on business school teachers' experiences with a student with autism, presenting a study that is qualitative in nature. The findings indicate that teachers generally express that working with students with autism is a very positive experience, but they describe such teaching as a challenge. The authors point out that cooperation with experts and parents is crucial for success.

The second paper, *Advancing the Scholarship of Teaching and Learning using Learning Theories and Reflectivity* by Lester Brian Shawa from South Africa, discusses advancing the scholarship of teaching and learning (SoTL) using learning theories and reflectivity. In the article, the author describes the use of a postgraduate diploma module entitled Higher Education Context and Policy to show how a facilitator can draw from learning theories and reflectivity to teach and advance SoTL.

Although the countries of the former Yugoslavia are facing similar changes and challenges, it is good to see their potential and the work that has been put into chemistry education research and development in the last thirty years. I am happy that I had a chance to meet and collaborate with colleagues from almost all of the states. I am very thankful to them for giving me and other readers an insight into the development of their work. Finally, I would like to thank all of the authors for their contributions to this focus issue.

Silvija Markic

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Chemical Education Research in Slovenia after 1991: A Systematic Review

Iztok Devetak*[1] and Vesna Ferk Savec[2]

During the last three decades, chemical education in Slovenia has developed mainly in two chemistry education research groups, one located at the University of Ljubljana and the other at the University of Maribor. The present study aims to identify research papers in the field of chemical education published between 1991 and 2019 through a database survey. From a total of 273 identified research papers in the field of chemical education, an analysis of the papers published in respected international and Slovenian journals and monographs revealed four main research fields: (1) Submicrorepresentations, Models and Animations, (2) Chemistry Teacher Education, (3) Experimental Work, and (4) Conceptions of Basic Chemical Concepts. For further analysis, only papers published in English in respected peer-reviewed international journals were used (N = 41). Based on citations in Web of Science or Scopus, it seems that papers published in the first field have the greatest impact on the international research community. Some research monographs published in Slovenian aim specifically at contributing to bridging the gap between chemical education research and classroom practice, but further actions are necessary to achieve this goal in the future.

Keywords: chemical education research, Slovenia, teaching and learning chemistry

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Raziskovanje v kemijskem izobraževanju v Sloveniji po letu 1991: sistematični pregled

Iztok Devetak in Vesna Ferk Savec

V zadnjih treh desetletjih se je kemijsko izobraževanje v Sloveniji razvijalo predvsem v dveh raziskovalnih skupinah, ena na Univerzi v Ljubljani in druga na Univerzi v Mariboru. Namen te raziskave je na osnovi analize podatkov v bibliografskih bazah ugotoviti področja raziskovanja v kemijskem izobraževanju, objavljena med letoma 1991 in 2019. Od skupno 273 identificiranih raziskovalnih prispevkov s področja kemijskega izobraževanja, objavljenih v uglednih mednarodnih in slovenskih revijah in monografijah, je analiza razkrila štiri glavna raziskovalna področja: 1) submikroreprezentacije, modeli in animacije; 2) izobraževanje učiteljev kemije; 3) eksperimentalno delo; 4) razumevanje osnovnih kemijskih pojmov. Za nadaljnjo analizo so bili uporabljeni samo članki, objavljeni v angleškem jeziku v uglednih mednarodnih revijah ($N = 41$). Glede na citate, spremljane v Web of Science ali Scopus, se zdi, da prispevki, objavljeni na prvem področju, najbolj vplivajo na mednarodno raziskovalno skupnost. Prispevki, objavljeni v monografijah, objavljenih predvsem v slovenskem jeziku, pa prispevajo k premostitvi vrzeli med raziskovanjem v kemijskem izobraževanju in poukom kemije, vendar so za dosego tega cilja v prihodnosti potrebni nadaljnji ukrepi.

Ključne besede: raziskovanje v kemijskem izobraževanju, Slovenija, poučevanje in učenje kemije

Introduction

In the 28 years of Slovenian independence, chemical education research has developed rapidly. The significance of national research lies in the development of new approaches that can be applied in specific professional activities, and this is also true for education. Cooperation between members of research groups can lead to progress in a specific field of research, including in chemical education research. This kind of cooperation is, however, quite weak in Slovenia. There are two major research groups in these fields, one at the University of Ljubljana and one at the University of Maribor. These two research groups have started to cooperate in some projects in the last few years. There are no research activities in the field of chemical education at the University of Primorska. The major focus of the present paper is to review research published in international peer-reviewed journals. However, there are also publications in Slovenian that chemistry teachers can easily read and apply the research results to practice (e.g., Devetak, 2007; Devetak & Metljak, 2014; Ferk Savec & Devetak, 2017; Glažar, Wissiak Grm, & Devetak, 2019; Grubelnik, 2010). In the Slovenian context, there is also the journal *Kemija v šoli in družbi* (Chemistry in School and Society), which is popular in school, but not as present as it should be in the chemical education research community. Similar problems can be identified with the journal *Naravoslovna solnica* (The Natural Science Saltcellar), which is not particularly relevant for chemistry teachers, but rather for teachers of earlier science at the preschool and primary school level.

Chemical Education in the Slovenian School System

Slovenian primary school education is organised in a single-structure nine-year basic school for students aged 6 to 15 years. It is mandatory, 99 percent public, and state financed. After entering basic compulsory nine-year education, students in primary education (aged 6–11; grades 1–5; Learning about the Environment, and Science and Technology courses) learn basic science concepts including chemical concepts, such as states of matter, mixtures and pure substances, basic separation methods, burning, air and water pollution, and solutions. Students aged from 12 to 13 years (grades 6 and 7) upgrade their knowledge of basic chemical concepts (chemical reactions, elements and compounds, particles of matter) in a course simply called Science. This level of compulsory basic education can be referred to as a lower secondary school. In the last two years of compulsory basic education, students are engaged in chemistry courses, because science is separated into three basic science courses (chemistry, biology and physics). The students are 14 to 15 years old and attend grades 8 and 9. At this point, they develop more specific chemical knowledge, as they are engaged in two years of chemistry classes. Topics range from the structure of atoms and molecules, to chemical reactions, properties of elements and their compounds, acids and bases, and organic chemistry topics (e.g., hydrocarbons, oxygen, and organic nitrogen compounds). After finishing basic compulsory education, students can proceed to the next level of education, which is two to four years of non-compulsory education. This upper secondary education can be: 1) four-year general upper secondary education (*gimnazija*), which prepares students to enter university and concludes with the *Matura* exam (external national final exam); and 2) vocational and technical upper secondary education, with programmes of various levels of difficulty (two- to four-year programmes). In *gimnazija,* students learn chemistry for three years, while those who choose chemistry as a *Matura* exam subject prepare for the external exam for an additional year. The chemistry topics are similar to those in lower secondary school, but upgraded (e.g., the orbitals of atoms, chemical equilibrium, redox reactions, organic chemical reactions, etc.).

Vocational and technical education programmes can have from zero to three years of chemical education, depending on the nature of the programme (e.g., economics has only one year of science, pharmacy has three years of chemistry similar to the chemistry in *gimnazija*). We can conclude that Slovenian students who finish general upper secondary school enter a university programme with five years of chemical education, and those who finish the chemistry *Matura* exam complete six years of advanced chemical education (Torkar & Devetak, 2018).

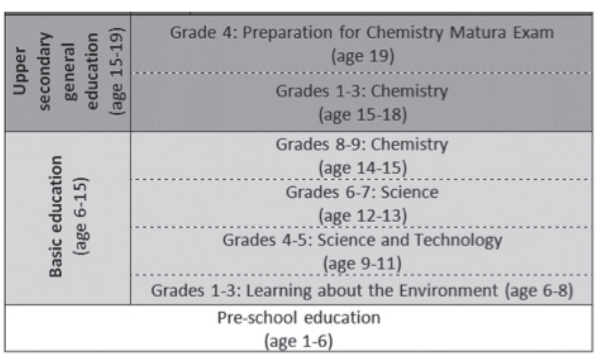

Figure 1. The structure of chemistry education in Slovenia. Adapted from Devetak & Ferk Savec, 2018.

The Beginnings of Slovenian Chemical Education Research

One of the most important landmarks in Slovenian chemical education research can be identified in the first issue of the International Journal of Science Education (entitled the European Journal of Science Education at that time). Aleksanda Kornhauser Frazer wrote a review paper identifying key trends in chemical education research in the late 1970s, dealing with visionary issues of chemical education. Entitled *Trends in Research in Chemical Education*, the paper projected future aspects of research in chemical education following an extensive review of the then recent research in chemical education. The review analysed some 250 different papers published mainly in the period 1975–77, under the following keywords: general research in chemical education, content-oriented research, research into methods of chemical education, teaching aids and the use of educational technology, and research in assessment and evaluation (Kornhauser, 1979). Since then, research has significantly influenced chemical education in Slovenia at all levels of education, both on the systemic level in curriculum development as well as in school practice.

Judging by the trends presented in the review paper 40 years ago, similar topics have remained interesting in the chemical education research community both internationally and in the Slovenian context. However, a more detailed analysis of the chemistry education research field in Slovenia since its independence in 1991 is needed.

Research Problem

The present study was carried out to survey papers published by recognised scientific journals from 1991 to 2019, with the aim of examining evidence from chemistry education research conducted in the Slovenian context. The main focus is on reviewing chemistry education research in Slovenia after 1991 and evaluating the research methodologies and research results that could influence chemistry learning.

Based on this research focus, the following research question can be formed:

- What are the characteristics of Slovenian research papers published between 1991 and 2019, and what are the main findings that could help to determine which aspects teachers should consider when teaching abstract chemical concepts at all levels of chemistry education?

Method

A systematic review of research papers in the field of chemistry education research in Slovenian in the last 28 years was undertaken. In accordance with the definition of "systematic review", we combined evidence from multiple studies by identifying relevant research, appraising study quality and summarising findings. The systematic approach of a literature review uses systematic methods to collect secondary data, critically appraise research studies and synthesise findings qualitatively or quantitatively. Systematic reviews formulate research questions to identify and synthesise studies that directly relate to the systematic review's research problem. With such studies, a complete, exhaustive summary of current evidence relevant to a research question is provided (Smith et al., 2011).

Search strategy

In the first step of the study, we determined the following inclusion criteria: (1) the study was written by Slovenian authors, (2) the study was related to chemistry learning, (3) primary, secondary and university students participated in the study, and (4) the study was conducted between 1991 and 2019, was peer reviewed and was reported in English. Relevant studies were selected based on these criteria.

The *Slovenian Current Research Information System (SICRIS*) database was used to identify the relevant Slovenian authors. This database is supported by the Information Service for Slovenian Science, Culture and Education (IZUM) and the Slovenian Research Agency (ARRS). The main search classification was used following the scientific field as social science, the area of education and the subarea of special didactics. A total of 255 researchers were identified. After screening the researchers' database, 22 chemical education researchers were identified.

A specific research algorithm was applied to the SICRIS database to identify all peer-reviewed research papers written by these 22 chemical education researchers and published in English by journals or as chapters of monographs. Papers in respected peer-reviewed journals and international monographs were included in the systematic review.

Through this research, a total of 148 journal papers and 125 monograph chapters were identified for further analyses. The final selection of the journal papers and monograph chapters was conducted using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses, Moher et al., 2009) flow diagram (Figure 2).

Content analysis was performed on the 41 selected studies that are exclusively from the chemical education field. Descriptions of four topics were examined: (1) participants, (2) supported methods, (3) chemistry content, and (4) basic results applicable in the school context. The papers that were not analysed were from other fields of science education.

Selection of studies and data extraction

Two authors (ID and VFS) independently checked the titles and abstracts identified in the search. They examined the full texts of the studies for possible relevance for assessment, decided which papers met the inclusion criteria, and specified the codes and categories formed by extracting relevant data from the included studies. The authors then met to compare and confirm the results. Any disagreements were resolved by discussion between the authors. If there were not enough data about a certain content-analysis criterion, the corresponding author of the specific paper was contacted for additional information on methodology or results. If no response was obtained within three weeks after two separate written requests, the analysis was done using the available data.

Results and discussion

The search identified 273 papers from researchers in the field of chemical education in Slovenia in the last 28 years, published in journals and monographs. After screening the titles and abstracts, 113 papers were selected for full-text screening (Figure 2). The main reason for rejecting 160 papers was that the articles did not discuss research problems from the field of chemical education in Slovenia in the last 28 years. After contacting the authors of unpublished research regarding the aim of our study, no additional papers were received. Some 15 research fields were identified and 113 papers and monograph chapters were arranged in these fields (Table 1).

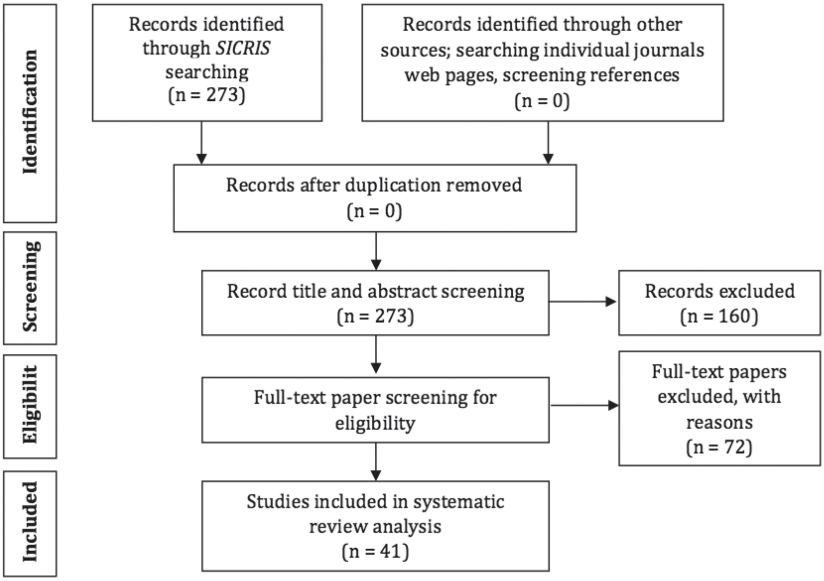

Figure 2. PRISMA flow diagram for our study. Adapted from Moher et al., 2009.

As can be seen in Figure 2, 72 of the journal papers and monograph chapters were excluded because the papers were in Slovenian, Bosnian or French, or because they explored problems other than chemical education (e.g., chemistry, science informatics, science education in general, technology education, curriculum development, higher education quality, teachers' medical education and so on). A total of 41 published papers (Figure 2 and Table 1) met the inclusion criteria of (1) chemical education research paper, (2) publication in a peer-reviewed international journal, and (3) language of publication is English.

Table 1

The research focuses identified in Slovenian research reports and the number of papers and chapters published in these research areas

Research Focus	Language of Publication	Type of Research Publication	
		Journal Paper *f / f%*	Monograph Chapter *f / f%*
Submicro Representations, Models and Animations*	Slo.	-	3 / 6
	Eng.	14 / 21	2 / 4
Chemistry Teacher Education*	Slo.	1 / 2	3 / 6
	Eng.	10 / 15	6 / 13
Experimental Work*	Slo.	-	7 / 15
	Eng.	9 / 14	2 / 4
Conceptions of Basic Chemical Concepts*	Slo.	2 / 3	6 / 13
	Eng.	8 / 12	1 / 2
Environmental Chemistry	Slo.	1 / 2	3 / 6
	Eng.	5 / 8	-
Interdisciplinary Education	Slo.	-	1 / 2
	Eng.	2 / 3	-
Context-Based Learning	Slo.	-	3 / 6
	Eng.	1 / 2	1 / 2
Motivation & Performance in Chemistry	Slo.	1 / 2	1 / 2
	Eng.	2 / 3	2 / 4
Assessment of Knowledge in Chemistry	Slo.	1 / 2	1 / 2
	Eng.	1 / 2	1 / 2
History of Chemistry and Chemical Education	Slo.	3 / 5	-
	Eng.	-	-
Inquiry-Based Chemical Education	Slo.	-	-
	Eng.	1 / 2	-
Concept Mapping	Slo.	-	-
	Eng.	2 / 3	1 / 2
The Relevance of Chemical Education, School-University-Industry Collaboration	Slo.	-	1 / 2
	Eng.	-	1 / 2
Stoichiometry	Slo.	-	-
	Eng.	1 / 2	-

Research Focus	Language of Publication	Type of Research Publication	
		Journal Paper *f* / *f*%	Monograph Chapter *f* / *f*%
Education of the Gifted	Slo.	-	-
	Eng.	1 / 2	1 / 2
Total	Slo.	9 / 14	29 / 62
	Eng.	57 / 86	18 / 38
		66	**47**

Note. Research focuses that were analysed in more detail due to the fact that they were identified as the main research fields of Slovenian chemistry education researchers (papers in peer-review journals in English n = 41).

An analysis of papers published in respected international and Slovenian journals and monographs identified four main research focuses: (1) Submicrorepresentations, Models and Animations, (2) Chemistry Teacher Education, (3) Experimental Work, and (4) Conceptions of Basic Chemical Concepts. A total of 75 papers and monograph chapters were published in English and Slovenian focusing on these four topics. For further analysis, only papers published in English in respected peer-reviewed international journals were used. There were 41 papers in this category (Figure 2 and Table 1).

Characteristics of the Analysed Studies

The analysed studies were divided into four sub-sections of the main research fields:

(1) Submicrorepresentations, Models and Animations, (2) Chemistry Teacher Education, (3) Experimental Work, and (4) Conceptions of Basic Chemical Concepts.

Submicrorepresentations, Models and Animations

One of the largest research areas concerns Submicrorepresentations, Models and Animations used in chemical education. The characteristics of papers published in the last 28 years by Slovenian chemical education researchers in this area are presented in Table 2. It can be concluded that the majority of these papers have had an impact on the international chemical education research community, because all of those published before 2018 in respected peer-reviewed international journals have at least one citation in Web of Science or Scopus.

Table 2

Characteristics of the analysed papers that met the inclusion criteria in the research field of Submicrorepresentations, Models and Animations (listed according to publication year)

Authors	Title	Characteristics*
Ferk Savec, V., Vrtačnik, M., Blejec, A., Gril, A.	Students' understanding of molecular structure representations	J: *International Journal of Science Education* ISSN: 0950-0693; PY: 2003; PP: 18; NoR: 55 NoCit: Wos 77 Scopus 92
Devetak, I., Urbančič, M., Wissiak Grm, K. S., KrneL, D., Glažar, S. A.	Submicroscopic representations as a tool for evaluating students' chemical conceptions	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2004; PP: 15; NoR: 22 NoCit: Wos 15 Scopus 13
Ferk Savec, V., Vrtačnik, M., Gilbert, J. K., Peklaj, C.	In-service and pre-service teachers' opinion on the use of models in teaching chemistry	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2006; PP: 9; NoR: 18 NoCit: Wos 5 Scopus 5
Devetak, I., Vogrinc, J., Glažar, S. A.	Assessing 16-year-old students' understanding of aqueous solution at submicroscopic level	J: *Research in Science Education* ISSN: 0157-244X; PY: 2009; PP: 22; NoR: 46 NoCit: Wos 32 Scopus 40
Devetak, I., Hajzeri, M., Glažar, S. A., Vogrinc, J.	The influence of different models on 15-years-old students' understanding of the solid state of matter	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2010; PP: 7; NoR: 37 NoCit: Wos 2 Scopus 4
Devetak, I., Glažar, S. A.	The influence of 16-year-old students' gender, mental abilities, and motivation on their reading and drawing submicrorepresentations achievements	J: *International Journal of Science Education* ISSN: 0950-0693; PY: 2010; PP: 32; NoR: 52 NoCit: Wos 17 Scopus 15
Devetak, I., Vogrinc, J., Glažar, S. A	States of matter explanations in Slovenian textbooks for students aged 6 to 14	J: *International Journal of Environmental and Science Education* ISSN: 1306-3065; PY: 2010; PP: 18; NoR: 40 NoCit: Scopus 7
Sikošek, D., Žuželj, M.	Using chemical models for developing natural science competences in teaching chemistry: from pupils as model assemblers to pupils as creators of self-made models	J: *Problems of Education in the 21st Century* ISSN: 1822-7864; PY: 2013; PP: 9; NoR: 20
Nuić, I.,Glažar, S. A.	Application of web-based learning material for teaching states of matter in 8th grade primary school chemistry - a pilot study results	J: *Glasnik Hemičara i Tehnologa Bosne i Hercegovine* ISSN: 0022-9830; PY: 2015; PP: 7; NoR: 25
Ferk Savec, V., Hrast, Š., Devetak, I., Torkar, G.	Beyond the use of an explanatory key accompanying submicroscopic representations	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2016; PP: 9; NoR: 43 NoCit: Wos 4 Scopus 6

Authors	Title	Characteristics*
Hrast, Š., Ferk Savec, V.	The integration of submicroscopic representations used in chemistry textbook sets into curriculum topics	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2017; PP: 8; NoR: 34 NoCit: Wos 0 Scopus 1
Hrast, Š., Ferk Savec, V.	Informational value of submicroscopic representations in Slovenian chemistry textbook sets	J: *Journal of Baltic Science Education* ISSN: 2538-7138; PY: 2017; PP: 11; NoR: 30 NoCit: Wos 0 Scopus 1
Torkar, G., Veldin, M., Glažar, S. A., Podlesek, A.	Why do plants wilt? Investigating students' understanding of water balance in plants with external representations at the macroscopic and submicroscopic levels	J: *Eurasia Journal of Mathematics, Science and Technology Education* ISSN: 1305-8223; PY: 2018; PP: 11; NoR: 44 NoCit: Wos 0 Scopus 0
Pavlin, J., Glažar, S.A, Slapničar, M., Devetak, I.	The impact of students' educational background, interest in learning, formal reasoning and visualization abilities on gas context-based exercises achievements with submicro-animations	J: *Chemistry Education Research and Practice* ISSN: 1756-1108; PY: 2019; PP: 16; NoR: 79 NoCit: Wos 0 Scopus 0

Note. J = Journal; PY = Publication Year; PP = No. of pages; R = No. of references; NoCit = Number of citations in Web of Science (WoS) and Scopus (citations until 16.08.19).

A more detailed analysis of the research problems and main conclusions of these papers indicates that the most important subfield was research of students' understanding of molecular representations, such as various models and modelling activities. Ferk Savec, Vrtačnik, Blejec and Gril (2003) investigated the meanings attached by students to the different kinds of molecular structure representations used in chemistry teaching. The research indicates that students' appreciation of three-dimensional molecular structures differs according to the kind of representation used. The best results were achieved with the use of concrete and pseudo-concrete types of representations (e.g., three-dimensional models, their photographs, computer-generated models), while the use of more abstract types (e.g., schematic representations, stereochemical formula) was less effective. Similar research was conducted by Sikošek and Žuželj (2013) investigating students' ability to assemble commercial models and oversee the production of self-made models. The research showed that this activity leads to a better understanding of chemical concepts and subsequently sustained knowledge. It is also important to emphasise that students who model their own models develop more complete skills in the areas of problem-solving, practical competences, mathematical competences and critical thinking skills. Multi-modelling activities (the use of physical models in teachers' demonstrations, student modelling, and virtual models of solid states in the educational process) aimed at acquiring a better understanding of the crystal structures of substances were also researched in a study involving first-year general upper secondary school students (Devetak, Hajzeri, Glažar, & Vogrinc, 2010). The results indicate that the students who modelled physical models scored better on a post-test than both those who used virtual models and those who were taught the solid state of matter by the teachers' demonstration of physical models. It can be concluded that students who are engaged in active learning strategies that include modelling or computer interaction using virtual models develop more adequate mental models of solid-state substance structures. There were also studies of teachers' opinions about using models in chemistry teaching. Many teachers claimed that 3D models are still not available in sufficient numbers at their schools; they also pointed out a lack of available computer facilities during chemistry lessons. The research revealed that, besides the inadequate material circumstances, less than one-third of the participants were able to use simple (freeware) computer programs for drawing molecular structures and their presentation in virtual space; however, both groups of teachers expressed a willingness to improve their knowledge in the subject area. The investigation indicates several actions that could be undertaken to improve the current situation (Ferk Savec, Vrtačnik Gilbert, & Peklaj, 2006).

A large body of research concerns the importance of integrating the triple nature of chemical concepts, especially submicrorepresentations of substances, into teaching, and the correlations between different students' abilities and understanding of chemical concepts at the submicro level. In this regard, Devetak, Urbančič, Wissiak Grm, Krnel and Glažar (2004) concluded that students who had chosen chemistry as part of their *Matura* exam (final external examination at the end of upper secondary school before entering the university) achieved better results in problems involving basic chemical concepts about solutions, acids and bases, as well as equilibria based on submicrorepresentations, than those who had not. The authors found that students who took the *Matura* exam prepared for the exam by practising linking the three levels of chemical concepts (macro, submicro and symbolic). However, this way of learning and teaching chemistry was rarely practised in Slovenian secondary schools at that time.

In a study by Devetak, Vogrinc and Glažar (2009), the authors investigated the level of upper secondary school students' understanding of solution concentration and the process of dissolving ionic and molecular crystals at the particulate level. Possible misconceptions about this process were identified in the study. Students showed rather low achievement scores in the problem regarding drawing the SMR of an ionic substance aqueous solution (7.6% correct answers), and an even lower success rate in a problem regarding drawing the SMR of diluted and saturated aqueous solutions of a molecular crystal (no completely correct answers).

The use of animated submicrorepresentations in biochemical systems was researched by Torkar, Veldin, Glažar and Podlesek (2018), who applied the eye tracking methodology to measure students' attention to different parts of a presentation of osmosis. It was established that the students who were more successful in providing correct answers to the tasks at the multi-level of concept presentations spent less time processing information provided by the macro photo of the plant and the submicro animation of the osmosis in the plants' cell. Using the eye tracking methodology to assess participants' visual attention to specific elements at the explanatory key of submicrorepresentations was also examined in research by Ferk Savec, Hrast, Devetak and Torkar (2016). Eye-fixation patterns and students' verbal explanations indicated that the presence of colour in the key does not influence students' task solving. The results indicate that the type of explanatory key may play an important role in revealing students' representational competence with regard to submicroscopic representations.

In addition, two papers were published explaining how students' different abilities can influence their achievements in solving a submicrorepresentations problem. The results show moderate but statistically significant correlations between students' intrinsic motivation, formal reasoning abilities and chemical knowledge at the submicroscopic level, based on reading and drawing submicrorepresentations. Visualisation abilities are not statistically significantly correlated with students' success on items that comprise reading or drawing submicrorepresentations (Devetak & Glažar, 2010). A similar study was conducted by Pavlin, Glažar, Slapničar and Devetak (2019). The context-based gas exercise is indicated as being difficult for students. Difficulties are detected in students' explanations of different levels of chemical concepts and representation. Students' achievements in solving context-based gas exercises do not depend on interest in learning chemistry and visualisation abilities. However, statistically significant differences exist in total fixation duration on the correct submicrorepresentation animation between students with different formal reasoning abilities.

Four papers examined the importance of integrating the submicro level of chemical concepts in chemistry textbooks or online learning materials. The basic aim of a study by Devetak, Vogrinc and Glažar (2010) was to investigate the content of textual and pictorial material in Slovenian science textbooks and notebooks on the topic of states of matter. The paper presents the results of an analysis of educational material from two randomly selected publishers for students aged 6 to 14 in Slovenian primary and lower secondary schools. The results reveal quite a few similarities between the analysed textbooks (number of pages, type of items), but some differences could be detected when comparing the type of images in the educational material. Content analysis of the selected textbooks also shows that they retain the content directed by the national curriculum, but the ways (examples, content of the images, etc.) in which authors present the topics differ. A paper by Hrast and Ferk Savec (2017a), entitled The Informational Value of Submicroscopic Representations in Slovenian Chemistry Textbook Sets, describes four holistic submicro representation descriptors (direct, indirect, combined descriptor and submicro representations without descriptors) that support learners' recognition of the informational value of submicro representations at different levels by providing different accompanying submicro representation add-ons. The same authors also published the paper Hrast and Ferk Savec (2017b), in which they focus on how submicroscopic representations are integrated into Slovenian chemistry textbooks. The analysis of textbook sets revealed that the number of submicroscopic representations varies significantly with regard to different curriculum topics, but that the overall proportion of the descriptors that enable the learner direct recognition of submicro representations is low in all curriculum topics. The final paper in this group deals with the results of a study that investigated the progression in primary school students' conceptions of the structure and states of matter while learning with a new web-based instructional approach containing macro and submicro representations. The results showed a better understanding of the structure and states of matter, but also revealed some persistent misconceptions that could be addressed in further research (Nuić & Glažar, 2015).

Chemistry Teacher Education

An analysis of publications in the field of Chemistry Teacher Education revealed that researchers focused on three main aspects of preservice and inservice chemistry teacher training: active learning, the role of teaching practice, and international collaboration. The citations of these papers are low.

Table 3

Characteristics of the analysed papers that met the inclusion criteria in the research field of Chemistry Teacher Education (listed according to publication year)

Authors	Title	Characteristics*
Sikošek, D.	Student self-evaluation of co-lecture activities	J: *Problems of Education in the 21st Century* ISSN: 1822-7864; PY: 2009; PP: 6; NoR: 6
Sikošek, D.	Student self-evaluation of seminar activities	J: *Problems of Education in the 21st Century* ISSN: 1822-7864; PY: 2009; PP: 6; NoR: 8
Ferk Savec, V., Devetak, I.	Evaluating the effectiveness of students' active learning in chemistry.	J: *Procedia - Social and Behavioral Sciences* ISSN: 1877-0428; PY: 2013; PP: 8; NoR: 9 NoCit: Scopus 0
Wissiak Grm, K. S., Ferk Savec, V.	Bridging the gap between educational research and school practice through cooperation of university and primary school teachers.	J: *Procedia - Social and Behavioral Sciences* ISSN: 1877-0428; PY: 2013; PP: 8; NoR: 11 NoCit: Scopus 0
Sikošek, D., Žarić, K.	Implementation of process-targeted activities of prospective chemistry teachers during continuous teaching practice: a rational comparative analysis of teaching methods according to the expressed competencies.	J: *Problems of Education in the 21st Century* ISSN: 1822-7864; PY: 2013; PP: 14; NoR: 16
Wissiak Grm, K. S., Ferk Savec, V.	The self-evaluation of Slovenian prospective chemistry teachers' progress during their practical pedagogical training in primary schools.	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2014; PP: 8; NoR: 20 NoCit: Wos 3 Scopus 3
Ferk Savec, V., Urankar, B., Aksela, M., Devetak, I.	Prospective chemistry teachers' perceptions of their profession: the state of the art in Slovenia and Finland	J: *Journal of the Serbian Chemical Society* ISSN: 1820-7421; PY: 2017; PP: 17; NoR: 57 NoCit: Wos 0 Scopus 0
Ferk Savec, V., Wissiak Grm, K. S.	Development of chemistry pre-service teachers during practical pedagogical training: self-evaluation vs. evaluation by school mentors.	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2017; PP: 9; NoR: 27 NoCit: Wos 1 Scopus 1
Ferk Savec, V., Hrast, Š., Šuligoj, V., Avsec, S.	The innovative use of ICT in STEM teacher training programmes at the University of Ljubljana.	J: *World Transactions on Engineering and Technology Education* ISSN: 1446-2257; PY: 2018; PP: 6; NoR: 16 NoCit: Wos 0 Scopus 0
Kousa, P., Aksela, M., Ferk Savec, V.	Pre-service teachers' beliefs about the benefits and challenges of STSE based school-industry collaboration and practices in science education.	J: *Journal of Baltic Science Education* ISSN: 2538-7138; PY: 2018; PP: 11; NoR: 41 NoCit: Wos 0 Scopus 0

Note. J = Journal; PY = Publication Year; PP = No. of pages; R = No. of references; NoCit = Number of citations in Web of Science (WoS) and Scopus (citations until 16.08.19).

As many as five articles in this field focused on active learning in preservice and in-service chemistry teacher training, strategies for facilitating the active role of students, and the role of ICT (Information and Communication Technology) in the learning process. Sikošek (2009a) analysed active learning approaches in the chemistry teacher education programme at the Faculty of Education of the University of Maribor (i.e., the subjects Didactics of Chemistry, Experiments, and Natural Activities-Mentorship). The research showed that co-lecture activities were valued regarding optional AADIDG (Activity, Autonomy, Differentiation and Individualisation, Democracy, and Gradual Study) didactic principles. Later, Sikošek (2009b) focused on the curricular innovations of methodological subjects for chemistry teachers at undergraduate education at the University of Maribor. The redesign of the seminar, understood as an essential curricular form, was based on ongoing consideration of topical didactic principles. Thereby, their research findings aimed to serve the optimisation of the performance of activities during the seminar. Other researchers (Ferk Savec, Hrast, Šuligoj, & Avsec, 2018) focused on the development of preservice teachers' competencies related to the use of ICT, which is necessary for the successful implementation of ICT-supported innovative approaches and effective teaching and learning in their future school practice. The renewed study subjects were also studied based on the theoretical framework of the SAMR (Substitution, Augmentation, Modification and Redefinition) model, which defines four different degrees of ICT integration in the learning process. Regarding in-service teacher training, Ferk Savec and Devetak (2013) evaluated the active learning approach PROFILES. The results underline various advantages of the treatment classes with the use of approach PROFILES in comparison to regular chemistry classes, when guided by trained in-service chemistry teachers, but also indicate that 8th graders need some time to adapt to the innovative learning strategy. With regard to in-service teacher training, Wissiak Grm and Ferk Savec (2013) focused on the gap between chemistry education research and teaching practice, reporting about a collaboration between researchers at the University of Ljubljana and in-service teachers in the PROFILES project. The findings point out the importance of very concise and unequivocal instructions for in-service teachers to ensure that all parts of the project are performed in line with the research plan.

The next three papers focused on the role of teaching practice and the experiences that students gain during practice at schools. Sikošek and Žarić (2013) pointed out that teachers of chemistry need to gain or develop learner competencies for appropriate teaching/learning in the subject of chemistry by using innovative teaching methods. The main result of the study was a list of potential competencies by prospective chemistry teachers using innovative teaching methods. Wissiak Grm and Ferk Savec (2014) conducted a study about students performing teaching practice. An analysis of the results revealed that students believe that teaching practice makes a crucial contribution to their education in light of their future profession. A similar study was conducted later by Ferk Savec and Wissiak Grm (2017), who studied the self-evaluation of the progress of 4th year preservice chemistry teachers during their second year teaching practice in primary schools in comparison to the perception of their progress by their school mentors. The results revealed that student teachers were stricter in their self-evaluation than their school mentors after their first chemistry lecture at school; however, after their last lecture, the evaluations were similar for most of the studied characteristics.

The last two papers in the chemistry teacher education field dealt with international collaboration and exchange of experiences in preservice chemistry teacher training. The researchers (Ferk Savec, Urankar, Aksela, & Devetak, 2017) especially with regard to their understanding of the role of the triple nature of chemical concepts (macro, submicro and symbolic studied Slovenian and Finnish preservice chemistry teachers' perceptions of their future profession. The results indicate that the majority of preservice teachers from both countries believe that personal characteristics, enthusiasm and understanding the triple nature of chemical concepts are the most important attributes of a successful chemistry teacher. A further study (Kousa, Aksela, & Ferk Savec, 2018)teachers´ negative beliefs, lack of knowledge, resources, support and opportunities to collaborate with companies can impede the efficient implementation. In this case-study, 42 Finnish and Slovenian pre-service teachers´ STSE beliefs were first examined before and after the school-industry collaboration course by survey. After the course, beliefs of 8 Finnish pre-service teachers were analyzed in more detail by open-ended questionnaires and reflective writing. The pre-service teachers were more confident to teach STSE issues after the course in both countries. However, they needed more support and knowledge from the community members they collaborated with (i.e. representatives of industries, university teacher, student colleagues and school teachers of Slovenian and Finnish preservice chemistry teachers focused on their science, technology, society and environment (STSE) beliefs. The preservice teachers needed more support and knowledge from the community members they collaborated with (i.e., representatives of industries, university teachers, student colleagues and school teachers). The results of this research highlight the importance of preservice teacher education and practices with STSE issues, and pointed out that both positive and negative beliefs should be examined frequently even during preservice education in order to develop tools for teacher support and encouragement in their future teaching practice.

Experimental Work

Nine papers were published in the field of Experimental Work. Again, these papers do not seem to have been so influential on the international research community, given that the citation rates are lower than in the Submicrorepresentations, Models and Animations field analysed above.

Table 4

Characteristics of the analysed papers that met the inclusion criteria in the research field Experimental Work (listed according to publication year)

Authors	**Title**	**Characteristics***
Zupančič-Brouwer, N, Glažar, S. A., Vrtačnik, M.	Using starch to dispense indicators and reagents.	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2000; PP: 7; NoR: 21 NoCit: Wos 0 Scopus 0
Gros, N., Vrtačnik, M.	A small-scale low-cost gas chromatograph.	J: *Journal of Chemical Education* ISSN: 0021-9584; PY: 2005; PP: 2; NoR: 7 NoCit: Wos 5 Scopus 4
Pavlin, J., Vaupotič, N., Glažar, S. A., Čepič, M., Devetak, I.	Slovenian pre-service teachers' conceptions about liquid crystals.	J: *Eurasia Journal of Mathematics, Science and Technology Education* ISSN: 1305-8223; PY: 2011; PP: 7; NoR: 20 NoCit: Wos 0 Scopus 6
Logar, A., Ferk Savec, V.	Students' hands-on experimental work vs lecture demonstration in teaching elementary school chemistry.	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2011; PP: 9; NoR: 39 NoCit: Wos 6 Scopus 8
Urbančič, M., Glažar, S. A.	Impact of experiments on 13-year-old pupils' understanding of selected science concepts.	J: *Eurasia Journal of Mathematics, Science and Technology Education* ISSN: 1305-8223; PY: 2012; PP: 11; NoR: 25 NoCit: Wos 3 Scopus 3
Juriševič, M., Vrtačnik, M., Kwiatkowski, M., Gros, N.	The interplay of students' motivational orientations, their chemistry achievements and their perception of learning with the hands-on approach to visible spectrometry.	J: *Chemistry Education Research and Practice* ISSN: 1109-4028; PY: 2012; PP: 10; NoR: 71 NoCit: Wos 6 Scopus 6
Vrtačnik, M., Gros, N.	The impact of a hands-on approach to learning visible spectrometry upon students' performance, motivation, and attitudes.	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2013; PP: 11; NoR: 45 NoCit: Wos 2 Scopus 2
Rizman Herga, N., Glažar, S. A., Dinevski, D.	Dynamic visualization in the virtual laboratory enhances the fundamental understanding of chemical concepts.	J: *Journal of Baltic Science Education* ISSN: 1648-3898; PY: 2015; PP: 14; NoR: 42 NoCit: Wos 3 Scopus 3
Logar, A., Peklaj, C., Ferk Savec, V.	Effectiveness of student learning during experimental work in primary school	J: *Acta Chimica Slovenica* ISSN: 1318-0207; PY: 2017; PP: 10; NoR: 53 NoCit: Wos 0 Scopus 1

Note. J = Journal; PY = Publication Year; PP = No. of pages; R = No. of references; NoCit = Number of citations in Web of Science (WoS) and Scopus (citations till 16.08.19).

An analysis of the papers about experimental work revealed various focuses of the research in this field. The first group of papers dealt with the development of new experimental procedures and special equipment for the school chemistry laboratory. The paper by Zupančič-Brouwer, Glažar and Vrtačnik (2000) described the development of a new experimental method that could be used in teaching and learning acid-base concepts. In the described method, a soft medium based on flour was used as a reaction medium to carry out chemical reactions that can normally run in water solution. Gros and Vrtačnik (2005) proposed the design and application of a small-scale portable gas chromatograph for hands-on learning of the basic concepts of chromatography. The operation of the instrument was optimised so that it offers a low-cost solution for presenting chromatography that does not require the use of a computer for recording data.

In a follow-up paper, researchers (Vrtačnik & Gros, 2013) evaluated the effect of introducing visible spectrometry concepts through hands-on laboratory work within four vocational programmes. The results showed no correlation between students' motivational components (intrinsic, regulated and controlled), their chemistry self-concept and their achievement in an experiential knowledge test, on the one hand, and knowledge gained from the hands-on approach, on the other. All of the students, regardless of their study programme, gave a positive evaluation of the relaxed atmosphere that contributed to their self-confidence in completing their laboratory activities. With regard to the described hands-on approach to visible spectrometry, the researchers (Juriševič, Vrtačnik, Kwiatkowski, & Gros, 2012) also aimed to determine the relationship between students' motivational orientations and their chemistry achievements, based on a sample of students from Polish and Slovenian vocational and technical high schools. The results indicated that hands-on laboratory work with autonomy-supportive teachers could create a motivating learning environment for students to learn with understanding and to cooperate with each other in academic tasks at a higher level of cognitive complexity.

The main focus of further articles in this field was the evaluation of students' cognitive achievements gained through hands-on experimental work related to selected content. Pavlin, Vaupotič, Glažar, Čepič and Devetak (2011) evaluated students' general conceptions related to liquid crystals and their properties, as well as to the state of matter in general. The students' achievements depended on their gender, their self-assessed knowledge of liquid crystals, and their field of study. Based on the results of the study, learning units were developed to stimulate students' knowledge development about liquid crystals. The researchers (Urbančič & Glažar, 2012) also studied the impact of experimental work on the understanding of scientific concepts. The results show that one third of the pupils in the experimental group were unable to write down even one experiment they remembered from science classes; of the remaining two thirds of the pupils who wrote down at least one experiment, none of them managed to describe it correctly. Although they were unable to describe the experiments, the students' achievements in the experimental group were significantly higher than those in the control group. The results also show that pupils believe experiments to be the most popular part of science classes. The research by Herga, Glažar and Dinevski (2015) examined the classroom application of a virtual laboratory in integrating the triple levels of chemistry. The results revealed that, in terms of knowledge acquisition, the use of a virtual laboratory improved pupil performance relative to pupils who did not use elements of dynamic visualisation in the classroom, and that the virtual laboratory positively influenced pupils' understanding of selected chemical concepts.

Researchers (Logar & Ferk Savec, 2011) also focused on an evaluation of the effectiveness of different forms of experimental work. The results indicated that student content knowledge gained through a teacher's demonstration of an experiment was better, and with better knowledge retention, than student knowledge gained through students' hands-on experimental work. However, most of the interviewed students stated that they preferred conducting experiments themselves rather than observing a teacher's demonstration. A follow-up study (Logar, Peklaj, & Ferk Savec, 2017) aimed to provide further details related to the effectiveness of student learning based on experimental work in primary schools. The results identified eight factors that seem to be the most important for effective student learning, of which four factors are part of the teacher's preparation for experimental work, and the other four are related to the thoughtful implementation of experimental work in the classroom.

Conceptions of Basic Chemical Concepts

Another influential area of research is Conceptions of Basic Chemical Concepts. Eight papers were published in this area. The number of citations achieved by some of the papers is shown in Table 5.

Table 5

Characteristics of the analysed papers that met the inclusion criteria in the research field Conceptions of Basic Chemical Concepts (listed according to publication year)

Authors	Title	Characteristics*
Krnel, D., Watson, R., Glažar, S. A.	Survey of research related to the development of the concept of "matter"	J: *International Journal of Science Education* ISSN: 0950-069; PY: 1998; PP: 32; NoR: 101 NoCit: Wos 51 Scopus 76
Vrtačnik, M., Ferk Savec, V., Dolničar, D., Zupančič-Brouwer, N., Sajovec, M.	The impact of visualisation on the quality of chemistry knowledge	J: *Informatica: An International Journal of Computing and Informatics* ISSN: 0350-5596; PY: 2000; PP: 6; NoR: 19 NoCit: Scopus 1
Vrtačnik, M., Sajovec, M., Dolničar, D., Razdevšek-Pučko, C., Glažar, S. A., Zupančič-Brouwer, N.	An interactive multimedia tutorial teaching unit and its effects on student perception and understanding of chemical concepts	J: *Westminster Studies in Education* ISSN: 0140-6728; PY: 2000; PP: 14; NoR: 14
Krnel, D., Glažar, S. A., Watson, R.	The development of the concept of "matter": a cross-age study of how children classify materials	J: *Science Education* ISSN: 0036-8326; PY: 2003; PP: 18; NoR: 42 NoCit: Wos 23 Scopus 35
Krnel, D., Watson, R., Glažar, S. A.	The development of the concept of "mater": a cross-age study of how children describe materials	J: *International Journal of Science Education* ISSN: 0950-0693; PY: 2005; PP: 16; NoR: 51 NoCit: Wos 10 Scopus 18
Devetak, I., Drofenik Lorber, E., Juriševič, M., Glažar, S. A.	Comparing Slovenian year 8 and year 9 elementary school pupils' knowledge of electrolyte chemistry and their intrinsic motivation	J: *Chemistry Education Research and Practice* ISSN: 1109-4028; PY: 2009; PP: 9; NoR: 43 NoCit: Wos 9 Scopus 12
Slapničar, M., Devetak, I., Glažar, S. A., Pavlin, J.	Identification of the understanding of the states of matter of water and air among Slovenian students aged 12, 14 and 16 years through solving authentic tasks	J: *Journal of Baltic Science Education* ISSN: 1648-3898; PY: 2017; PP: 15; NoR: 48 NoCit: Wos 2 Scopus 2
Slapničar, M., Tompa, V., Glažar, S. A., Devetak, I.	Fourteen-year-old students' misconceptions regarding the sub-micro and symbolic levels of specific chemical concepts	J: *Journal of Baltic Science Education* ISSN: 1648-3898; PY: 2018; PP: 12; NoR: 35 NoCit: Wos 0 Scopus 0

Note. J = Journal; PY = Publication Year; PP = No. of pages; R = No. of references; NoCit = Number of citations in Web of Science (WoS) and Scopus (citations until 16.08.19).

In this period, three papers by three authors in the area of early science education chemistry concept development were published. All three papers presented specific parts of the same study, in which the development of the concept of matter was explored by interviewing 84 students aged 3–13 in Slovenia. The children were asked to describe objects and substances. The patterns of the responses indicate that children first develop prototypes for substances by acting on objects and substances. This is followed by increasing the use of properties to describe objects and substances, leading to a growing awareness of the distinction between the intensive properties of matter and the extensive properties of objects. Through their actions, children gradually develop a more elaborated schema that enables them to distinguish between extensive and intensive properties, and hence between object and matter (Krnel, Glažar, & Watson, 2003; Krnel, Watson, & Glažar, 1998, 2005).

Lower and secondary school education chemistry concept development was discussed in three papers. Slapničar, Tompa, Glažar and Devetak (2018) aimed to identify potential misconceptions of chemical concepts: the states of matter, a pure substance, a mixture, an element, a compound, a physical change, and a chemical reaction at the submicro level when solving problems incorporating submicrorepresentations. The results showed that the majority of students had formed inadequate mental models (misconceptions) for the chemical concept of the liquid state of water (66.5%). The lowest level of misconceptions is related to the gaseous state of matter, with almost all of the students (98.5%) solving the problem correctly. The aim of the research presented in the next paper by Slapničar, Devetak, Glažar and Pavlin (2017) was to identify how Slovenian primary and secondary school students of various age groups (12, 14 and 16 year-olds) explain the particulate nature of the states of matter of water and air. The results show that all of the students correctly identified the states of matter of water at the particulate level, but not of air. The study confirmed the existence of (a) misconceptions regarding the interpretation of the particulate nature of matter, (b) a failure to distinguish between particle and matter, and (c) the inadequate description of the submicroscopic level of matter with a macroscopic level concept. The last study presented in this context, by Devetak, Drofenik Lorber, Juriševič and Glažar (2009), was undertaken to illustrate the most drastic general curriculum change in the Slovenian school system. It explored the differences between eight-year primary school pupils (before the curriculum reform) and nine-year primary school pupils (soon after the curriculum reform) with regard to specific chemistry knowledge and motivation to learn chemistry. The results show that pupils of nine-year primary school do not achieve significantly better chemistry knowledge test scores than eight-year elementary school pupils. Similar results were obtained when comparing intrinsic motivation. It can be concluded that students develop different misconceptions of selected chemical concepts no matter what type of school they attend.

The last two papers discussed the impact of visualisations on chemistry concept understanding. The first study, by Vrtačnik, Ferk Savec, Dolničar, Zupančič-Brouwer and Sajovec (2000), examined the impact of a long-term project entitled Computer Literacy, which equipped the majority of Slovenian primary and secondary schools with multimedia computers and LCD projectors. The authors discussed how chemistry teachers can use specialised Internet websites for visualising chemical structures and processes on the macroscopic and microscopic level and correlate properties of molecules with their structure. The presented results demonstrate the effects of different visualisation elements on the quality of chemical knowledge.

In their study, Vrtačnik, Sajovec, Dolničar, Razdevšek-Pučko, Glažar and Zupančič-Brouwer (2000) researched the effects of an interactive multimedia tutorial unit on students' perception of the new learning environment and their understanding of chemical concepts. Based on the findings, it is possible to conclude that chemistry can be considered a difficult and rather unpopular school subject. No significant differences in these perceptions can be found regarding the students' chemistry grade or their average study grade. Multimedia should therefore be used in teaching with a certain degree of caution, and only after a short introduction to the concepts presented in the unit has been given. Nevertheless, regardless of the mixed feelings about the new learning environment, the multimedia teaching unit has promising effects on students' acquisition of knowledge.

Conclusions

The main focus of this paper was to review the characteristics of Slovenian papers published between 1991 and 2019 and identify the main findings that could help to determine which aspects teachers should consider when teaching abstract chemical concepts at all levels of chemistry education. Four major fields of chemical education research emerged from the analysis: (1) Submicro Representations, Models and Animations, (2) Chemistry Teacher Education, (3) Experimental Work, and (4) Conceptions of Basic Chemical Concepts.

Papers published in the first field have had the greatest impact on the international research community. It is important to emphasise, as Juriševič et al. (2012) conclude, that the main implication for teachers in chemistry classes is to plan their teaching more systematically and creatively in order to provide students with individualised, cognitively and motivationally challenging learning situations, and to foster learning with understanding even within very abstract and cognitively complex learning activities. Such activities can contribute to diminishing existing misconceptions and preventing the formation of new ones.

Another aspect of bridging the rifts between chemical education research and classroom practice could be addressed by forming a journal (indexed in international databases) dedicated to in-service chemistry teachers. This would also provide an opportunity for researchers to publish their manuscripts. However, in-service chemistry teachers should be part of innovative teaching and learning approaches, such as participatory action research that combines theoretical knowledge and practical experience in mixed teams of university personnel, in-service and preservice teachers (Tolsdorf & Markić, 2018). A major part of these activities should comprise reading research papers, whereby students would learn how to use such materials to their advantage in planning effective teaching.

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Initial Beliefs of Preservice Chemistry Teachers in Croatia

Lana Šojat[1]

In the past thirty years, there have been many political changes in Croatia. These changes have had an impact on the education system, as well. The success of such educational changes depends on the teacher. The importance of teachers' knowledge and their beliefs about teaching and learning for their action in the classroom is well known. Beliefs influence teachers' representation of science, science knowledge and the organisation of knowledge and information. Keeping teacher professional development in mind, preservice teachers' beliefs need to be sought out and examined by educators. These beliefs should be developed in the direction of teaching chemistry taking into account recent reforms, as well as teaching and learning theories. Various studies have been undertaken in different education backgrounds and systems regarding the beliefs of both preservice and in-service teachers. These studies show different results depending on the context in which they are undertaken. Transferring data to the Croatian system is therefore difficult. However, there are no studies in Croatia focusing on the teachers' beliefs regrading teaching and learning chemistry. The present study evaluates the initial beliefs of preservice chemistry teachers in Croatia. The participants were instructed to draw themselves as chemistry teachers in a typical classroom situation in chemistry, and to answer four open questions. Data analysis follows a pattern representing a range between the predominance of more traditional orientations versus more modern teaching orientations, in line with educational theory focusing on: 1) beliefs about classroom organisation, 2) beliefs about teaching objectives, and 3) epistemological beliefs. The data revealed mostly traditional and teacher-centred knowledge among all of the participants. In the present paper, the data will be discussed and the implications for Croatian chemistry teacher training will be established.

Keywords: initial teacher education, preservice teachers' beliefs, teacher professional development

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Prepričanja študentov študijskih programov izobraževanja učiteljev kemije na Hrvaškem

Lana Šojat

V zadnjih tridesetih letih je bilo na Hrvaškem veliko političnih sprememb. Te so vplivale tudi na izobraževalni sistem. Uspeh sprememb na področju izobraževanja pa je odvisen od učiteljev. Znano je, da imata na učiteljevo delovanje v razredu velik vpliv njegovo znanje ter prepričanje o poučevanju in učenju. Prepričanja vplivajo na učiteljevo predstavljanje naravoslovja, naravoslovnega znanja ter na organizacijo znanja in informacij. Upoštevajoč poklicni razvoj učiteljev, je treba ugotavljati in preučevati prepričanja študentov študijskih programov, ki se izobražujejo za učitelje. Ta prepričanja bi morala biti razvita v smer poučevanja kemije, upoštevajoč nedavne reforme pa tudi teorije poučevanja in učenja. Različne raziskave so bile izvedene v različnih izobraževalnih kontekstih in sistemih glede na prepričanja študentov študijskih programov izobraževanja učiteljev pa tudi učiteljev iz prakse. Raziskave kažejo različne rezultate, odvisno od konteksta, v katerem so bile izvedene. Prenos podatkov v hrvaški sistem je zato težaven, vendar na Hrvaškem ni raziskav, ki bi se osredinjale na prepričanja učiteljev glede poučevanja in učenja kemije. V prispevku preučujemo začetna prepričanja študentov študijskih programov izobraževanja učiteljev kemije na Hrvaškem. Udeleženci so dobili navodilo, da se narišejo kot učitelji kemije v tipičnem razredu pri pouku kemije in odgovorijo na štiri odprta vprašanja. Analiza podatkov sledi vzorcu, ki predstavlja razpon med prevlado tradicionalnih usmeritev nad sodobnejšimi učnimi usmeritvami skladno z edukacijsko teorijo, ki se osredinja na: 1) prepričanja o organizaciji učilnic; 2) prepričanja o učnih ciljih; 3) epistemološka prepričanja. Podatki vseh udeležencev raziskave kažejo večinoma tradicionalne in na učitelja osredinjene načine poučevanja. V prispevku razpravljamo o rezultatih in ugotavljamo njihovo mogočo uporabo v hrvaških študijskih programih izobraževanja učiteljev kemije.

Ključne besede: študijski programi izobraževanje učiteljev, prepričanja študentov študijskih programov izobraževanja učiteljev, profesionalni razvoj učiteljev

Introduction

Teachers' Beliefs in Science Education Research

Research on beliefs provides a better understanding of humans thought patterns and actions. According to Thompson (1992), the first attempts to research beliefs can be observed at the beginning of the twentieth century, and they become a prominent issue in science education and research in the late 1980s, as cited in Markic (2008). The strong influence of behaviourism shifted the focus from the beliefs in earlier years. In later years, however, the turn away from behaviourism towards constructivism (Kang & Keys, 2000) put beliefs, as well as research about them, back in focus as a point of interest.

Nespor (1987) characterises beliefs as strongly affective and evaluative, deeply personal, stable and lying beyond the individual's controlled knowledge, unaffected by persuasion. According to him, beliefs create an ideal or alternative situation that may sometimes differ from reality; they are rooted deep in vivid memories of experience from the past. As cited in Markic (2008), Nespor speaks of "critical experience" that "[…] produces a richly-detailed episodic memory which later serves the student as an inspiration and a template for his or her own teaching practice" (p. 320). The formation of beliefs based on personal experience is also supported by O'Loughlin and Campbell (1988). Beliefs are defined as psychologically held understandings, premises or prepositions about the world that are felt to be true (Richardson, 2003).

Thus, in the continuation, the definition of beliefs will be adapted from Markic (2008), who claims that:

- *beliefs are separate from knowledge,*
- *beliefs refer to all mental representations that teachers or student teachers hold (consciously and unconsciously) in their minds that influence, to a certain extent, their (potential) behaviour as teachers of science,*
- "*all beliefs are personal constructs influenced by experience, knowledge, and societal backgrounds.*" (Markic, 2008, p. 11)

Teachers play a crucial role in changing classroom reality and supporting the success of different education reforms (De Jong, 2007). They are the binding component of a chain reaching from the ministry of education, to school textbooks and students. Teachers should be the starting point of any changes in the education system. The question is: What influences/affects teachers' actions in the classroom?

In researching the influence of the teacher on their activities in the classroom, different foci are taken. Teachers' practical knowledge consists of *knowledge* and *beliefs* combined with interactive cognition (Meijer, Verloop, & Beijaard, 2002). However, beliefs and knowledge can sometimes be mixed or misinterpreted. The similarities of both terms are pointed out by Anderson (1980): both knowledge and beliefs are experienced acquired information that continues in a person's mind. Nespor (1987), on the other hand, separates these two terms and sees beliefs as a framework for systematic and comparative investigations of teaching. A summary of the characteristics of and differences between beliefs and knowledge, as discussed in the literature (see Savasci-Acikalin, 2009), is given in Table 1. While beliefs seem to be well defined and focus on one direction, teachers' knowledge seems to be more differentiated.

Table 1
Differences between teachers' beliefs and knowledge

Beliefs	Knowledge
Refer to suppositions, commitments and ideologies	Refers to factual propositions and understandings that inform skilful action
Do not require a truth condition	Must satisfy the "truth condition"
Are based on evaluation judgment	Is based on objective fact
Cannot be evaluated	Can be evaluated or judged
Are episodically stored material influenced by personal experiences or cultural and institutional sources	Is stored in semantic networks
Are static	Often changes

Note. Adapted from Savasci-Acikalin, 2009, p. 4.

Teachers' beliefs influence how they represent science in general, and chemistry in particular, in their classrooms and the kinds of opportunities they provide for students to learn (Roth et al., 2006). They are the best indicator of one's behaviour, actions and decision making (Bandura, 1986). Beliefs influence the interactions between teachers and their students, as Koballa, Gräber, Coleman and Kemo (2000) conclude, adding that teachers' beliefs about teaching and learning always include aspects of beliefs exclusive to their chosen discipline or subject. Beliefs play an important role in how teachers organise knowledge and information and are essential in helping them to adapt, understand and make sense of themselves and their world (Schommer, 1990).

Beliefs are sometimes represented as a bridge between a person and the environment (Pajares, 1992; Törner, 2002). They can also be compared to "old clothes" (Schommer-Aikins, 2004, p. 22): they become more comfortable with time and use. This is sometimes an obstacle, inhibiting the necessary change in beliefs of some people. For these reasons, teacher education must work with the beliefs that guide teachers' actions (behaviour) with the principle and evidence that underlie the choices teachers make (Shulman, 1987). A synthesis of findings on beliefs was made by Pajares (1992, pp. 324–326), as follows:

- Beliefs are formed early on and tend to be self-eternalised. They tend to be preserved throughout time, experience, reason and schooling.
- People develop a belief system that contains all of the beliefs attained through the process of cultural transmission.
- Beliefs are prioritised according to their link or relationship to other beliefs.
- The earlier a belief is incorporated into the belief system, the more difficult it is to change.
- Modification of beliefs is relatively rare during adulthood.
- Beliefs are strongly influenced by perceptions.
- The beliefs individuals possess strongly affect their behaviour.
- Beliefs about teaching are well established by the time a student attends college.
- Beliefs play a key role in defining tasks and selecting the cognitive tools used to interpret, plan and make decisions regarding such tasks.

In the past ten years, the focus of science education research has moved to teachers' and student teachers' beliefs (De Jong, 2007). Five interrelated research zones (Calderhead, 1996) are differentiated:

1. Beliefs about learners and learning.
2. Beliefs about teaching.
3. Beliefs about the subject.
4. Beliefs about learning how to teach.
5. Beliefs about "self" and the teaching role.

Preservice teachers commence their teacher training with the set of beliefs they (un)consciously possess. These beliefs are often based on their earlier experience (Markic & Eilks, 2008; Smith, 2005) and they influence their view of the relevance and usefulness of teacher education training. In order to overcome initial (traditional) beliefs, teacher education training must initiate changes through its courses (Choi & Ramsey, 2010).

There is no doubt that the beliefs of preservice and in-service teachers should be the focus of research in the field of science education. In the last thirty years, there has therefore been a significant increase in interest in beliefs in both general and science education (De Jong, 2007). In the literature, various studies can be found about science (student) teachers' beliefs regarding teaching and learning (e.g., Buldur, 2017; Bursal, 2010; Hamilton, 2017; Markic, 2008; Markic & Eilks, 2013). However, these studies have been carried out in different educational backgrounds and systems, with political systems, cultures and religions that are incomparable in most cases. Studies like that by Al-Amoush, Markic, Usak, Erdogan and Eilks, (2014), comparing beliefs about teaching and learning held by chemistry teachers from different countries, reveal significant differences. Similarities can be found in a study by Cakiroglu, Cakiroglu and Boone (2005), conducted on a sample of Turkish and American preservice teachers. In their study, Uzuntiryaki, Boz, Kirbulut and Bektas (2010) show that preservice teachers lack beliefs about constructivism in science teaching. The tendency towards a more constructivist approach to science teaching is demonstrated by experienced teachers rather than beginners (Caleon, Tan, & Cho, 2018). Bryan (2012) presents a review of research on the beliefs of prospective and practising science teachers. With time, under the influence of a teacher training programme or reform initiative, beliefs are influenced. Epistemic beliefs have a significant role in defining different types of teaching knowledge among preservice teachers (Greene & Yu, 2016). They also have an influence on the practice (Brownlee, Schraw, & Berthelsen, 2011; Lunn Brownlee, Ferguson, & Ryan, 2017) and future classrooms of these teachers (Feucht, 2010; Schommer-Aikins, 2004). Furthermore, studies such as those by Alexander (2001), Markic et al. (2016) or Woolfolk-Hoy, Davis and Pape (2006) reveal differences between teachers from different cultural backgrounds within one country.

In Croatia, research on chemistry education is still in its early stages. Vladusic, Bucat and Ozic (2016a) have undertaken research on the understanding of chemical bonding by participants at all levels of the chemical education system in Croatia. The existence of alternative conceptions is noted at all levels of education, but the PCK (pedagogical content knowledge) of teachers cannot be based on an inadequate level of content knowledge. A study on students' understanding of scientific words and representations and everyday words used in chemistry teaching (Vladusic, Bucat, & Ozic, 2016b) indicates considerable differences in the extent of understanding from word to word and symbol to symbol. Although some of the findings are in line with other studies (English-speaking countries), there are some differences specific to the Croatian language (similar sounding words with different meanings, words with different meanings in everyday life and the science context). Research on the use of particulate drawing (Simicic, 2018) in analysis learning, testing and the improvement of conceptual knowledge in initial chemistry teaching found that progress was noticeable in both a control group and a treatment group, with no statistically significant difference. The students in both groups were taught by the same methodical approach, with a slight difference in the use of particulate drawing in the treatment group only. After the instruction, the misconceptions were partly retained, but considerably less so in the treatment group. There is no research about chemistry teachers' beliefs for either preservice or in-service teachers.

Teachers' Beliefs and Curriculum Reforms

In general, teachers' deeply held beliefs need to be sought out by teacher educators in order to provide student chemistry teachers with ample opportunities to create teaching and learning aligned with recent reforms. Preservice teachers' beliefs need to be developed in a direction that ensures that chemistry will be taught according to recent teaching and learning theories. Fenstermacher (1979) argued that one goal of teacher education is to help young teachers transform tacit or unexamined beliefs about teaching, learning and the curriculum into objectively reasonable or evidentiary beliefs. In teacher education, preservice and in-service teachers' beliefs should be a central focus for teacher educators in order to challenge belief systems about teaching and learning. Research into the beliefs of in-service and preservice teachers is very important, yet such beliefs are an insufficiently explored field in science education research, especially in Croatia. Many initial beliefs do not mirror modern educational theories, and teacher educators should raise the awareness of the initial beliefs and preconceptions held by preservice teachers (Bryan & Atwater, 2002). In most Croatian schools, teaching is still based on traditional views. Traditionally orientated in-service teachers (in)directly influence students who are potential future pre-service teachers, affecting their beliefs, as well. Teaching and learning should be student-oriented with students as the central point of the teaching and learning process. There is therefore a need for change at all levels of education.

Reforms in the Croatian Education System

Since the 1990s and the war in Croatia, many political and structural changes have been made. These are evident in the education system, as well. In the past decade, and especially in the past five years, there has been an urgent need for a new, more western-world-oriented education reform. In the past almost thirty years, chemistry has been a mandatory subject in in the final two years of primary school (grades 7 and 8, age 13–15). In secondary school, the inclusion of chemistry depends on whether it is a grammar school (all four years, ages 15–18/19) or vocational school (one or two years for non-chemist vocation, four years for vocation connected with chemistry with a special emphasis on certain typical chemistry knowledge).

Some basic knowledge about matter, atoms, chemical reactions and the basics of organic chemistry are gained in primary school. In secondary school (grammar school), chemistry is divided into general chemistry (1st grade), through physical and inorganic chemistry in the 2nd and 3rd grades, to organic chemistry with the basics of biochemistry in the final year. Although there are connections and interweaving of content, the curriculum – mainly in secondary school – is focused on memorisation and does not link the content with, for instance, social and environmental issues. Teaching chemistry in secondary school (grammar school) is often subject to the pressure of the National Graduation Exam or the university entrance exam.

A new education reform (Jokic, 2016) has been presented in the last few years. Since September 2018, it has been applied in a minority of schools as an experiment, but it is scheduled for implementation in September 2019. From the standpoint of chemistry, this concerns the 7th grade in primary schools and the 1st grade of grammar schools in the territory of Croatia. Chemistry is presented as a mandatory subject in primary school (7th and 8th grade) and the first three years of secondary school. In the final year of secondary school, chemistry is an optional subject for students who plan a career in the area of science. The content is divided into three chemistry macro concepts: (i) Matter, (ii) Chemical Process and Changes, and (iii) Energy, all of which are united in Scientific Literacy (Bybee, 1997). The inquiry-based approach is seen as the main resource for acquiring knowledge, and the experiment is the foundation for gaining new knowledge, which should be integrated into existing knowledge (Gormally, Brickmann, Haller, & Armstrong, 2009). The curriculum is conceived as a spiral, with concepts being upgraded every year, and teaching should be student-centred. There is no change in the number of classes per week (primary school and the first three grades of secondary school, while the number of classes is still not determined for the final year), but it is possible to have chemistry classes once per week (90 minutes) rather than twice per week (45 minutes).

The main characteristics of the "old" and "new" curriculum (primary and grammar school) are given in Table 2.

Table 2
Characteristics of both curricula

	Old Curriculum	New Curriculum
Obligatory	7th and 8th grade of primary school 1st–4th grade of secondary school	7th and 8th grade of primary school 1st–3rd grade of secondary school 4th grade optional (secondary school)
Primary School	• matter and its properties • chemical reactions • atom and PTE • chemical kinetics • basics of organic chemistry and biochemistry (hydrocarbons, carboxylic acid, alcohol, esters, carbohydrates, proteins) • ecological themes	3 macro concepts: Matter, Energy and Chemical Process: • matter and its properties – accent on practical work • chemical reactions • atom and PTE • basics of organic chemistry • ecological themes • everyday life chemistry Scientific Literacy
Secondary School	1st year: general chemistry (atomic structure, bonds, basics of stoichiometry) 2nd year: physical chemistry (thermochemistry, liquids, solutions, kinetics, equilibrium, acids, bases and salts) 3rd year: electrochemistry, periodic table – groups 1, 2, 14, 15,16, 17, Fe, Al, Cu – main characteristics and properties 4th year: organic chemistry (hydrocarbons, organic compounds with oxygen and nitrogen, basics of biochemistry)	3 macro concepts: Matter, Energy and Chemical Process: • 1st year (atomic structure, bonding, properties of liquids and gases, stoichiometry) • 2nd year (thermochemistry, solutions, kinetics, basics of organic chemistry, main characteristics of metals and non-metals) • 3rd year (electrochemistry, acids, bases and salts, chemical equilibrium) • 4th year (optional choice of 3 main topics out of 6 offered) Scientific Literacy Cross-Curriculum Topics (ICT, Health and Care, Ecological Themes, Sustainable Development, etc.)
Evaluation	Oral exam, written exam, practical usage of knowledge	Adoption of chemical concepts Scientific Literacy

In comparing the differences between the old and new curricula with regard to teaching chemistry in Croatia, the question arises as to whether future chemistry teachers in Croatia are ready and prepared for implementing such a reform, which follows different and – for the teachers – new goals. However, no studies have been undertaken in Croatia focusing on preservice teachers' beliefs about teaching and learning chemistry, and showing how preservice teachers' development is compatible with the development of education and new educational theories.

The first step is to make both preservice and in-service teachers aware of the existence of beliefs, making beliefs explicit and discussing them. Preservice teachers in Croatia are not yet aware of the existence of beliefs or their effect on future teaching methods. The beginning of science education courses is a good starting point for making preservice teachers aware of the existence of preconceptions and beliefs that can influence their future teaching methods. The present study is focused on answering the following research question: *What beliefs about chemistry teaching and learning do Croatian preservice chemistry teachers hold at the beginning of their university teacher training?*

Method

Instrument

Due to the various difficulties that can be encountered (hesitation in expressing unpopular or undesirable beliefs, language issues, etc.), there are different instruments available for researching teachers' beliefs (Wehling & Charters, 1969). A list of instruments for the evaluation of teachers' beliefs is given by Markic (2008). Greater insight into teachers' beliefs is provided by a qualitative rather than a quantitative method (Lederman, 1992). Among the potential deficiencies of the instrument reported by Fischer (2001) are an inability to demonstrate a connection between beliefs and practice, and the inflexibility of evaluation due to the limitation of written text.

A good solution for taking a snapshot of (preservice) teachers' beliefs is image making and drawing (Wilson & Wilson, 1979), through which teachers' identities, as shaped and developed by years of many and varied influences, can be evaluated (Markic & Eilks, 2014). The participants in the present study were instructed to draw themselves as chemistry teachers in a typical classroom situation in their chosen subject and to answer four open questions: (i) What is the teacher doing? (ii) What are the students doing? (iii) What are the objectives of the teaching in the presented situation? (iv) What happened prior to the drawn teaching situation? This idea relates to the "Draw-A-Science-Teacher-Test Checklist" (DASTT-C) (Thomas, Pedersen, & Finson, 2001), supplemented with questions about teaching objectives and prior activities. Data analysis was undertaken following the evaluation pattern described by Markic (2008). The evaluation pattern, based on three categories, represents a range between the predominance of more traditional versus more modern teaching orientations in line with educational theory. Three 5-step scales focus on:

1. Beliefs about Classroom Organisation
2. Beliefs about Teaching Objectives
3. Epistemological Beliefs

The validity of the data was achieved through independent rating and searching for inter-subjective agreement (Swanborn, 1996). The rating of preservice teachers' drawings and responses was done by science education experts and teachers. The evaluation pattern does not present linear scales; the numbers are symbols for the descriptions that are made along with the data. A short description of the three categories is presented in Table 3.

Table 3
An overview of the three scales

	Traditional View		Modern View
Beliefs about Classroom Organisation	Classroom activities are mostly teacher-centred, directed, controlled and dominated by the teacher.	↔ -2, -1, 0, 1, 2	Classes are dominated by student activity and students are able to choose and control their activities.
Beliefs about Teaching Objectives	Science teaching is more or less exclusively focused on content learning.	↔ -2, -1, 0, 1, 2	Learning of competencies, problem-solving or thinking in relevant contexts are the main focus of teaching.
Epistemological Beliefs	Learning is passive, directed and controlled by the dissemination of knowledge.	↔ -2, -1, 0, 1, 2	Learning is a constructivist, autonomous and self-directed activity.

Note. Adapted from Markic, 2008.

The suggested terms *traditional beliefs* (transmission-oriented beliefs of learning with a focus on pure subject-matter knowledge) and *modern beliefs* (beliefs based on constructivist learning, student-oriented classroom structures and an orientation towards more general educational skills, including Scientific Literacy for all) are based on Grounded Theory, as stated in Markic and Eilks (2008).

Examples of preservice teachers' drawings are given in Figure 1. Both pictures represent a chemistry class in the 1st grade of secondary school. The drawing on the left (a) indicates the strong traditional beliefs of this preservice teacher, even with certain scientific misconceptions. The students are not working in groups and the teacher is explaining the shape of a water molecule (while the students listen carefully, as stated in the remark). The picture on the right (b) is from a preservice teacher who holds more modern beliefs. The students are learning about mixture separation through hands-on experiments. The groups are rotating so that the students get to know different ways of separating the mixtures. On the teachers' table is a demonstration experiment (distillation).

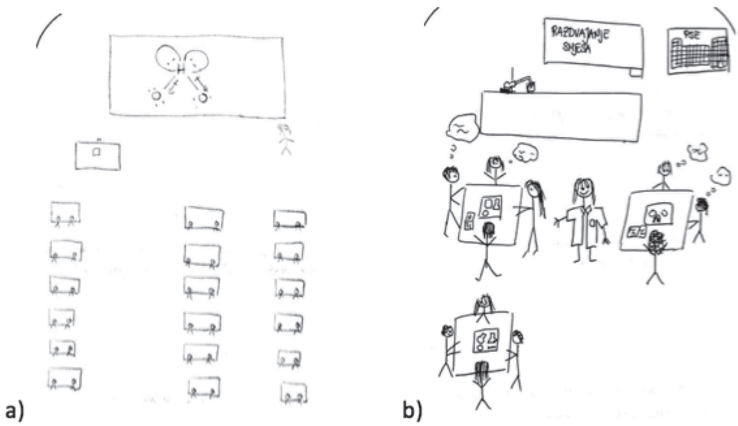

Figure 1. Examples of preservice chemistry teachers' drawings (DASST-C)

Sample

The study was conducted in 2016 and 2017 on a sample of 50 female Croatian preservice teachers aged between 21 and 26 years. Being a teacher in Croatia is traditionally regarded as a female occupation. The preservice teachers are from the Faculty of Science of three different Croatian universities: the Universities of Osijek (11 participants), Split (12 participants) and Zagreb (27 participants), which are currently the only universities in Croatia offering programmes in chemistry teacher education. In Croatia, there are two different types of study programmes for becoming a chemistry teacher. Their main characteristics are given in Table 4.

Table 4
Differences and similarities between teacher training programmes

	A	B
Differences	• chemistry and another scientific domain teacher • both subjects studied at the bachelor level • no bachelor thesis • Master of Education in Chemistry and either Biology or Physics	• chemistry teacher • focus on pure chemistry at the bachelor level • Bachelor of Science (B.Sc.) • Master of Education in Chemistry (M.Sc.)
Similarities	• duration: 5 years • first year of master's study: two-semester chemistry education module – seminar and lecture character (1st semester) and 120 hours of internship (2nd semester)	

Data were collected before the science education courses commenced, in order to evaluate the beliefs of the preservice teachers to which science teacher educators need to be attentive during their lessons and seminars. The sample is representative, as the data were collected from all of the preservice chemistry or chemistry and biology/physics teachers attending A and B study programmes in Croatia at all three universities.

Results

The presented data were analysed in terms of the three categories (Table 3). The majority (almost 90%) of preservice chemistry teachers in Croatia hold more traditional beliefs about classroom organisation. For 27.5% of the participants, the teacher dominates throughout the learning process and is the centre of any activity. The majority of preservice chemistry teachers hold beliefs that are rather teacher-centred, with slight interaction with the students (-1). A rather low percentage of preservice teachers have neither teacher-centred nor student-centred beliefs about classroom organisation (0 stands for balanced teacher-centred and student-centred activities). At the beginning of their science education courses, just 5.8% of preservice teachers have rather student-centred beliefs (at the core are student activities initiated and controlled by the teacher). None of the participants hold strongly student-centred beliefs (2).

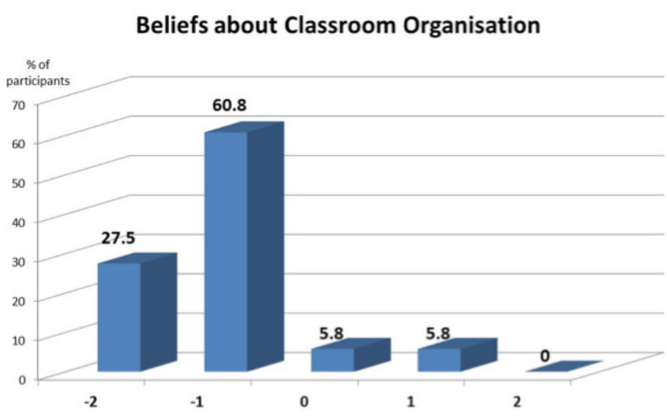

Figure 2. Beliefs about Classroom Organisation

Beliefs about teaching objectives (Figure 2) revealed a slightly more heterogeneous distribution, although most of the preservice teachers' beliefs (52.9%) were exclusively traditional and oriented towards content structure:

learning of facts is the central objective. Approximately the same percentage of participants hold either rather content-structure oriented beliefs (-1): the focus is on the learning of facts, with some non-cognitive objectives targeted; or neither content-structure nor scientific literacy oriented beliefs (0): there is a balance in learning content and applications/non-cognitive objectives, and motivational objectives are at the core. Before the science education training started, only 5.8% of the participants demonstrated beliefs that are slightly modern: learning competencies, problem-solving and thinking in a relevant context. None of the participants hold strongly scientific literacy-oriented beliefs about teaching objectives.

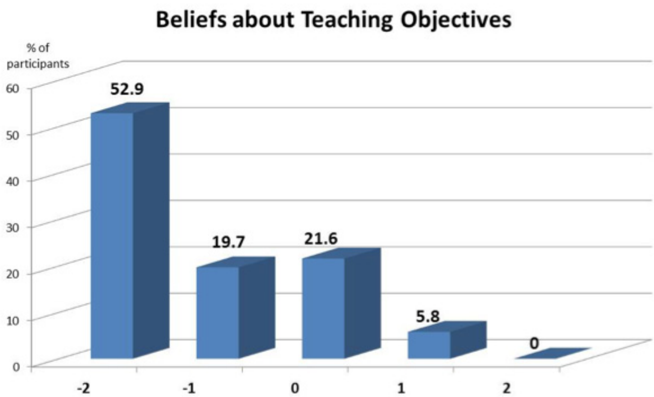

Figure 3. Beliefs about Teaching Objectives

More than 90% of the participants hold traditional epistemological beliefs, as shown in Figure 3. A slight shift can be seen from passive and over-directed learning, whose main goal is the dissemination of information/receptive learning (-2), towards over-directed learning with a student-active phase (learning is followed by a storyboard written, organised and directed by the teacher, but conducted by the students). Only 3.9% of the participants take into consideration the students' preconceptions when planning the learning process, which is still over-directed. Rather constructed learning (autonomous and self-directed learning initiated and partly directed by the teacher) is demonstrated by 5.8% of the preservice chemistry teachers, while none of the participants hold beliefs that include strongly constructive learning.

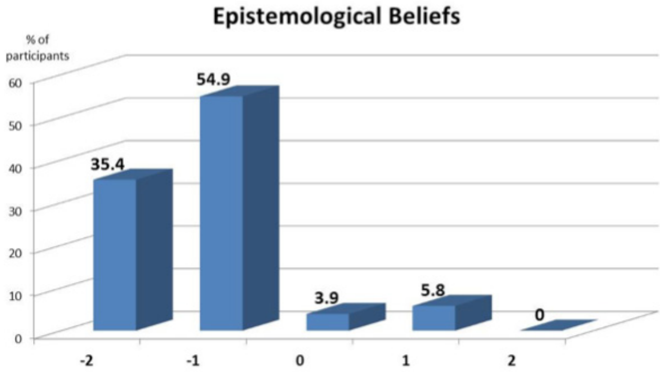

Figure 4. Epistemological Beliefs

A homogenous distribution can be observed within all three dimensions: epistemological beliefs, as well as beliefs about classroom organisation and teaching objectives, are more or less teacher-centred. The majority of preservice teachers in Croatia view learning chemistry as the teacher organised and directed transmission of knowledge. This traditional teacher-centred view is not oriented towards problem-solving and gaining competencies for today's (science) world through student-centred constructive learning, but rather towards learning science content structure and facts through receptive or over-directed learning.

The combination of coding from each category was made for each participant in order to explore the mutual equality of the three categories. Figure 4 shows the sum of the combinations. When the student teacher rating is closer to the upper, rear corner of the diagram, the preservice chemistry teacher holds more modern and student-centred beliefs. The opposite is the case for student teachers placed in the lower, front corner of the diagram: the beliefs that the students hold are more traditional and teacher-centred.

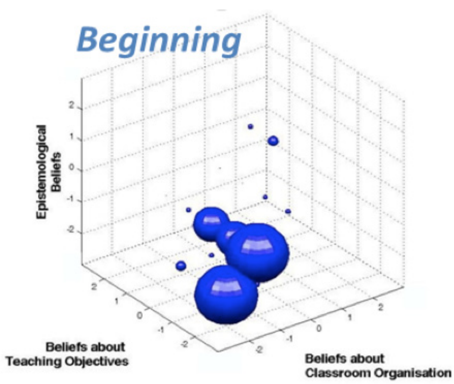

Figure 5. 3D representation of the data.
The size of the bubbles represents the number of preservice teachers.

Discussion, implications and conclusions

Beliefs about classroom organisation and epistemological beliefs are traditional rather than modern, but with a tendency towards modern beliefs. The majority of preservice teachers see themselves as the centre point of classroom activities, either as the dominant figure in the teaching process or the disseminator of information in the learning process. On the other hand, beliefs about teaching objectives are either strongly traditional and oriented towards learning the content of the subject, or located between a mild content orientation with some non-cognitive objectives and a balance between learning content and non-cognitive objectives. At this point of the study (the beginning of the teacher training courses), the majority of the preservice teachers have a code combination in the front lower part of the diagram (Figure 4), i.e., they hold rather traditional beliefs about all three categories.

Croatian preservice chemistry teachers' beliefs are very homogeneous, regardless of the university they attend. They hold more traditional beliefs about teaching and learning. It can be assumed that preservice teachers are influenced by their own experience as students in primary and/or secondary school. They reflect their own impressions based on traditional beliefs regarding teaching and learning. This indicates that the teaching and learning in the majority of Croatian schools was (and probably still is) more teacher-centred, so it is no surprise that the beliefs at the starting point of the research are traditional, as well. It is possible that the preservice teachers will develop another style of teaching after the teacher training course. This can be examined in a later study.

The present study suggests that the content of teacher training must focus on detection of preservice teachers' beliefs and making these beliefs explicit. Teacher training of preservice chemistry teachers must be grounded in modern educational theories: modern goals of chemistry lessons and student-centred methods in teaching and learning. Since teachers' beliefs influence their representation of science in the classroom and impact teacher-student interaction, they need to be sought out and made explicit. All teachers (preservice, in-service and university teachers) must be aware of the existence of beliefs and their influence on the way they organise knowledge and information, so that the teachers can, as Schommer (1990) remarks, make sense of themselves, as mentioned earlier. Since in-service teachers have an influence on the teaching styles and methods of preservice teachers, the focus should be on their beliefs, as well, through in-service teacher training.

As shown by this study, preservice chemistry teachers in Croatia hold rather traditional beliefs about teaching and learning at the beginning of their teacher training courses. There is a need to develop student-centred, constructivist-oriented and modern ways of teaching chemistry. This is in line with the new education reform that is in progress. But are preservice teachers, as well as in-service teachers, ready for new and different goals? Change is needed in the Croatian education system, not only at the primary and secondary level, but in university teacher education, as well. It would be possible to study in-service teachers' beliefs in terms of their years of experience, for instance. Workshops based on making teachers aware of their beliefs would be a good starting point for further study of Croatian chemistry teachers' beliefs. A longitudinal study of the same group of preservice chemistry teachers during their teacher training course as well as their in-service years would be possible. For an in-service teacher, the beginning of teacher training courses is a good starting point for the first step in dealing with beliefs.

More emphasis should be placed on making teachers, both preservice and in-service, aware of their beliefs, encouraging them to discuss them openly and work on making them more modern, thus fostering student-centred and constructivist-oriented ways of teaching chemistry in order to follow the new education reform. These must rely on the anticipated goals of the education reform.

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Evidence of the Development of Pedagogical Content Knowledge Related to Chemical Bonding during a Course for Preservice Chemistry Teachers

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The impression that many preservice chemistry teachers demonstrate issues in the application of their pedagogical content knowledge in teaching practice, especially in the area of fundamental chemistry topics, served as motivation for changes to the Chemistry Education 2 course curriculum. In order to stimulate pedagogical content knowledge, the course has been changed in the following areas: intending learning outcomes, the language of chemistry instruction, awareness of "Johnstone's triangle" of operations, and common alternative conceptions.

To obtain evidence of preservice teachers' in-practice pedagogical content knowledge about chemical bonding, especially pedagogical content knowledge related to the revised areas of the Chemistry Education 2 course, we designed and conducted a case study based on detailed monitoring of one preservice teacher's pre-teaching, teaching and teaching evaluation activities. The findings demonstrate evidence of growth of the preservice teacher's pedagogical content knowledge of chemical bonding, with particular characteristics indicating that the source of this growth is almost certainly the revised Chemistry Education 2 curriculum.

Keywords: chemical bonding, Chemistry Education course, pedagogical content knowledge, preservice chemistry teachers

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Razvoj pedagoškovsebinskega znanja o kemijski vezi med izobraževanjem učiteljev kemije

Roko Vladušić, Robert Bucat in Mia Ožić

Mnenje, da se v šolski praksi številni študentje študijskih programov izobraževanja učiteljev kemije spoprijemajo s težavami uporabe njihovega pedagoškega vsebinskega znanja, še zlasti na področju osnovnih kemijskih pojmov, je služilo kot motivacija za spremembe učnega načrta predmeta kemijsko izobraževanje 2. Z namenom spodbujanja razvoja pedagoškovsebinskega znanja je bil predmet spremenjen na naslednjih področjih: pričakovani učni dosežki, jezik pouka kemije, zavedanje pomena »Johnstonovega trikotnika« in pogosta napačna razumevanja. Da bi raziskali pedagoškovsebinsko znanje študentov študijskih programov izobraževanja učiteljev v praksi na temo kemijskih vezi, še zlasti pedagoškovsebinsko znanje, povezano s prenovljenimi področji učnega načrta predmeta kemijsko izobraževanje 2, je bila zasnovana in izvedena študija primera, ki je temeljila na natančnem opazovanju študenta in njegovih učnih priprav, poučevanja in evalvacije poučevanja. Izsledki kažejo na povečanje študentovega pedagoškega vsebinskega znanja, povezanega z učno temo kemijska vez, saj posebne značilnosti kažejo, da je vir te rasti skoraj gotovo prenovljeni učni načrt predmeta kemijsko izobraževanje 2.

Ključne besede: kemijska vez, predmet Kemijsko izobraževanje, pedagoško vsebinsko znanje, študenti študijskih programov izobraževanje učiteljev kemije

Introduction

Current Research in Chemistry Education in Croatia

In Croatia, research studies in chemical education have mainly been conducted by postgraduate students enrolled in the doctoral study programme *Research in Education in the Field of Natural and Technical Sciences* at the University of Split, as well as their mentors and colleagues.

Several authors have presented their findings through press releases, at scientific conferences, and as articles in national journals, while a few papers have had wider distribution in journals that can be found in international science databases.

Two of the international papers (Vladušić, Bucat, & Ožić, 2016a, 2016b) are related to the concept of pedagogical content knowledge (PCK) in the Croatian chemistry education context. PCK has come to be recognised as perhaps the most important part of the armoury of successful teachers.

The motivation for the research reported here was the belief that programmes for education of preservice teachers should include raising awareness of the importance of PCK, that is, knowledge beyond content knowledge and content-independent pedagogical knowledge.

University professors have perceived that, in the past, even when preservice teachers showed evidence of good chemistry knowledge and good pedagogical knowledge, many demonstrated deficiencies in PCK in their teaching practice, even with regard to fundamental chemistry topics. Traditionally, recognition of the importance of PCK, and accumulation of a store of PCK, has been derived only from experience as teachers.

At the University of Split, a preservice teacher education programme has been designed to develop the PCK of the enrolees, particularly with respect to the topic of chemical bonding. We have chosen to present insights into the efficacy of this course insofar as it has influenced the PCK of one participant. The research undertaken is in the form of a case study: a story of the experiences and thinking processes of one preservice chemistry teacher.

Pedagogical Content Knowledge

Shulman (1986) proposed distinguishing three categories of teacher knowledge: (a) knowledge of content, (b) pedagogical content knowledge (PCK), and (c) knowledge of the curriculum.

Among those categories, PCK is of particular interest (Shulman, 1987).

PCK is a specific form of knowledge based on the translation of content knowledge (e.g., chemistry) to content knowledge for teaching. More specifically, PCK is knowledge of the effective teaching of particular topics, concepts, issues and ideas.

Since Shulman introduced PCK, the concept has attracted a great deal of attention from both teachers and researchers. Its development has therefore continued intensively. Geddis, Onslow, Beynon and Oesch (1993) defined PCK as transforming knowledge of subject content into forms adapted for student teaching. Bromme (1997) reflects on PCK as the knowledge and skills necessary for the conversion of content items in the content adapted to lecture students, emphasising that the way of teaching is independent of the content that we present.

At the turn of the century, in the 1990s and early 2000s, new directions for the conceptualisation of PCK emerged. Some scholars have emphasised the role of PCK in action (Cochran, De Ruiter, & King, 1993; Van Driel, Verloop, & de Vos 1998, 2002), while others present PCK as a set of knowledge from multiple fields and highlight its role in monitoring and evaluating teaching itself (Magnusson, Krajcik, & Borko, 1999).

Major changes have come about in the last decade following the first PCK Summit held in 2012. Due to inconsistent models and different research methods, the PCK Summit identified weaknesses that have theoretically and practically limited the usefulness of PCK in this field (Carlson, Stokes, Helms, Gess-Newsome, & Gardner, 2015). The result of the multi-day discussion was a model of teacher professional knowledge (Gess-Newsome, 2015).

Over the years, various models have evolved, which occasionally diverge from the Shulman's original idea. We still cannot say that there is a consensus regarding the PCK model. One of the most accepted instances is the PCK model devised by Magnusson et al. (1999), which is constructed with five discrete components: 1) orientation towards science teaching, 2) knowledge and beliefs about the science curriculum, 3) knowledge of students' understanding of science, 4) knowledge of assessment in science, and 5) knowledge of instructional strategies. Due to its wide diffusion, we will follow Magnusson's PCK model in this paper.

The Research Context: The Design of a Preservice Teacher Education Programme

At the Faculty of Science, University of Split, preservice chemistry teachers enrol in a programme entitled *Diplomski sveučilišni studij Biologija i Kemija – nastavnički smjer* (approximately, University Diploma Study in Biology and Chemistry – Teaching Stream). Within this programme, those preparing to be school chemistry teachers undertake five courses, listed here in the order in which they are presented over three semesters: (i) *Metodika nastave kemije 1* (Chemistry Education 1), (ii) *Praktikum iz metodike nastave kemije 1* (Laboratory in Chemistry Education 1), (iii) *Metodika nastave kemije 2* (Chemistry Education 2), (iv) *Praktikum iz metodike nastave kemije 2* (Laboratory in Chemistry Education 2), and (v) *Metodička praksa* (Teaching Practice).

From our teaching experience and awareness of the chemical education literature, we recognised four specific aspects of chemistry-based PCK in which the students seemed to be deficient: a) intended learning outcomes, b) the importance of the "chemical triplet" (or "Johnston's triangle"; Johnstone, 1982), c) the hazards associated with the commonly used language of chemistry instruction (Markic & Childs, 2016; Vladušić et al., 2016b), and d) awareness of alternative conceptions commonly held by school students, that is, beliefs and explanations that are not consistent with accepted science (Barker & Millar, 2000; Boo, 1998; Coll & Treagust, 2003; Taber, 2002; Vladušić et al., 2016a).

This motivated us to redesign the curriculum of the Chemistry Education 2 course in order to raise preservice teachers' awareness of issues (a) to (d) above. We also decided to conduct research to look for evidence that the revised course had influenced preservice teachers' PCK in practice.

Due to the abstract nature and fundamental importance of chemical bonding, and in view of previous research highlighting the challenges related to teaching this topic (Vladušić et al., 2016a), we decided to focus this intervention on preservice teachers' PCK of chemical bonding models.

Design of the Revised Chemistry Education 2 Course

The curriculum of the Chemistry Education 2 course was changed so that there was less emphasis on content with respect to the psychology of learning, sources of knowledge and presentation instruments, types of "teaching lessons", and evaluation issues. Instead, the course now involves more extensive and focused considerations of the four aspects referred to above, as described below in more detail:

a) ***Intended learning outcomes***

Until a few years ago, the Croatian education system was based on teaching tasks, rather than on intended learning outcomes. Due to the fact that the change of paradigm from tasks to outcomes by teachers was more difficult than expected, this topic was included in the revised course.

Intended learning outcomes are firstly taught theoretically, with an emphasis on their importance and on algorithms of writing, focusing on the different levels and types of knowledge and abilities as well as their evaluation. Preservice teachers are then involved in writing and evaluating intended learning outcomes through two workshops.

b) ***The language of chemistry instruction***

This aspect was initially presented as a review of evidence from the literature regarding the importance of the careful use of chemistry language. In the revised curriculum, we introduced an original teaching and research method called OZO (Vladušić, 2017) for enhancing preservice teachers' awareness of the complexity of the language of chemical instruction and specific issues related to it, as well as for diagnosis of PCK changes. The method is based upon the use of two questionnaires: one designed to indicate students' expectations regarding the complexity of particular terms, and the other designed to evaluate students' understandings of those terms.

Special attention is also devoted to the meanings of scientific and non-scientific words, words with more than one meaning, and symbols used in chemistry instruction (Vladušić & Ožić, 2016), followed by discussion about the complexity of their meanings and preservice teachers' expectations of students' understandings.

c) ***Awareness of the "chemical triplet", or Johnstone's triangle***

The "chemical triplet", first suggested by Johnstone (1982), refers to chemists' operations at the levels of (i) macroscopic, observed phenomena, (ii) the submicroscopic modelled world of explanation, and (iii) symbolic language. Although the chemical triplet was part of the old curriculum, many preservice teachers demonstrated weaknesses in its application in teaching practice. In the revised curriculum, after theoretical consideration of the chemical triplet but before teaching praxis, preservice teachers were asked to design teaching scenarios focusing on the chemical triplet, and to explain the connectivity (and distinction) between the levels of the triplet.

d) ***Common alternative conceptions***

During Chemistry Education courses, it was noticed that preservice teachers have some alternative conceptions. This has been demonstrated with research focused on preservice teachers' understandings of covalent bonding models (Vladušić, 2017) and the ionic bonding model (Vladušić et al., 2016a).

Trying to reconstruct the understandings of preservice teachers, we created a specific teaching (and research) strategy based on cognitive conflict, called *Open Interview* (Vladušić, 2017). The strategy is based on a semi-structured conversation on a predetermined topic between two preservice teachers, observed by others. The conversation is led by questions, claims and graphics. At a specific moment, the observers are invited to participate in the discussion.

The Research: Overview and Research Questions

We designed and conducted a qualitative research study to obtain evidence of preservice teachers' in-practice PCK with respect to chemical bonding, with proofs of potential development of their PCK gained by learning and teaching.

The research is based on monitoring preservice teachers' pre-teaching, teaching and teaching evaluation activities, and is guided by research questions 1 (RQ1) and 2 (RQ2):

1. What evidence can be detected of the development of preservice chemistry teachers' PCK about chemical bonding that can be attributed to participation in the component of the Chemical Education 2 course that was designed to stimulate PCK?
2. What other evidence can be detected of the preservice chemistry teachers' PCK about chemical bonding that cannot be directly attributed to participation in the component of the course redesigned to stimulate PCK (and must therefore be an outcome of the preceding components of the Chemical Education programme)?

Method

A Case Study Approach

Sixteen preservice chemistry teachers enrolled in their last year of the Biology and Chemistry graduate study programme at the Faculty of Science, University of Split, were involved in the research. Each of them performed one teaching lesson in a first-grade class (15-year-old students) of a grammar school. Since we wanted to gain a deeper insight into a personal story, we decided to select one of the preservice teachers as a case study.

The selected student's understandings and thinking processes were monitored in considerable detail during her teaching (preparation, praxis and testing) in the topic Introduction to Chemical Bonding. For ethical reasons, we use a false name, Antonia.

Yin (2014) recommends that case study is the preferred method when (i) the main research questions are "how" or "why" questions, (ii) the researcher has little or no control over behavioural events, and (iii) the focus of study is a contemporary phenomenon (occurring in a real-world context). All of these conditions apply in the present study. Although one might argue that the researchers have influenced behaviour through the design of the course, in fact the new course is the real context and the researchers have no control over how the subject reacts to instances within that context: they can only investigate "How?" or "Why?".

Within the constraints of the limited resources, it was decided that the most valuable outcome could be derived from deep-level, forensic monitoring of just one student, rather than more superficially monitoring more students, the extreme case of which is a survey. In this way, the researchers expected that evidence of interaction between the nature of the course and the teacher's PCK growth would be insightful, even if it is not representative.

The selection of Antonia as the subject of study was entirely a matter of opportunity and circumstance: she had often demonstrated good analytical awareness of her thinking and understanding, and was relatively uninhibited in discussing them. Furthermore, she volunteered to participate.

Coincidentally, based on her previous performance in chemistry, Antonia could be described as a "middle-of-the-road" student. This is not to imply that the researchers regarded her as a statistical average of the whole class, or in some way representative of the entire class.

No attempts were made to compare the PCK development of Antonia with other students, either within the class or external to the class.

The case study was not concerned with comparability between students or groups of students, and no claims are made about the degree of commonality between the critical features that were influential in Antonia's PCK development, and those that might have influenced the development of others.

Rather, it was an exploratory study searching for evidence that the newly designed curriculum had indeed influenced Antonia's PCK, identifying circumstances under which such development occurred, and trying to understand the nature of Antonia's interactions with teaching situations that gave rise to increased PCK.

The case study may well serve as a starting point for further studies that compare how different classes of people (classifications based on gender, previous grades or personality types, for example) interact with particular situations designed to engender PCK.

Instruments

During the research, preservice teachers were involved in the following activities: a) analysis of the sequence of teaching units in the Chemical Bonding chapters of the textbook, and reflection upon how the sequence might be improved, b) completing a lesson preparation sheet, c) performing a teaching lesson, d) reflection and self-evaluation of teaching, and e) evaluation of colleagues' teaching.

More details about the instruments are provided below.

a) The preservice teachers' analysis of sequencing the Chemical Bonding chapters in the textbook, with reflections and decisions reported on blank paper, supported by arguments and justifications.
b) A lesson preparation sheet was designed in such a way that the preservice teachers needed to think about and express lesson goals, alternative conceptions published in the scientific literature, lesson-related terms that the preservice teacher expected the students would already know, new terms that should be introduced during the lesson, intended learning outcomes, questions for evaluation of the intended learning outcomes, possible limitations and obstacles, critical analysis of textbook content related to the lesson, big ideas, relevant examples of the distinction between the macroscopic and submicroscopic worlds, elaboration of sources of knowledge and key terms, the flow of teaching and learning activities, a plan of blackboard usage, and emotional prediction (about classroom atmosphere).
c) Teaching lesson performances were video recorded for analysis and evaluation.
d) A self-evaluation sheet was required to be completed within one day of the teaching performance. In addition, each preservice teacher was expected to give a final review of her/his performance and recommendations for possible improvement.
e) As well as the preservice teacher who was engaged in practice teaching, at least seven colleagues were present to keep field notes, which they were expected to use in an evaluation of the teaching performance.

The evaluation of teaching instrument (sheet) had two parts: the first was taken from the Handbook for Observation and Improvement of Teaching (Bezinović, Marušić, & Ristić Dedić, 2012.) and had 31 general questions related to classroom performance, each with 5 answer choices, while the second part required an expression of personal impressions of the teaching quality, aspects that were highly rated as well as aspects that could be improved, and self-evaluation of the development of the evaluator's own PCK related to chemical bonding.

Organisation of the Results

The achievement of the preservice teacher is expressed as a story. The story is guided by data collected with research instruments in the following order: teaching unit sequencing, lesson preparation sheet, teaching performance, self-evaluation of teaching, and evaluation of teaching. PCK evidence related to the four revised areas of the Chemistry Education 2 curriculum was searched in all of the instruments' data. However, they are mainly presented and discussed in the *teaching performance* paragraphs, because we are very interested in correlating the revised curriculum of Chemistry Education 2 and the PCK of the preservice teacher demonstrated in teaching practice. PCK evidence is recorded and classified according to the domains of the PCK conceptualisation of Magnusson et al. (1999).

Results and Discussion

The Story about Antonia's Thinking and Her Experience

Antonia had demonstrated middle-of-the-road achievement in Chemistry Education courses. She was responsible and committed. At the beginning of the Chemistry Education 1 course, she demonstrated a traditional view of teaching, that is, she chose teaching scenarios[4] mainly based on chalk, blackboard and the teacher's didactic verbal presentation.

Sequencing of the teaching units

The preservice teachers analysed the order of the teaching units in the two relevant chapters of the school textbook. In the chapter *Chemical Bonds*, the units were in the order "What is a Chemical Bond?", "The Covalent Bond", "The Arrangement of Atoms in Molecules", "Exceptions to the Octet Rule", "The Polarity of Molecules", "Intermolecular Forces", "The Ionic Bond" and "Metallic

4 At the beginning of preservice chemistry teachers' enrolment in the first Chemistry Education course – Chemistry Education 1 – candidates completed a questionnaire that consisted of tasks with different teaching scenarios. The results of the questionnaire served to indicate preservice teachers' starting points regarding chemistry teaching issues, and enabled the monitoring of their progress during and after completing all of the obligations related to Chemistry Education courses.

Bonding". In the following chapter, *Crystals*, the units were "The Type of Chemical Bond and the Properties of Crystals", "Metallic Crystals", "Ionic Crystals", "Molecular Crystals" and "Atomic Crystals".

Antonia was reasonably satisfied with the order of the units. However, she proposed some relatively small changes, because she thought large-scale reordering could cause difficulties for students to manage the textbook content.

She decided that she would introduce exceptions to the octet rule before the unit on the arrangements of atoms in molecules, so that *students will be able to understand how atoms in molecules with a trigonal bipyramid or octahedral shape are arranged.*

Also, she stated that she would teach about atomic and molecular crystals after intermolecular forces, but before ionic bonding, so that *students would be able to connect the covalent bond model and intermolecular forces with the macroscopic properties of atomic (covalent) and molecular crystals.*

I would teach ionic crystals after ionic bonding, she wrote. *In that way, students will connect macro and sub-micro worlds.*

By reordering the teaching units, or segments of units, Antonia demonstrated knowledge of the science (chemistry) curriculum (Magnusson et al., 1999). Sibandas (2018) believes that the way teachers sequence chemistry lessons can be an indicator of their topic-specific professional knowledge according to the PCK model of Gess-Newsome (Gess-Newsome, 2015). This sensible reordering of teaching units is a partial response to RQ2.

In addition, and with regard to RQ1, Antonia demonstrated an awareness of the chemical triplet and an understanding of how the levels of representation should be distinguished in the area of chemical bonding. The way a teacher presents chemistry through the triplet relationship corresponds to their knowledge of representations (Adams, 2012), so this observation was judged as evidence of Antonia's PCK development in the domain of knowledge of science instructional strategies, and more specifically as evidence of her knowledge of topic-specific teaching methods and strategies, including representations (Magnusson et al., 1999).

Lesson preparation sheet

Antonia's allocated lesson was *Introduction to Chemical Bonding*. In general, she prepared a teaching plan for dynamic, interactive instruction, with a focus on important questions (big ideas). In the following discussion, we focus our attention on particular points related to RQ1.

Firstly, in the scientific literature, Antonia identified a few common alternative conceptions about chemical bonding related to her lesson. However, none of them were about the reasons why bonding occurs. Always, and especially in cases like this one, when the teacher knows nothing about her students' knowledge, awareness of common alternative conceptions recognised by others can be helpful. This kind of knowledge, as identified by Antonia, can be considered to belong to the PCK domain Knowledge of Science Learners (Magnusson et al., 1999). Although its importance is obvious, it is unreasonable to expect a preservice teacher, especially one with no in-service experience, to have this type of PCK at a higher level.

Antonia's textbook analysis was very good. She recognised instances of anthropomorphism, such as "*...atoms feel...*" and "*Atoms of other chemical elements combine together to fulfil their valence shells*". She considered the latter sentence to be misleading because *"there is no explanation that atoms are combining to achieve the state with the lowest energy level"*. Although this could be considered as evidence of her PCK, it contradicts an intended learning outcome that she wrote: "S*tudents will understand the octet rule as a model used for the explanation of chemical bond formation*".

Antonia set three intended learning outcomes: a) *Students will understand the nature and reasons for chemical bond formation; b) Students will understand the octet rule as a model used for the explanation of chemical bond formation,* and *c) Students will be able to represent atoms with Lewis symbols.*

The intended learning outcomes were set on big ideas, but, as described above, one of them was based on an alternative conception, while two of Antonia's three intended learning outcomes were expressed with imprecise verbs (such as "*will understand*"). For example, a more precise expression of intended learning outcome a) is: *Students will be able to explain the nature of chemical bonds and why bonding occurs.*

Regarding the awareness of chemical language that can be recognised in Antonia's lesson preparation sheet, it was obvious that she gave it appropriate importance. All key terms were classified into two groups according to their novelty for students (new ones, or previously introduced ones). Some of them were imagined as focal points for discussions; for example, led by the instruction: "*Please define the term 'interaction'*". Since it was effective, we consider this to be evidence of the development of Antonia's PCK domain Knowledge of Science Instructional Strategy (Magnusson et al., 1999).

Once again, Antonia showed PCK related to valid usage of the chemical triplet and demonstrated Knowledge of Science Instructional Strategy (Magnusson et al., 1999). More specifically, she planned to start the lesson focusing on water as a substance, before shifting the focus gradually to molecules of water, asking questions such as: "*Why is our planet called a blue planet?*", *"What* *is water?"*, *"What holds water molecules together?"*, *"What atoms build water molecules?"* and *"What holds the atoms in water molecules together?"*.

Teaching performance

After completing the lesson preparation sheet, Antonia presented the lesson in school and the lesson was video recorded. Below is a short analysis of Antonia's accomplishment.

Antonia performed the teaching lesson based on a heuristic approach. She asked a lot of questions including the word *why*, but sometimes she was not patient enough and answered the questions herself. Although some students participated actively in the class, the lesson consisted almost entirely of student-teacher communication. Even discussions about her questions failed to provide opportunities for student-student interaction. The lesson was divided into three mini blocks, after each of which Antonia evaluated the students' knowledge.

It is not possible to draw conclusions about a teacher's orientation from one teaching lesson, but it seemed that Antonia had moved away from the traditional view of teaching presented at the beginning of the Chemistry Education 1 course to a preferable heuristic approach.

In the following paragraphs, we will shift our attention to evidence of Antonia's PCK demonstrated during her teaching, focusing on four modified areas of the revised Chemistry Education 2 course.

Learning Outcomes

We had the impression that Antonia's students had a reasonable level of understanding of the nature of chemical bonds and the reasons why chemical bonding occurs. However, many of them did not reach a point where they were able to write examples of atoms represented by Lewis symbols, and they could not fully explain Lewis symbol connectivity with an atom's electronic configuration using drawings of atomic orbitals. As might be expected of an inexperienced teacher, in the specific context regarding the teaching content and the limited lesson time, Antonia did not introduce the most appropriate examples of atoms for drawing Lewis symbols.

Specifically, Antonia's plan was to introduce Lewis symbols using a few simple examples just before the end of the class. In each example she decided to connect the Lewis symbol of an atom with the atom's electron configuration and its orbital distribution (she drew valence orbitals of an atom and placed electrons in orbitals), and to discuss the number of bonds an atom can establish in a molecule. She started with the example of an oxygen atom and followed with examples of carbon, beryllium and boron atoms, all three of which need to be supported with the simplest explanation of how atomic orbitals are imagined to form hybrid orbitals.

For example, when Antonia introduced a carbon atom Lewis symbol, and drew 2s and 2p orbitals and filled them with electrons, the students became confused as to why there is not a pair of dots and two single dots around the symbol for a carbon atom in its Lewis symbol when there is one full 2s orbital (with two electrons) and two 2p orbitals with a single electron in each of them. Antonia consequently mixed the orbitals, moving one electron from a 2s orbital into an empty 2p orbital, and explained that a carbon atom can use four single electrons for forming four bonds.

All of this was very challenging for the students, and they asked Antonia to explain it once more with a new example. Trying to help the students, she offered a new challenge – the example of a phosphorus atom's Lewis symbol – and made a mistake. One student called upon to draw a Lewis symbol of a phosphorus atom on the blackboard did it successfully, but Antonia asked him to draw valence orbitals of a phosphorus atom and move one 3s electron to the first free d orbital. The student did what she asked and tried to verbally link the electronic configuration of a phosphorus atom with its Lewis symbol. Now, the problem was that five single dots in the Lewis symbol of the phosphorus atom (which arise from the hybrid orbitals diagram) for five electrons led to the conclusion that a phosphorus atom can form five bonds in a molecule, which is possible but in contradiction with the octet rule the students had been learning about 15 minutes earlier. Antonia was confused, as were the students. In this case, Antonia demonstrated neither Knowledge of Science Instructional Strategies, nor Knowledge of Topic-Specific Teaching Methods and Strategies, including representations as particular examples.

Regarding the second intended learning outcome, Antonia's misunderstanding of the octet rule, expressed as: "*Students will understand the octet rule as a model used for the explanation of chemical bond formation*", as demonstrated by a sentence in the lesson preparation sheet, was introduced to the students as a scientific fact. This finding is consistent with the conclusion of Joki and Aksela (2018) based on a study on the teaching of chemical bonding using the octet rule; namely, that explanations in science education need to be promoted both before teacher education and during professional development.

Returning to Antonia's lesson and her intended learning outcomes, it seems that only one of the three outcomes (*Students will understand the nature and reasons for chemical bond formation)* was achieved. These findings, related to RQ1, indicate that the changes to the Intended Learning Outcomes area in the Chemistry Education 2 curriculum had not been effective in Antonia's case.

Language of Chemistry Instruction

There were more than a few instances to demonstrate that Antonia gave proper care to the language of chemistry instruction regarding the *Chemical Bonding Introduction* topic. She searched for the meanings of the word *interaction* in general and in the specific context. With the students, she discussed chemical bonds as interactions as well as intermolecular interactions, asking the following questions: "*Why are interactions between atoms considered as chemical bonds, but interactions between molecules are not bonds?*", "*What type of change will occur if we break the interactions between atoms (chemical), and what type of change will occur if we break the interactions between molecules (physical).*" In addition, she clearly stated that the octet rule is not a fact, but an artifice, principle or model, and that covalent, ionic and metallic bonds are nothing but models. For homework, the students had to write their own explanations of the following terms: atomic radii, ionisation energy, electron affinity and relative coefficient of electronegativity. This task demonstrates Antonia's awareness of the complexity and importance of concept words.

All of these meaningful questions, claims, activities and representations regarding the language of chemistry instruction are evidence related to RQ1 and the development of Antonia's Knowledge of Strategies for Specific Science Topics, which is part of Knowledge of Instructional Strategies (Magnusson et al., 1999). Moreover, Antonia's language task could be considered as an indication of her Knowledge of Assessment in Science (Chemistry), more specifically, as Knowledge of Methods of Assessment (Magnusson et al., 1999), which refers to RQ2.

Chemical Triplet

During the introduction, Antonia successfully applied her plan to connect macroscopic and submicroscopic views of water, focusing on the properties of the substance and attractive forces between the particles, and giving emphasis by announcing the title of the lesson with the sentence: "*Yes, those forces that keep atoms together we consider as chemical bonds.*" We have already written about chemical triplet findings as evidence relevant to RQ1 and Antonia's Knowledge of Instructional Strategies (Magnusson et al., 1999). The evidence of PCK described in this paragraph is an in-practice confirmation that, in Antonia's case, the Chemistry Education 2 curriculum redesign in the Chemical Triplet area was effective.

Alternative Conceptions

According to the lesson preparation sheet, Antonia was determined to recognise situations in which her students demonstrate or create alternative conceptions. We recognised this as evidence of her Knowledge of Students' Understanding of Science (Magnusson et al., 1999) and associate it with RQ1. However, besides the misconception regarding *the octet rule as a model for the explanation of chemical bond formation,* Antonia herself demonstrated an alternative conception, called *conservation of force* (Taber, 2003). This became obvious after she asked students why the atomic radii of different elements are smaller as we go to the right of any period of the Periodic Table of Elements. She agreed with a student answer that *it is because the attractive power of the nucleus is increasing, too*. Finally, using the sentence "*We will introduce a new model that we are using to explain why chemical bonds are forming*", Antonia gave wrong meanings to Lewis symbols.

These results show that, despite the focus on the school students' alternative conceptions and situations that could cause them, Antonia – as well as, we speculate, other preservice teachers – also holds alternative ideas and introduces them in practice. If preservice teachers were consistent with their own analysis of scientific literature about alternative conceptions (which is part of the lesson preparation sheet) during their preparation for each teaching unit, perhaps they would become aware of their own misconceptions and avoid them in future teaching situations.

Other Evidence of PCK

Antonia explained chemical bond formation with the help of graphical and numerical simulation of change in potential energy of a two-atom system if atoms were to approach each other and move away. The strong impression was that the students fully understood why bonding occurs, so it seems that the source of the knowledge (simulation) and the methods (demonstration and discussion) were selected and used successfully. Accordingly, we consider it as evidence of Antonia's PCK domain Knowledge of Science Instructional Strategies and, in this case, Knowledge of Strategies for a Specific Science Topic – Chemical Bonding. Since this evidence is not related to the areas of the Chemistry Education 2 course that were changed, but rather to the previous curriculum, this is associated with RQ2.

Self-Evaluation of Teaching

In general, Antonia was not satisfied with her accomplishment. More specifically, although she was very satisfied with the working atmosphere and some students' engagement, she thought that the intended learning outcomes were only partially achieved with regard to how the simulation of change in the potential energy of a two-atom system helped her to lead students to understanding why bonding occurs, and how discussion of the term *interaction* contributes to students' understandings of what a chemical bond is. She reported *"I think that the octet rule is only partially adopted, and Lewis symbols are not adopted at all*". One of the problems was that she overestimated the students' chemistry knowledge "*because the grammar school is well known in the country as one of the best, if not the best"* and when Antonia encountered the problem of students' poor understanding of Lewis symbols, she lacked ideas on how to bring the students to the outcome she had planned to achieve. She became aware that her range of Lewis symbol examples was not appropriate for introducing the concepts close to the end of the class, starting with symbol of the carbon atom: "*That example was given in the textbook, and when I noticed that students were not following me, I introduced examples that are also the same kind of exceptions* (she needed to mix atomic orbitals), *and confused them even more. I should have ignored what is in the textbook and given only a few of the simplest examples in that moment*", she concluded, demonstrating the growth of her PCK in the domains Knowledge of Science Learners, Knowledge about Science Curriculum, and Knowledge of Science Instructional Strategies (Magnusson et al., 1999). Such knowledge arises from in-practice topic-specific activities and could not be linked to Antonia's enrolment in previously conducted Chemistry Education courses.

Apart from the aforementioned details, Antonia recognised other aspects of her own teaching that could be improved: "*I should insist on even more student interaction, especially of those students who weren't active at all. My questions need to be clearer and to provoke higher levels of knowledge. If I realise that the students are not following me, I should stop introducing new content and reflect on what they didn't understand*". Finally, she concluded: "*I'm not satisfied, I lack experience and creativity*".

Antonia's self-evaluation shows numerous instances of how her PCK regarding teaching in general, and more specifically regarding teaching the *Chemical Bonding Introduction* for 1st grade grammar school students, has grown. This is illustrated by her awareness of what was functioning in the classroom and what was not. Some evidence, such as language item discussion, is connected specifically with the revised Chemistry Education 2 curriculum, and thus RQ1.

A very important finding is that Antonia's PCK of chemical bonding models was developed through the process of her teaching. This is consistent with the findings of de Jong and van Driel (2004), who showed that an opportunity for learning from teaching appeared to be an effective way to evoke student teachers' awareness of specific teaching difficulties, as well as student-learning difficulties.

Evaluation of Teaching

Seven preservice teachers evaluated Antonia's teaching. Their judgements, written in free style, were organised in four blocks: a) general impression of teaching, b) good aspects of the teaching process, c) areas of teaching that need improvement, and d) the development of their own PCK. Below are interpretations from their reports.

a) Although everybody had to study Antonia's lesson preparation sheet before she executed her teaching in order to become familiar with her intended learning outcomes, all of her colleagues concluded that Antonia's teaching was successful. A few of them highlighted the end of the lesson with the introduction of Lewis symbols as the weakest part.

b) Extracts that refer to the good aspects of Antonia's teaching, which represent the largest share of her colleagues' thoughts, are: *the example of water for introducing chemical bonding (because it enables linkage of tangible and abstract), the simulation of change in potential energy*, *lesson structure, clearly presented lesson content and explanation of language items related to the lesson,* and *communication with students.*

c) We also identified a few of Antonia's colleagues' opinions regarding her teaching that suggest possible improvement:
Benita: *When introducing Lewis symbols, Antonia didn't explain why, in cases of atoms of some elements, electrons should be transferred from one orbital to another, such as in the case of beryllium, but in some other cases should not, and it was a direct question of a student! That must be answered!*
Marta: *Lewis symbols should be explained much more simply. The term hybridisation should not be mentioned at all.*
Ante: *I was surprised that she was connecting Lewis symbols with orbital and going into it so deeply.*
Neda: *She should activate more students.*

d) The preservice teachers were asked the question: "Has your knowledge about teaching of chemical bonding increased during this lesson?". Interestingly, everybody answered no. Two of them stated that it helped them to recall some chemistry concepts, such as Hund's rule.

The preservice teachers' evaluations indicate their lack of competence in the evaluation of teaching: nobody referred to the intended learning outcomes and whether they were achieved; they thought that their own impression was sufficient for judgement. However, they did recognise good aspects of teaching, some of which can be related directly to the redesigned areas of Chemistry

Education 2 (water example – chemical triplet, language item discussion). These findings strengthen our judgements about the evidence of Antonia's PCK development related to RQ1.

The preservice teachers' specific knowledge of chemistry learners' understanding is negligible: just like Antonia, they expected better prior knowledge among the chemistry students. This was also the case regarding knowledge about the curriculum: the preservice teachers discussed how deep Antonia should go, forgetting that Antonia was following the grammar school chemistry curriculum and textbook content.

It was surprising that the preservice teachers who recognised the good aspects of Antonia's teaching, as well as the aspects that could be improved, think that they learned nothing about how to teach chemical bonding. We can only speculate that they did not understand the question correctly, and thought that their chemistry knowledge was being questioned.

Limitations of the Study

The present study has certain limitations. One of the authors was involved in the research as a teacher of Chemistry Education courses as well as a researcher, which could influence the reliability of the study. In order to ensure reliability, various instruments were used for gathering data and all of the researchers were included in the assessment of PCK evidence.

The study results are based on one participant's activities, so the findings cannot be generalised.

The PCK model (Magnusson et al., 1999) was used to categorise the PCK evidence. This is one of many PCK conceptualisations, so it is possible that some of the PCK evidence we found would be categorised in different groups according to other PCK models.

Future Direction

Although the preservice chemistry teachers were involved in various activities and the data was evaluated by three researchers, it is sometimes difficult to judge whether a certain example, procedure or other kind of treatment by the teacher can be considered as evidence of PCK. Accordingly, we plan to promote this type of research, seeking school students' thoughts about teaching and learning activities that work or do not work for them, and facing preservice teachers with school students in interviews and/or focus groups.

Conclusion

Regarding RQ1, the component of the Chemistry Education 2 course that was redesigned in order to stimulate PCK resulted in some development of one preservice teacher's PCK related to chemical bonding. However, it was not possible to associate a positive impact with all of the redesigned areas of the Chemistry Education 2 course.

In particular, evidence of the development of Antonia's PCK of chemical bonding in the areas of the chemical triplet and the language of chemistry instruction was found regardless of which data-gathering instrument was used. According to data gathered with the lesson preparation sheet, Antonia's self-evaluation sheet and some lesson performance details, Antonia demonstrated evidence indicating a positive effect of the Chemistry Education 2 curricular changes regarding alternative conceptions related to chemical bonding.

On the other hand, she did not demonstrate development of PCK regarding intended learning outcomes related to chemical bonding, especially regarding the rules of their settings. This indicates that the changes in the Chemistry Education 2 curriculum related to Intended Learning Outcomes did not hit the target. However, after teaching, Antonia was fully aware of the scope of her success in learning objective achievement.

Taking everything into account, we conclude that the Chemistry Education 2 curriculum changes regarding the Chemical Triplet, Language of Chemistry Instruction and Alternative Conceptions have had a positive impact on the development of Antonia's PCK of chemical bonding, while the curricular change regarding Intended Learning Outcomes has not.

Regarding RQ2, Antonia demonstrated a range of evidence of her PCK of chemical bonding that cannot be attributed to participation in the component of the Chemistry Education 2 course redesigned to stimulate PCK, but is an outcome of the preceding components of the Chemical Education programme.

Based on the classification of PCK evidence into the PCK domains of Magnusson et al. (1999), Antonia showed her orientation towards science teaching by choosing a heuristic approach for the Chemical Bonding Introduction lesson, and took into account literature-based alternative conceptualisations, demonstrating an element of Knowledge of Chemistry Learners. Offering her own sequencing of teaching units, which is more sensible than that provided in the textbook, Antonia provided evidence of Knowledge about Chemistry Curricula. Conducting effective teaching related to two atoms' potential energy change simulation, chemical triplet representations and the language of chemistry instruction activities, she showed different aspects of Knowledge of

Chemistry Instructional Strategies. By assigning students a specific language task for homework that corresponds with her awareness of concept word complexity, Antonia indicated an element of Knowledge of Chemistry Assessment.

Last but not the least, Antonia's self-evaluation data showed that her PCK about chemical bonding and, more specifically, about introductory teaching of chemical bonding, had developed during in-practice activities. This cognition highlights the importance of in-practice activities in chemistry education programmes and, consequently, its importance for the development of preservice teachers' PCK.

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Chemistry Education in Bosnia and Herzegovina

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In this paper, the education system in Bosnia and Herzegovina is presented in the light of current state-level legislation, with an emphasis on chemistry education at the primary, secondary and tertiary level. The consequences of the last war in our country still persist and are visible in many aspects of everyday life, including the education system, thus limiting the efforts of education professionals to follow international trends in education. There are three valid curricula for primary education at the national level, each of which differs in the national group of school subjects. Teaching methods are common for all three curricula and are mainly teacher-oriented. The situation is similar with regard to secondary education. Study programmes at the university level are organised in accordance with the Bologna principles. The programmes are made by the universities themselves and approved by the corresponding ministry of education. Chemical education research in Bosnia and Herzegovina is mainly conducted at the University of Sarajevo. It deals with (1) the problems of experimental work in chemistry teaching, resulting in more than 60 experiments optimised for primary and secondary school, (2) integrating the knowledge of chemistry, physics and physical chemistry for university students, with regard to students' difficulties observed during university courses and potential solutions, and (3) the effectiveness of web-based learning material in primary school chemistry for the integration of macroscopic and submicroscopic levels. For the purpose of this paper, official documents for primary, secondary and higher education have been used.

Keywords: chemistry education, Bosnia and Herzegovina, primary school, secondary school, higher education

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Kemijsko izobraževanje v Bosni in Hercegovini

Meliha Zejnilagić-Hajrić in Ines Nuić

V prispevku je predstavljen izobraževalni sistem v Bosni in Hercegovini z vidika veljavne državne zakonodaje, s poudarkom na kemijskem izobraževanju na osnovnošolski, srednješolski in na univerzitetni ravni. Posledice zadnje vojne še vztrajajo in so opazne v vseh vidikih vsakdanjega življenja, vključno z izobraževalnim sistemom, v katerem se kaže omejevanje prizadevanj strokovnjakov s področja izobraževanja, da sledijo mednarodnim smernicam v izobraževanju. Na nacionalni ravni obstajajo trije veljavni kurikulumi za osnovnošolsko izobraževanje; vsak izmed njih se razlikuje v naboru šolskih predmetov. Metode poučevanja so skupne vsem trem kurikulumom in so večinoma osredinjene na učitelja. V srednješolskem izobraževanju je situacija podobna. Na univerzitetni ravni pa so študijski programi oblikovani skladno z bolonjskimi načeli. Programe oblikujejo univerze same, potrdi pa jih ministrstvo, pristojno za izobraževanje. Raziskovanje na področju kemijskega izobraževanja v Bosni in Hercegovini v največji meri poteka na Univerzi v Sarajevu. Ukvarja se: 1) s problemi eksperimentalnega dela v poučevanju kemije; 2) z integracijo znanja kemije, fizike in fizikalne kemije na osnovi težave študentov, ki so zaznane med študijem; 3) z učinkovitostjo spletnih učnih gradiv za poučevanje kemije v osnovni šoli, ki integrira makro- in submikroskopsko raven predstavitev kemijskih pojmov. Za potrebe prispevka so bili v raziskavi uporabljeni uradni dokumenti za osnovno-, srednje- in za visokošolsko izobraževanje.

Ključne besede: kemijsko izobraževanje, Bosna in Hercegovina, osnovna šola, srednja šola, visokošolsko izobraževanje

Introduction

Before exploring the background of the development of chemistry education, we provide a brief overview of the political and demographic contexts of education in our country.

Bosnia and Herzegovina (informal, Bosnia) was part of the former Yugoslavia (Socialist Federal Republic of Yugoslavia, SFRY) from 1943 to 1992. However, its beginnings as an independent kingdom date back to the Middle Ages (Radušić et al., 2010), while its territory has been inhabited since Neolithic times (Malcolm, 1994). The country's political and cultural history is unique in Europe: the Roman Empire, the Ottomans and the Austro-Hungarians, as well as the religions of Roman Catholicism, Eastern Orthodoxy, Islam and Judaism have combined and overlapped (Malcolm, 1994).

The SFRY disintegrated in the 1990s and the independence of the Republic of Bosnia and Herzegovina was declared in March 1992. The country was recognised by the United States of America and the European Economic Community in April 1992, and admitted to the UN in May 1992. This was followed by the siege of Sarajevo (1992–1996), where infantry, artillery and mechanised units of the Yugoslav People's Army, in cooperation with the fifth-column armed formations of the Serbian Democratic Party, established complete control over all vital communications. The aggressor closed all access to the city on 6 April 1992. This date had symbolic significance, as it was on 6 April 1945 that Sarajevo was liberated at the end of World War II. The Bosnian war ended in December 1995 after peace negotiations in Dayton, USA.

Since the war, Bosnia and Herzegovina has, according to the Dayton Agreement, consisted of two administrative entities: the Federation of Bosnia and Herzegovina (FB&H), the Republika Srpska (RS), each with its own constitution, while the self-governing Brčko District is a part of both entities. The FB&H consists of ten cantons, each with its own government.

There are three official languages in Bosnia and Herzegovina – Bosnian, Croatian and Serbian – and two alphabets, Latin and Cyrillic. According to the population census of 2013, the total population of B&H is 3.5 million.

The Education System – Basic Structure

Education in B&H is organised on four main levels: preschool, primary, secondary and higher education. There are both public and private institutions at all levels of education. Public primary and secondary schools are funded by the government and are not allowed to demand any fees. Textbooks for students in a state of social need are usually provided free of charge.

The education system in B&H is a reflection of the internal organisation of the state. At the national level, the Ministry of Civil Affairs and its Sector for Education are responsible for issues related to education. In the Republika Srpska, education is regulated by the relevant ministry through the Republic Education Institute. In the Brčko District, education is regulated by its Department of Education.

In the FB&H, jurisdiction has been transferred to the ten cantons and their education institutes or ministries (Table 1), all of which are coordinated by the Federal Ministry of Education and Science (Ibrahimović, 2015). This means that every canton adopts a curriculum for the primary and secondary schools located in its territory.

Table 1
The organisational structure of education authorities in the FB&H

Ministry of Education, Science, Culture and Sport of Posavina Canton
Ministry of Education, Science, Culture and Sport of Una-Sana Canton
Ministry of Education, Science, Culture and Sport of Tuzla Canton
Ministry of Education, Science, Culture and Sport of Zenica-Doboj Canton
Ministry of Education, Science, Culture and Sport of Central Bosnia Canton
Ministry of Science, Education, Culture and Sport of Canton 10
Ministry of Education, Science and Youth of Sarajevo Canton
Ministry of Education, Youth, Science, Culture and Sport of Bosnian-Podrinje Canton
Ministry of Education, Science, Culture and Sport of Herzegovina-Neretva Canton
Ministry of Education, Science, Culture and Sport of West Herzegovina Canton

Primary Education

Primary education in B&H lasts for nine years and comprises levels 1 and 2 of the *International Standard Classification of Education – ISCED* (UNESCO Institute for Statistics, 2011): *Primary Education* and *Lower Secondary Education*. It is compulsory and free for all children. The nine years of primary education are divided into three triads (ages 6–9, 9–12 and 12–15, respectively). Children are enrolled in the 1^{st} grade of primary school at the age of 6 and complete the 9^{th} grade at the age of 15.

Primary education has recently been extended from eight to nine years, but the reform has not been implemented simultaneously and systematically across the country. In the Republika Srpska, nine-year primary education was introduced in 2003/04.[3] In the FB&H, different cantons introduced this system in different school years, starting in 2004/05 and ending with the 2009/10 school year (Ministry of Civil Affairs of Bosnia and Herzegovina, 2017).

In 2011, an expert group formed by the Ministry of Education, Science and Youth of Sarajevo Canton made an analysis of the curriculum for nine-year primary education in the Sarajevo Canton (Fejzić et al., 2011). They reported that only formal changes had been made in comparison with eight-year primary education, such as the introduction of an additional year (9th grade), while the core of the traditional curriculum, with prescribed content and frontal teaching methods, had been retained. Emphasis is placed on input (teaching content) instead of learning outcomes. In 2016, a revised version of the curriculum for nine-year primary education was prepared in Sarajevo Canton (Ministry of Education, Science and Youth of Sarajevo Canton, 2016). Although there are no significant changes compared to the previous curriculum in terms of teaching content, more attention is paid to the formulation of learning outcomes.

An analysis of the curriculum valid in the Republika Srpska has shown that it is too prescriptive and overly demanding. The lower levels of Bloom's taxonomy are encouraged and the number of clearly formulated learning outcomes with respect to SMART[4] criteria is low (Drobac, Hadžić-Krnetić, Mikanović, & Zečević, 2013).

In B&H, there are three valid curricula for primary education, all of which are similar in their structure and teaching methods, with teaching content being prescribed instead of learning outcomes. Certain differences exist in the teaching content within the national group of teaching subjects[5] (Ibrahimović, 2015). In 2017, a project supported by the organisation USAID and Save the Children in B&H resulted in the *Common Core Defined on Learning Outcomes* for eight educational domains, both for primary and secondary levels (Agency for Pre-Primary, Primary and Secondary Education, 2017). Guidelines for its implementation are also provided (Agency for Pre-Primary, Primary and Secondary Education, 2015), but their implementation in schools is still limited.

One current paradox of the education system is the so-called *two schools under one roof*, which refers to some primary schools in the FB&H where students are segregated according to ethnicity: they attend school in the same building, but are physically separated. The original intention was to bring

3 Pupils who finished grades I–VII at the end of the 2002/2003 school year were enrolled in grades III–IX at the beginning of the 2003/2004 school year (Recommendation of the Ministry of Education and Culture of the Republika Srpska for the change to nine-year primary education, from 7 March 2003).

4 SMART: S – specific, M – measurable, A – achievable, R – realistic, T – timely.

5 Mother tongue, history, geography and religious education.

students together after the war, uniting them in one building. However, what was intended to be a temporary solution became highly politicised.

Figure 1. An example of “two schools under one roof” in Travnik, B&H. Retrieved from https://www.reddit.com/r/europe/comments/9iv99w/an_example_of_two_schools_under_one_roof_in/.

According to Čustović (2018), there are 54 schools in three cantons that work under this divided system. Even though these schools are deemed unconstitutional, they continue to operate.

In both entities and in the Brčko District, the number of students enrolled in primary schools is continuously decreasing, with some fluctuations (Agency for Statistics of Bosnia and Herzegovina, 2017). According to a report by the Federal Ministry of Education and Science (2017), the number of primary school students in the 2017/18 school year was 5.61 percent lower than in the 2013/14 school year.

Secondary Education

Secondary school lasts for three or four years and corresponds to the ISCED’s *Upper Secondary Education* (level 3). Secondary schools are of a general (grammar school/*gimnazija*, art school or religious school, duration four years) or vocational type (technical, medical, etc., duration of three or four years), and are organised as public or private institutions.

According to Haskić (2015), there is no specific data or official register of the number of private primary and secondary schools in Bosnia and Herzegovina, but research suggests the existence of 11 primary and 36 secondary private schools, including centres for additional training. There are also combined primary and secondary schools: 15 public schools owned by different religious communities.

Secondary education is not compulsory, which may be why the changes are slowest in this sector (Ibrahimović, 2015). There are secondary schools operating in accordance with international standards (United World College Mostar, the IB programme in Druga gimnazija Sarajevo, the Cambridge International School programme in Prva bošnjačka gimnazija Sarajevo), but these are not affordable for all students due to their tuition fees.

A decrease in the number of students in all administrative divisions, and consequently at the national level, is evident at the secondary school level, as well. The number of students in the FB&H in the 2017/18 school year was 8.38 percent lower than in 2013/14 (Federal Ministry of Education and Science, 2017).

Higher Education

Higher education is available to anyone who has completed four years of secondary education. It comprises ISCED levels 6–8 (Bachelor, Master and Doctoral study) and is organised in accordance with the Bologna principles. There are eight public universities in Bosnia and Herzegovina[6] and a number of private higher education institutions. With respect to the duration of the study programmes, universities use two higher education concepts: 4+1+3 and 3+2+3, which differ in the duration of the bachelor's degree (4 or 3 years; 240 or 180 ECTS points, respectively) and master's programmes (1 or 2 years; 60 or 120 ECTS points, respectively). Doctoral studies last for three years and are assigned 180 ECTS points.

The oldest and largest higher education institution in B&H is the University of Sarajevo. Its beginnings date back to 1573, when Gazi Husrev-bey signed the Waqfname (Book of Endowment). The modern history of the university dates back to 1940, just before the Second World War.

While primary and secondary education is free, higher education funding is provided by the government for a limited number of students.

6 University of Sarajevo, University of East Sarajevo, University of Banja Luka, University of Mostar, University Džemal Bijedić Mostar, University of Zenica, University of Bihać, University of Tuzla.

Chemistry Education

The main teaching and learning resource for both students and teachers is chemistry textbooks. There are several published chemistry textbooks in B&H. The responsible ministry recommends the textbooks each school year, and teachers choose the one that best suits their students. There is, however, an evident lack of teaching resources, as highlighted by teachers: there are no published manuals or workbooks, so teachers mostly rely on Internet resources or manuals published in the region (Serbia and Croatia).

There are some differences in the number of weekly class hours for most subjects within the domain *Science*, but not within *Chemistry* itself. Table 2 presents the number of school hours per week for science-related subjects in primary schools in FB&H and RS.

Table 2

Overview of the weekly number of class hours for primary school subjects related to chemistry

School Subject	FB&H									
	I	II	III	IV	V	VI	VII	VIII	IX	Total
My Environment	2	3	3	3						11
Science					2					2
Biology						1	2	1	2	6
Physics							1	2	2	5
Chemistry								2	2	4
School Subject	**RS**									
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**Total**
My Environment	5									5
Science and Society		2	2	2						6
Science					2					2
Biology						2	2	2	2	8
Physics							2	2	2	6
Chemistry								2	2	4

In the first five grades, the number of lessons per week is similar, but with different school subject names. The difference is greater when it comes to the number of lessons per week for biology and physics: primary school students in the RS have two lessons of biology (6^{th} grade and 8^{th} grade) and physics (7^{th} grade) per week more than their colleagues in the FB&H.

Within primary education, students begin to learn about basic science concepts (such as the states of matter: gas, liquid and solid) in the 2nd/3rd grade within *My Environment/Science and Society*. Within *Science* in the 5th grade, students learn about substances, their states and transitions between states through simple science experiments (such as measuring the temperature of ice, water and boiling water). According to the curricula examined, the first notion of atoms and molecules is scheduled in 7th grade within *Physics*. *Chemistry* is taught as a separate school subject in the 8th and 9th grade of primary education.

In the 8th grade, students learn about the development of chemistry, safety precautions in the laboratory, matter and its properties, chemical and physical changes, chemical elements (the periodic table), valence, formulas and bonding. They also learn about chemical reactions and equations, chemical laws and properties of non-metals[7] (hydrogen, oxygen, nitrogen, sulphur and chlorine), as well as about the types of chemical compounds (oxides, acids, bases and salts).

The 9th grade is characterised by teaching content on metals (sodium, calcium, magnesium, aluminium, iron, copper and gold), their compounds and alloys, corrosion and corrosion protection. After that, students learn about organic chemistry (hydrocarbons, carbohydrates, alcohols, organic acids, fats, oils, soaps, detergents) and biochemistry (amino acids, proteins, polymers). This grade ends with teaching content on ecology and environmental protection.

The *Common Core Defined on Learning Outcomes* is rather different in its structure than present curricula based on teaching content. The domains, which consist of components, are defined within each school subject. For each component, the learning outcomes are determined, with corresponding indicators reflecting the degree of the achievement of each learning outcome. Indicators are specified according to the development of children at the end of primary (14–15 years) and secondary (18–19 years) school. Four domains are defined for *Chemistry*,[8] each composed of four components (Agency for Pre-Primary, Primary and Secondary Education, 2017).

In the curriculum for grammar schools (*gimnazija*), *Chemistry* is taught in all four years with two hours per week. The exception is Canton Sarajevo, where *Chemistry* in grammar schools is taught in the first two grades as a mandatory school subject with two hours per week, and in the following two years as part of the elective domain *Science* with three hours per week. The decreasing number of students and the teachers' experience indicate a lack of interest in this domain among students.

7 Teaching content on selected non-metals (nitrogen, sulphur and chlorine) in the RS is planned at the beginning of the 9th grade.

8 Domains within Chemistry: Substances, The Structure and Functional Connection of Processes in Nature, Processes and Interactions between Living and Non-Living Systems, The Structure of Substances and Energy.

Chemistry education at the university level started in 1950 within one of the eight subject areas at the Faculty of Philosophy. Instruction took place in Gazi Husrev-bey Madrasah's building.[9] The Department of Chemistry became part of the newly founded Faculty of Science in 1960.

Bosnia and Herzegovina signed the Bologna declaration in September 2003. This model of the study was then introduced at universities in different academic years. Universities are autonomous in making their study programmes, which need to be verified by the corresponding ministry.

The education of future chemistry teachers is organised at six public universities.[10] Five of them provide 1st and 2nd cycle chemistry education study programmes (Table 3), while the University of Mostar provides only the 2nd cycle after completion of the 1st cycle *Chemistry* study programme. It is also the only university that provides two-subject studies, where Chemistry can be combined with Biology, Physics or IT.

The only institution in the country that provides a doctoral study programme in chemistry education is the University of Sarajevo, within the framework of the joint doctoral study programme *Science and Mathematics Education*, which includes *Chemistry Education.*

Table 3
Overview of chemistry education study programmes at universities in B&H with respect to the ECTS credits of the relevant courses

Institution	Study Programme	1st cycle		2nd cycle	
		General Education Courses*	Chemistry Education Courses	General Education Courses*	Chemistry Education Courses
University of Sarajevo, Faculty of Science	Chemistry Education	10 M 3 E	43 M 10 E	-	9 M 14 E
University of Mostar, Faculty of Science and Education	Biology-Chemistry Education	-		12 M	20 M (B) 20 M (C)
	Chemistry-Physics Education	-		12 M 4 E	21 M (C) 13 M (Ph)
	Chemistry-IT Education	-		15 M	28 M (C) 23 M (IT)
University Džemal Bijedić of Mostar, Teachers Faculty	Chemistry Education	12 M 9 E	18 M 11 E	Not provided	
University of East Sarajevo, Faculty of Technology	No data available on the website**				

9 Muslim high school.
10 The Universities of Sarajevo, East Sarajevo, Dzemal Bijedić Mostar, Tuzla and Banja Luka have study programmes in chemistry education. The University of Mostar only provides study programmes that are a combination of chemistry with physics, biology and informatics.

Institution	Study Programme	1st cycle		2nd cycle	
		General Education Courses*	Chemistry Education Courses	General Education Courses*	Chemistry Education Courses
University of Tuzla, Faculty of Science	Chemistry Education	6 M 6 E	27 M 6 E	-	6 M
University of Banja Luka, Faculty of Science	Chemistry Education	12 M	19 M 12 E	-	5 E

Note. M = mandatory courses; E = elective courses; B = Biology; C = Chemistry; Ph = Physics; IT = Information Technologies.
*General courses refer to courses in the scientific fields of general pedagogy, psychology and didactics.
**According to the University of East Sarajevo website (https://www.ues.rs.ba/en/faculty-of-technology/), the study programme (1st cycle) Chemistry, with the diploma "Graduate Chemistry Professor", is carried out at the Faculty of Technology.

It should be noted that for most universities only the number of ECTS points is provided (along with the number of lessons per week and information as to whether the course is compulsory or elective), while the programme of the specific courses is unavailable (with the exception of the University of Sarajevo). Therefore, the title of the course was the only factor in determining whether the course falls into the category of a general or chemistry (biology/physics/IT) education course.

According to the EU Teacher Education Standard, the minimum number of ECTS points for Teaching Competency courses in the 1st and 2nd cycle is 60 (5 years, a total 300 ECTS) (Boban & Perić, 2015). As shown in Table 3, the Chemistry Education study programme at the University of Sarajevo fully meets this criterion, with a total of 62 ECTS points for compulsory teaching competence courses. The University of Mostar fulfils this criterion with the Chemistry/IT Education programme.

More recently, some efforts have been made toward introducing an integrated study programme for teachers at the University of Sarajevo. The authors of the present paper have participated in making the proposed curriculum for chemistry teachers, which contains courses from the PPDM[11] group in a total of 73 ECTS. Its introduction is planned for the 2019/2020 academic year.

Štrbo and Sabljica (2011) analysed the perspectives of chemistry education at the University of Sarajevo, as well as students' attitudes toward the vocation of chemistry teacher after the completing the faculty. They emphasised a negative trend in the number of students graduating from the Chemistry Education study programme. Students are given the opportunity to change their field of the study, which results in a decrease of the number of students in the 3rd year of study compared to the 1st year, and, consequently, in a low number of graduate chemistry teachers.

11 PPDM – Psychology, Pedagogy, Didactic and Teaching Methods.

Among students (and the public), a negative image of the teaching profession prevails: students believe that a person is more appreciated when he/she graduates in *Chemistry*, that chemistry teachers have lower salaries than chemists with the same level of education, and that primary and secondary school students are not motivated to learn chemistry, thus making the teaching process more difficult (Štrbo & Sabljica, 2011).

Who can teach chemistry?

In primary schools, a significant number of teachers who have graduated from two-year study programmes at pedagogical academies or faculties of science implemented before the introduction of the Bologna principles are still employed. These study programmes included a combination of Chemistry with Biology, Physics or Home Economics.

In secondary schools, graduate students of chemical education, as well as chemical engineers (with appropriate training in pedagogy, psychology, didactic and teaching methods), may teach chemistry. After Bologna, students who have completed both the 1st and 2nd cycles of study are employable in both primary and secondary schools. This refers to both masters of chemistry education and masters of chemistry. This was common practice even before the Bologna study programmes.

In order to be considered for employment in school, masters of chemistry/chemistry engineers must complete and pass pedagogical training. This training contains a core of general pedagogy, psychology, didactics and teaching methodology, and is organised at various public as well as private higher education institutions. However, its quality is rather questionable and, more importantly, it does not generally contain didactical and methodological content that is specific to chemistry or teaching practice in chemistry at school. The fact that graduate chemistry teachers do not have priority in employment is a growing problem. It leads students to believe that they will have more opportunities for employment if they complete a *Chemistry* study programme; even if they "have to" work at school, they can complete the required pedagogical training afterwards. This results in a low level of interest in chemistry education study programmes; the teaching profession is simply not so attractive.

Another problem is the lack of chemistry teaching hours per week compared to the "norm" (the number of hours per week that teachers need to teach in order to receive a full salary). It is therefore common for teachers to teach in two or even three schools, and/or to teach other courses (such as Home Economics at the primary school level). It appears that this is one of the major obstacles to good chemistry teaching at the primary school level, in addition to poorly and inadequately equipped classrooms for practical work and the increased administrative requirements that teachers need to perform.

Chemistry Education Research in B&H

Based on an examination of bibliographies of university professors who teach courses in the field of chemistry education, available on the websites of their institutions and on Google Scholar®, we can conclude that chemistry education research in our country is underrepresented. The examined bibliographies indicate that these researchers mainly focus on other domains, and that courses in chemistry education are mostly supplemental to their primary scientific field. There is little interest in research into chemistry education, which is predominantly conducted by academic staff at universities who are also highly engaged in the teaching process and therefore rather busy and preoccupied.

Chemistry education research conducted at the University of Sarajevo is focused on examining the relevant (mostly domestic) issues in primary, secondary and tertiary chemistry education, grouped into several categories:

(1) Problems of experimental work in chemistry teaching. This research, conducted among students and teachers and accompanied by several workshops, resulted in more than 60 experiments optimised for the primary and secondary school level (e.g., Muštović, Zejnilagić-Hajrić, & Milićević, 2003; Zejnilagić-Hajrić, 2006, 2009a, 2009b; Zejnilagić-Hajrić, Ljubijankić, Čopra-Janićijević, Vidic, & Nuić, 2016).

(2) Integrating knowledge in chemistry, physics and physical chemistry for university students. Students' difficulties observed during university courses, their origins and causes, as well as potential solutions, were examined, giving rise to a number of issues that need to be addressed (e.g., Gojak, Galijašević, Hadžibegović, Zejnilagić-Hajrić, Nuić, & Korać, 2012; Gojak-Salimović, Korać, Zejnilagić-Hajrić, & Nuić, 2018; Hadžibegović, Zejnilagić-Hajrić, Galijašević, & Nuić, 2012; Nuić, Zejnilagić-Hajrić, Hadžibegović, & Galijašević, 2011).

(3) The effectiveness of web-based learning material in primary school chemistry for the integration the macroscopic and submicroscopic levels. The idea for this research, which deals with examining sources of difficulties at the level of primary school, arose from the findings of a study on integrating knowledge (e.g., Nuić & Glažar, 2015, 2016, 2017).

(4) Testing the use and applicability of various teaching methods in B&H schools (e.g., problem-based learning, inquiry-based

learning, pre-learning strategy) (e.g., Smerdel & Zejnilagić-Hajrić, 2018; Zejnilagić-Hajrić, Delić, & Nuić, 2015; Zejnilagić-Hajrić & Nuić, 2015; Zejnilagić-Hajrić, Šabeta, & Nuić, 2015).

Papers dealing with educational issues are published in domestic journals such as *The Bulletin of Chemists and Technologists of Bosnia and Herzegovina*, *Naša škola* and *Didaktički putokazi*. The latter two journals are written in Bosnian, which makes them more usable for teachers.

Several domestic scientific projects and studies are also being conducted at this university. They deal with enhancing learning and education at the primary and secondary school level, integrating STEM content into primary and secondary schools, advancements in the teaching profession, understanding the multi-level of chemistry, etc.

Conclusion/Final Remarks

Many developed countries have an efficient education system thanks to their stability and economic growth. Generally speaking, education in our country is an instrument creating three educational frameworks that deepen the separation based on ethnicity, culture and history (Čustović, 2018). With regard to *Chemistry*, the syllabuses produced after 1992 were mostly based on those from the SFRY. Although there are some subtle differences between the curricula, the similarities exceed the differences. While some schools have a certain degree of flexibility, programmes and structures are relatively uniform.

Today, we face many challenges in our country. On the one hand, there are efforts to modernise education through curriculum reform, focusing on learning outcomes and the application of knowledge. On the other hand, the resistance of the present system, with political disagreements and a lack of will among the responsible structures, make any change rather difficult, if not impossible. As a consequence, there is a decrease in the number of students due to the fact that many teachers cannot receive full salaries and have to teach in several schools (up to three). This affects their motivation to innovate in their teaching and to work on their own professional development. Our politicians still prefer to talk about past events than about enhancing the progress of industry, the economy and education.

In order to have competent men and women to achieve the stability of the country in every field, we must first address our education system. We believe that the teaching profession should be more appreciated by government institutions, as well as by individuals. Our efforts should therefore be directed towards common issues that we face in every part of the country, instead of focusing on differences. With regard to chemistry education, we need to work together and to unite our potentials in order to improve the current status. The *Common Core Defined on Learning Outcomes*, which is accepted throughout the entire country, shows that we are able to work together and that we all have the same interests.

It should be noted that the authors of the present paper live in Sarajevo Canton (FB&H), so the paper may not fully reflect events in other cantons, the RS entity or the Brčko District, due to the limitations of the available data.

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The Development of Research in the Field of Chemistry Education at the University of Novi Sad since the Breakup of the Socialist Federal Republic of Yugoslavia

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The first PhD thesis in the field of Chemistry Education at the Faculty of Sciences, University of Novi Sad, was defended in 1992. This can be regarded as the symbolic dawn of Chemistry Education as a scientific discipline in this region. After the official breakup of the Socialist Federal Republic of Yugoslavia, research that had started in the 1980s, and which was focused on the development of tools for assessing the quality and flexibility of student knowledge, was continued through the 1990s. This research included the application of computers to chemistry teaching, as well as the development of appropriate chemistry learning programmes. In the following period, research focused on the analysis of chemical teaching programmes in the Republic of Serbia, with a special emphasis on the possibility of including eco-chemical content in curricula. Accordingly, potentially efficient models were suggested. The most recent research has been focused on the investigation of the effectiveness of instructional strategies based on a systemic approach and a triplet model of content representation, using combined measures of students' performance and mental effort. In this regard, tools for the efficient assessment of knowledge (systemic synthesis questions, context-based questions) have been developed along with tools for the efficient assessment of students' misconceptions (multi-tier tests). Furthermore, in order to make teaching more effective, procedures for assessing the cognitive complexity of chemical problems have recently been developed and subsequently validated both statistically and by applying Knowledge Space Theory.

Keywords: research in chemical education, directions of research, chair of chemistry education

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Razvoj raziskovanja na področju kemijskega izobraževanja na Univerzi v Novem Sadu po razpadu Socialistične federativne republike Jugoslavije

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Prvi zagovor doktorata znanosti na področju kemijskega izobraževanja na Fakulteti za naravoslovje Univerze v Novem Sadu je bil leta 1992. To lahko štejemo za simbolni začetek kemijskega izobraževanja kot znanstvene discipline v tej regiji. Po uradnem razpadu Socialistične federativne republike Jugoslavije se je raziskovanje, začeto v 80. letih prejšnjega stoletja ter osredinjeno na razvoj orodij za ocenjevanje kakovosti in fleksibilnosti znanja študentov, nadaljevalo tudi v 90. letih prejšnjega stoletja. V raziskavo smo vključili uporabo računalnikov v poučevanje kemije pa tudi razvoj primernih programov za učenje kemije. V naslednjem obdobju se je raziskovanje osredinjalo na analizo programov za poučevanje kemije v Republiki Srbiji, s posebnim poudarkom na možnosti vključevanja ekokemijskih vsebin v kurikulum. Skladno s tem so bili predlagani potencialno učinkoviti modeli poučevanja kemije. Najnovejše raziskave se osredinjajo na preučevanje učinkovitosti učnih strategij, ki temeljijo na sistemskem pristopu in trojnem modelu predstavljanja vsebine z uporabo preverjanja uspešnosti učencev in njihovih miselnih naporov pri tem. S tem namenom so bila razvita orodja za učinkovito ocenjevanje znanja (sistemska sintezna vprašanja, kontekstualna vprašanja), skupaj z orodji za učinkovito ocenjevanje napačnih razumevanj študentov (večdelne naloge v preizkusih znanja). Poleg tega so bili za izboljšanje poučevanja pred kratkim razviti postopki za ocenjevanje kognitivne kompleksnosti kemijskih problemov, ki so bili potrjeni statistično in tudi z uporabo teorije prostorskega znanja (KST – Knowledge Space Theory).

Ključne besede: raziskovanje v kemijskem izobraževanju, smeri raziskovanja, katedra za kemijsko izobraževanje

The Beginning of Research at the Chair of Chemistry Education

The beginning of scientific research in the field of chemical education at the University of Novi Sad is related to the establishment of the Chair of Chemistry Education (CCE) in 1974. As early as in 1975, specialist and masters programmes in chemistry education were established, and in 1992 the first PhD dissertation in the field of chemical education was defended.

At the beginning of the breakup of the Socialist Federal Republic of Yugoslavia (SFRY), the focus of the research group formed around the CCE was the application of tests in chemistry teaching. To this end, knowledge tests were designed as instruments for identifying the factors of creativity and success in chemistry teaching and learning, for assessing students' achievements in chemistry teaching and their ability to learn chemistry, and for evaluating the flexibility of chemical knowledge. The construction of instruments was based on the application of Bloom's taxonomy. Therefore, the possibility of specifying and operationalising educational goals and tasks in some teaching areas was analysed (Segedinac & Halaši, 1998). The factors of creativity in chemistry teaching and of success in learning chemistry were identified by the means of factor analysis. In secondary school chemistry, three factors of creativity were identified: (i) the factor of flexibility of thinking, (ii) the general reasoning factor, and (iii) the factor of originality and fluency (Segedinac, Konjović, & Dukić, 1994).

An important part of research within the CCE pertained to chemistry teaching content in primary and secondary education. Particular attention was paid to the possibilities of updating teaching content in the field of chemical production. It was found that, in the period after 1975, a large quantity of outdated content regarding chemical production and applied chemistry had been excluded from the primary school chemistry programme, but new content had not subsequently been included. Accordingly, a model for curriculum extension was proposed with the content of modern chemical production and applied chemistry (Cvjetićanin, Segedinac, & Letić, 2008, 2009). In addition, significant attention was devoted to the development of functional chemistry programmes for the needs of secondary vocational education (Segedinac, Adamov, & Halaši, 2007).

The Evolution of Research at the Chair of Chemistry Education

Research on the Use of ICT in Chemistry Teaching

In education, different countries follow different innovations regarding information and communication technology (ICT). ICT plays an important role in education in general and in chemical education in particular by providing better opportunities for visualisations, simulations and modelling of content, and by supporting laboratory instructions (cited in Krause, Pietzner, Dori, & Eilks, 2017).

Research on the application of educational technology in chemistry teaching commenced within the CCE in 1995, when the possibilities of applying computers to the individualisation of chemistry teaching were examined (Halaši, Segedinac, Konjović, & Halaši, 1995).

Later, the use of computers in the teaching practice of chemistry teachers in primary and secondary schools in our country (Adamov & Segedinac, 2006a) and in neighbouring countries (Halaši, 2004) was examined. It was shown that although in the last decades, in line with education reforms and harmonisation with European standards, teachers were aware of the need to use information and communication technology (ICT), and although computers were quite accessible to teachers, the level of their application was lower than expected. In cases of greater use of ICT, it was shown that such use only covered a narrow range of applications, while the use of computers by students during class time was not recorded. Teachers considered that they needed wider support and training to increase the use of ICT in teaching.

Further studies also included research on the characteristics and possibilities of using a virtual classroom in modern teaching practice (Adamov & Segedinac, 2006b), explaining the advantages and disadvantages of computer-assisted education and examining the prejudices that e-learning designers encounter during dissemination. The state of e-education in our country was investigated and described, and the importance of the role of ICT in defining and evaluating interaction in online learning was emphasised (Adamov & Segedinac, 2007). Different roles and forms of interaction between students, between teachers and in student-teacher relations were discussed in the light of designing e-learning models, while the difficulties that educators inexperienced in the field of electronic learning and design of electronic courses encounter during implementation were also pointed out. The conditions and necessary prerequisites for the development and organisation of an electronic teaching course as an integral part of formal education, as well as various forms of non-formal education, were examined (Adamov & Segedinac, 2006c).

Eco-Chemical Education as a Research Focus

Environmental chemistry is a very important part of chemistry education. It is aimed at raising awareness of the effects, both negative and positive, of using chemical products and processes in our environment (Aram & Manah, 1995). Research in the field of eco-chemical education within the CCE started with the aim of developing models for the eco-chemical education of employees in some branches of chemical production. Since 2014, CCE members have been dealing with ecological and eco-chemical teaching content in current chemistry and chemistry-related curricula in secondary vocational schools (Maravić, Ivković, Segedinac, & Adamov, 2014). Problems and barriers that the existing education system imposed on the development of ecological awareness among students were described and, due to insufficient representation of this content, proposals for curriculum extension were developed with content relevant to certain educational profiles (Maravić, Ivković, Adamov, & Segedinac, 2014).

As part of the study on ecocompetences, the awareness of employees in the chemical industry regarding knowledge of the ecological impact of the substances they encounter in their professional work was examined and, on the basis of the results obtained, a model for their permanent eco-chemical education was proposed (Cvjeticanin, Segedinac, & Adamov, 2010). The ecopedagogical competences of primary school teachers (class teachers and subject teachers of different fields of science) are assessed on the basis of examining their ecological literacy, expressed through attitudes, behaviour and knowledge of ecological and eco-chemical content.

Analysis of Factors Influencing Student Achievement in Chemistry

One of the recent directions of research within the CCE relates to investigation of the motivation of pupils and students to learn chemistry, their learning styles and the approaches to learning (deep, superficial or strategic) that they apply while learning chemistry, as well as the correlation of these factors and student achievements in chemistry.

Researchers who have noted the important role of motivation in learning science often mention its complex and multidimensional nature (Salta & Koulougliotis, 2015). The development of instruments for measuring student motivation has therefore received growing interest (Glynn & Koballa, 2006; Salta & Koulougliotis, 2015; Tuan, Chin, & Shyang, 2005). At the University of Novi Sad in the Republic of Serbia, a suitable questionnaire with five subscales was adapted to examine student motivation for learning chemistry content, and its psychometric characteristics were validated on a sample of 750 grammar school students. It was shown that the indicators of reliability and representativeness of the questionnaire were satisfactory for its application in further research (Olić, Ninković, & Adamov, 2016). Using this questionnaire, the distribution of five different elements of motivation in the sample of grammar school students was examined. It was shown that students were mostly oriented towards learning, followed by the application of strategies of active learning and an orientation towards achievement, while the least developed was the feeling of self-efficacy and understanding the importance of chemistry as a science. Motivation for learning was shown to be a significant predictor of student achievement (Olić, Adamov, & Babić-Kekez, 2014).

Another group of research within the CCE included learning styles. The theoretical background for this research was Kolb's experimental learning theory (Kolb & Kolb, 2005), as one of the most influential theories in the field of learning styles. An earlier study conducted by Kidanemariam, Atagana and Engida (2014) showed that learning styles had little effect on the adoption of fundamental chemical concepts. However, the authors concluded that further research was needed to examine the relationship between different students' learning styles and their achievement in chemistry. Therefore, by examining differences in achievement in chemistry between students who prefer different learning styles, researchers within the CCE showed that students who prefer a convergent learning style achieve better performance, while teachers most often apply teaching strategies that suit students with assimilating and convergent learning styles (Olić & Adamov, 2016, 2018a). Teaching strategies that correspond to a convergent learning style proved to be the most powerful predictor of achievement (Olić & Adamov, 2017). A similar study conducted on a sample of students from the Department of Chemistry of the Faculty of Sciences in Novi Sad showed that individuals with high perceived learning efficiency had higher achievements, and that student motivation is a constant predictor of academic success (Olić, Adamov, & Babić-Kekez, 2017). On a sample of chemistry students, it was shown that there was a positive correlation between student success and the presence of a deep approach to learning chemistry, although the students with the highest grades preferred a strategic approach to learning (Olić & Adamov, 2018b).

Research on Gifted Students in Chemistry

Within the CCE, research on gifted students commenced in parallel with research about learning styles. It was noticed decades ago that students can differ in terms of different learning styles and expressions of giftedness, which have different manifestations (Passow, 1981). In the initial studies about the characteristics of gifted students and their recognition, as well as teaching strategies for such students, the knowledge of class and subject teachers was examined (Adamov, Olić, & Segedinac, 2014). In order to help teachers work with such students, proposals for an individualised curriculum for teaching chemistry in primary and secondary schools were prepared (Adamov & Olić, 2014).

Chemical Experiments and Mini Projects

Research within the CCE was also focused on chemical experiments and the application of projects at all educational levels. The influence of independent student laboratory experiments on the acquisition of chemical knowledge in the population of Roma students was specifically examined, and it was found that such experiments significantly increase the students' motivation for learning chemistry and facilitate their progress (Adamov, Segedinac, Ković, Olić, & Horvat, 2012). The importance and possibility of applying experiments in the integrated teaching of natural sciences to different teaching topics were examined (Cvjetićanin, Segedinac, Adamov, & Branković, 2008a; Cvjetićanin, Segedinac, & Halaši, 2010), as well as the importance of applying a heuristic approach to the formation of the knowledge of second-grade students about the influence of heat on living beings and materials (Cvjetićanin, Segedinac, Adamov, & Branković, 2008b).

In addition, content for mini projects for including chemical and multidisciplinary topics in the integrated teaching of natural sciences within the teaching subject Nature and Society were proposed (Adamov, Olić, & Halaši, 2014; Adamov & Segedinac, 2011). It is well known that project teaching as an instructional strategy puts the student in the position of researcher, and that the student's work on projects with other students is followed by an increment in intrinsic motivation (Blumenfeld et al., 1991; Lam, Cheng, & Choy, 2010).

Models for a New Chemistry Curriculum

After publishing the official educational standards for the end of compulsory education, their realisation on a sample of over one thousand students was examined. It was shown that, in the case of chemistry, these standards had not been achieved for either the basic or the intermediate level, and that there is no correlation between students' knowledge and their grades in chemistry at the end of compulsory education (Adamov & Olić, 2015). The results obtained were the reason for carrying out research on the attitudes of teachers and students on the need for the introduction of chemistry in the sixth grade of primary school (Adamov, Radanov, Olić, & Segedinac, 2012). The opinions of teachers and students obtained in this research indicated the need for chemistry curriculum reform in order to arrange a three-disciplinary chemistry programme in three years of learning (sixth, seventh and eighth grade). Additionally, a proposal for a sixth grade curriculum is provided.

Research Related to Scientific Literacy

Part of the research within the CCE is dedicated to studies of scientific literacy (Adamov, Marković, & Olić, 2012). The key component of scientific literacy is chemical literacy, which is very important because it represents the capability to understand key chemistry concepts (Shwartz, Ben-Zvi, & Hofstein, 2006).

The results of research on the scientific literacy of an adult non-chemical population in Vojvodina gave a generally positive impression. The lowest achievement of respondents was recorded in the category that refers to the knowledge of concepts in the field of health, which is a significant determinant of adult health behaviour (Adamov, Olić, Segedinac, Ninković, & Kovačević, 2013). The data obtained indicated the need to develop a systemic approach to meeting the requirements for the scientific literacy of adults. This would contribute significantly not only to the professional mobility of adults, but also to an improvement in the productivity of the national economy.

The Effectiveness of Using Concept Maps

Concept maps were introduced in the early 1970s as tools that show how new concepts are integrated into the learner's cognitive structure (Novak, 2010). Thus, they are hierarchical representations of the learner's organisation of their own cognitive structures (Novak & Govin, 1984). Such maps have been used in science education and have not been overlooked in chemistry (Johnstone & Otis, 2006; Pendley, Bretz, & Novak, 1994; Regis, Albertazzi, & Roletto, 1996).

In chemical education, concept maps have been widely investigated, as they can help in building connections between abstract concepts. Regarding the strategies of learning and teaching chemistry, the possibility of using concept maps as tools for diagnosing the acquisition and retention of knowledge in the field of biochemistry in secondary schools was examined within the CCE (Adamov, Segedinac, Cvjeticanin, & Bakoš, 2009). The findings suggested using concept maps in determining the level of acquired knowledge and in determining students' ability and efforts in learning biochemical content, as well as using them as an indicator of knowledge retention and for assessing the effectiveness of the applied teaching method and the performance of teachers.

The Latest Research within the Chair of Chemistry Education

The latest research within the CCE is being undertaken in two parallel directions: (i) the development and evaluation of effective instructional models; and (ii) the construction and validation of tools for assessing the quality of student cognitive structures.

Examination of the Effectiveness of Instructional Strategies

The examination of the effectiveness of instructional strategies is based on combined measures of performance and invested mental effort. In addition to the classic approach to measuring mental effort, which is based on the application of subjective measurement scales, a methodology for assessing the cognitive complexity of items has been elaborated, which, in addition to the assessment of objective item difficulty, takes into account the interactivity of elements. A combination of measurement of students' achievement, mental effort and cognitive complexity has provided valid and a reliable assessment method and upgraded tools for assessment of task and test quality (Knaus, Murphy, Blecking, & Holme, 2011; Raker, Trate, Holme, & Murphy, 2013).

Within the CCE, research in this domain began with the teaching area of stoichiometry. The Table for the Assessment of the Difficulty of Concepts Present in Stoichiometric Problems was developed (Horvat, Segedinac, Milenković, & Hrin, 2016). Each stoichiometric concept was evaluated according to its difficulty as easy, medium or difficult. By summing the obtained values of concept difficulties and adding the value of their interactivity, a numerical rating of the cognitive complexity of a problem can be calculated. For the validation of this procedure, linear regression analysis was used, correlating student achievement and applied mental effort as dependent variables with the numerical rating of the cognitive complexity of the problem as an independent variable. In addition to the statistical procedure for validating the method for assessing the cognitive complexity of stoichiometric tasks, this method was further validated by applying Knowledge Space Theory (Segedinac, Horvat, Rodić, Rončević, & Savić, 2018). Knowledge Space Theory enabled the fine differentiation of concepts and the identification of differences between the expected knowledge space, which was constructed based on the numerical rating of cognitive complexity, and the real knowledge space, which was constructed based on the students' achievements. The differences between the knowledge spaces were determined as the graphs' differences. The continuation of the research involved the development of procedures for the assessment of the cognitive complexity of tasks in the field of chemical production and the calculation of the hydrogen exponent (Horvat, Rodić, Rončević, & Segedinac, 2019; Horvat, Rodić, Segedinac, & Rončević, 2017).

Regarding the research related to the assessment of efficiency, the efficiency of two instructional models was examined: Model 1, which is based on the application of the chemistry triplet, and Model 2, which is based on the application of the systemic approach to chemistry teaching and learning. Model 1 is based on an early idea of Johnstone (1991, 1993), who highlighted the notion that chemical knowledge can be represented at three levels: *macroscopic*, which includes perceptible properties of chemical substances and processes that can be experienced with the senses; *submicroscopic*, which refers to the structure of atoms, molecules and ions; and *symbolic*, which includes chemical symbols, formulas and equations. The research was conducted in the form of a pedagogical experiment with parallel groups (experimental and control). The experimental group was trained through instruction based on the idea of a triplet model, where each experiment and new concepts were studied through the constant interplay between macroscopic, submicroscopic and symbolic levels, while the control group was trained in a traditional way. The study applied a pretest-posttest design, and differences in respondents' performance, as well as differences in perceived mental effort, were compared statistically. In addition, the aforementioned variables were also used in the assessment of instructional efficiency. The results of this study have shown that a strategy that relies on the application of a chemistry triplet model had a positive impact on the performance of the respondents, and that it had an equally positive effect on the performance of both male and female respondents. It was also shown that this kind of instruction had a positive effect on the amount of invested mental effort by both male and female students, which eventually resulted in greater efficiency of students in the experimental group in solving the majority of problems (Milenković, Segedinac, & Hrin, 2014). It should also be noted that the applied instruction had a significant influence on the elimination of students' misconceptions (Milenković, Hrin, Segedinac, & Horvat, 2016a).

Linking the Cognitive Load Theory and Constructivist Theory of meaningful learning, Hrin, Fahmy, Segedinac and Milenković (2016a) have developed Model 2, which emphasises the potential use of the systemic approach, or more precisely systemic synthesis questions [SSynQs], as efficient instructional tools in secondary school organic chemistry teaching and learning. The systemic approach to teaching and learning chemistry was designed, presented, implemented and evaluated for the first time by Fahmy and Lagowski (2003). Examining the structure of concept maps, these authors designed systemic diagrams and systemic assessment questions as an interacting system of arranged concepts in which all relations between the set of concepts are clearly stated (Fahmy & Lagowski, 2003). There are several different types of systemic assessment questions. One example of a systemic synthesis question [SSynQ] designed for the teaching and learning of hydrocarbons is presented in Figure 1. Besides higher performances in the final testing, secondary school students from one high school from Novi Sad, Republic of Serbia, who were exposed to [SSynQs] in organic chemistry classes invested lower levels of mental effort in comparison to students who were subjected to the traditional instructional method (i.e., teacher lecturing, discussion sections, solving conventional problems). The correlation between the students' performances and invested mental effort allowed the researchers to analyse the real instructional efficiency of both applied instructional methods: [SSynQs] and traditional. A value of high, positive instructional efficiency was calculated for the applied instructional method in the experimental group, whereas a low, negative value of instructional efficiency was calculated for the traditional instructional method applied in the control group. It was emphasised that the application of [SSynQs] was more suited to female students than male students. As possible reasons for this, the characteristics of [SSynQs] as teaching and learning tools as well as learning style differences between genders, were noted. In addition to being characterised as efficient instructional tools focused on helping students to overcome difficulties in learning organic chemistry content (Hrin et al., 2016a; Hrin, Milenković, & Segedinac, 2016b), after conducting an exploratory factor analysis of the obtained data, [SSynQs] were characterised as highly effective, valid and reliable tools for assessing students' meaningful understanding (Hrin et al., 2016b).

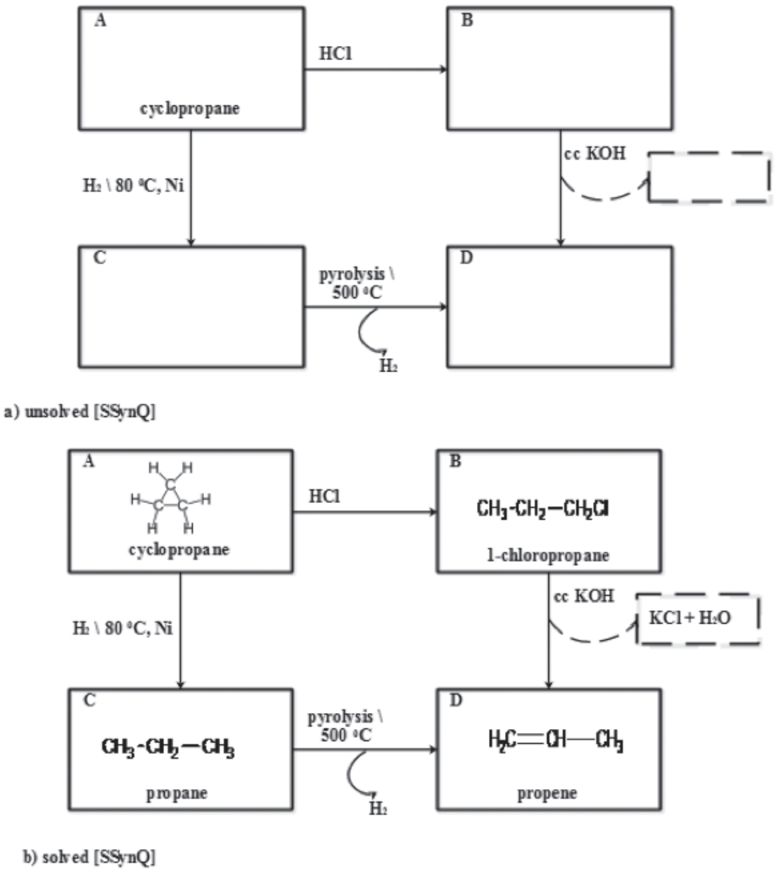

Figure 1. Example of an [SSynQ] designed for the teaching and learning of hydrocarbons

Construction and Validation of Assessment Tools

The second direction of research relates to the development and validation of teaching tools for (i) determining students' misconceptions, (ii) evaluating the conceptual understanding of chemistry content, (iii) system thinking assessment, and (iv) examining students' capacity to understand and reflect on written texts.

Two-tier and three-tier multiple-choice tests have been constructed to identify student misconceptions. Taking into account directions from the previous studies, test tasks were constructed in such a way that the first-tier contains a content problem, the second-tier contains a reasonable explanation of the first-tier question, and the third-tier is called a confidence tier, where students indicate whether they are sure of their answers and confident that they understand the content of the task (Chandrasegaran, Treagust, & Mocerino, 2007; Cetin-Dindar & Geban, 2011). Contrary to common multiple-choice items, multi-tier items reduce the ability to guess the correct answers and enable more accurate identification of students' misconceptions. Within the CCE, the designed two-tier and three-tier instruments were validated and, on the basis of the results, a large number of misconceptions in the field of inorganic chemistry was identified among secondary school students (Milenković, Segedinac, Hrin, & Horvat, 2016), as well as in the field of biochemistry among students of pharmacy (Milenković et al., 2016a). An example of one three-tier multiple-choice item included in the research is presented below.

1. Circle the letter of the correct answer. Which of the following compounds **does not give** a red coloured product by reaction with Fehling's solution?

a. Lactose
b. Mannose
c. Sucrose
d. Fructose

The reason for your answer is:

a. Sugars whose molecules contain an aldehyde group cannot be oxidised by weak oxidising agents.
b. Sugars whose molecules contain a keto group cannot be oxidised by weak oxidising agents.
c. Disaccharides whose molecules do not contain a free hemiacetal group cannot be oxidised by weak oxidising agents.
d. Disaccharides whose molecules contain a free hemiacetal group cannot be oxidised by weak oxidising agents.

Are you sure of your answers?

a. Yes
b. No

In addition, misconceptions that occur among students who are gifted for chemistry, i.e., students involved in national chemistry competitions, have also been analysed (Milenković, Hrin, Segedinac, & Horvat, 2016b).

In order to examine and compare the quality of the cognitive structures of secondary school students and pre-service chemistry teachers (who were in their final (fourth) year of study towards a bachelor's chemistry degree) in the organic chemistry domain, a new form of [SSynQs] were applied in a study by Hrin, Milenković, and Segedinac (2018). In our previous studies (Hrin et al., 2016a, 2016b; Hrin, Milenković, Segedinac, & Horvat, 2016c, 2017), [SSynQs] had a more constrained format in which students should have recognised defined relations or some initial concepts that were missing (i.e., filling empty fields in the provided diagrammatic form, as shown in Figure 1). In the new study, however, our intention was to analyse the students' and pre-service chemistry teachers' thoughts about organic chemistry compounds using so-called student-generated [SSynQs] (Hrin et al., 2018). This type of [SSynQ] is an individual visual representation of the closed framework of the provided concepts, in which, within the organic chemistry domain, the participant should establish proper relations between organic chemistry compounds using labelled lines with reagents and/or reaction conditions. Using the described student-generated [SSynQs], the overall quality of the cognitive structures, the size (extent) and strength (complexity) of the conceptual structures, were analysed. Observing the written responses of our participants, the results showed that both high school students and pre-service chemistry teachers had a relatively good familiarity with IUPAC naming and the chemical structures of a wide range of organic chemistry compounds except for ethers, which have a substantial quantity of conceptual structures. On the other hand, the strength of the conceptual structures (i.e., inter-correlations between organic chemistry concepts) was evaluated as weak for high school students, and medium for pre-service chemistry teachers. In addition, it was important that we were able to identify the main learning difficulties, accompanied by a lack of understanding (potential misconceptions) with regard to the chemical properties and relations of organic compounds in both high school students and pre-service chemistry teachers.

Taking into account the fact that, within the traditional instructional method, teachers usually pass on facts to students that are not properly linked to other facts, but are fragmented or chunked, two studies were conducted by the same team of researchers (Hrin et al., 2016c, 2017) in order to work on the development and assessment of one of the higher-order thinking skills: systems thinking, defined as the ability to more deeply understand and interpret the characteristics of complex systems (Evagorou, Korfiatis, Nicolaou, & Constantinou, 2009). The importance of such understanding has recently been recognised in chemical education. Firstly, secondary school students' difficulties in dealing with complex organic chemistry systems were considered in both studies (Hrin et al., 2016c, 2017). Then, two parallel groups were formed, each of which was subjected to different learning environments. This enabled us to examine the benefit of [SSynQs] as instructional tools that may help students in developing systems thinking skills, comparing them with traditional instruction. In the first study (Hrin et al., 2016c), three different types of systems thinking were analysed in both groups: structural systems thinking, level I of procedural systems thinking, and level II of procedural systems thinking. The students exposed to the [SSynQs] achieved higher performance scores in all of the aforementioned types of systems thinking, with the greatest difference between the groups being found in the most complex type: in level II of procedural systems thinking. In our second study (Hrin et al., 2017), the scoring rubric was developed to evaluate students' responses to [SSynQs]. Four levels of systems thinking were defined, and the findings showed that differences between the two groups' abilities to think systemically grow linearly with the complexity of these levels. The students subjected to [SSynQs] made meaningful progress, reaching the highest levels of systems thinking. Observing gender as an independent variable, it was found that the female students in the experimental group outperformed the male students, demonstrating a better aptitude for dynamic and cyclic systems thinking. In this part, the study was linked with our previous results (Hrin et al., 2016a), highlighting the need to discuss this issue in more detail in our future research.

Finally, tools to examine students' capacity to understand written texts, i.e., to examine the influence of the context of the task on student achievement and invested mental effort, have been developed (Milenković, Segedinac, Hrin, & Gajić, 2015). In this research, tasks were constructed in three levels of context complexity (tasks without context, and tasks with moderate and rich context). Within each task, there was a seven-point Likert type scale. The results of the research showed that students were most successful in solving tasks without context (they achieved high performances while investing small amounts of mental effort), while their efficiency in solving tasks with a moderate and rich context was considerably weaker. These results indicated the problem of the functional reading of respondents involved in this research, that is, problems that include finding, selecting, interpreting and evaluating information from a broad textual context.

Dissemination of the Results and Implications for Further Research

The results of our latest research were disseminated among chemistry teachers within the three-year accredited CPD programme Contemporary Forms of Evaluation in Teaching Chemistry. To date, the CPD programme has been executed three times, with a total of 64 primary and secondary school chemistry teachers taking part in the first year of implementation. It should be emphasised that the innovations in knowledge evaluation were very well accepted by chemistry teachers, who evaluated the programme with a very high grade (3.78 out of 4.00).

Future research will be oriented towards the construction of new rubrics for the assessment of cognitive complexity for various teaching topics; the development of four-tier diagnostic instruments as the most reliable tools for the identification of students' misconceptions; the application of eye-tracking methodology to examine the quality of student cognitive structures; and, last but not least, textbook analysis as a possible source of students' misconceptions and misunderstandings, with a special focus on textbook illustrations.

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Chemistry Education in Kosovo: Issues, Challenges and Time for Action

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Although several reforms have shifted the direction of education, a debate on the strengths and limitations of science education in Kosovo has not yet been initiated. The present article analyses the development of chemistry education in Kosovo and encourages questions that could shape science education practices in general. In particular, the article analyses the pre-university chemistry curriculum in Kosovo over the years, as well as examining chemistry teacher education programmes. The analysis is based on descriptive research of data and document analysis. The multi-dimensional analysis of the issues and challenges of chemistry education will provide recommendations for future research on chemistry education and chemistry teaching practices in order to make chemistry education and the pre-university chemistry curriculum relevant to the context of Kosovo. As pre-university education curricula, especially the curriculum for the natural sciences, and the preparation of both pre-service and in-service teachers in Kosovo are considered challenging, a firm conclusion for actions has not been reached. Nevertheless, the article seeks to spark a debate in the field.

Keywords: chemistry education, chemistry curriculum, chemistry teacher education, pre-service chemistry education

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Kemijsko izobraževanje na Kosovu: vprašanja, izzivi in čas za ukrepanje

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Čeprav je vrsta reform že spremenila smer izobraževanja, se razprava o prednostih in omejitvah naravoslovnega izobraževanja še ni začela. Prispevek analizira razvoj kemijskega izobraževanja na Kosovu in postavlja vprašanja, ki bi lahko na splošno oblikovala naravoslovno izobraževalno prakso. Natančneje, prispevek analizira preduniverzitetni kurikulum na Kosovu v zadnjih nekaj letih pa tudi študijske programe za izobraževanje učiteljev kemije. Raziskava temelji na deskriptivni analizi podatkov in analizi dokumentov. Multidimenzionalna analiza vprašanj in izzivov kemijskega izobraževanja bo omogočila oblikovanje priporočil za prihodnje raziskave na področju kemijskega izobraževanja in prakse poučevanja kemije z namenom narediti kemijsko izobraževanje in preduniverzitetni kurikulum relevanten za kosovski kontekst. Ker se učni načrti preduniverzitetnega izobraževanja, zlasti učni načrti za naravoslovje in učni načrti študijskih programov za izobraževanje učiteljev ter za programe izpopolnjevanja učiteljev na Kosovu, štejejo za zahtevne, nekih zavezujočih sklepov za ukrepe še ni bilo doseženih. Kljub temu pa je namen tega prispevka sprožitev razprave na tem področju.

Ključne besede: kemijsko izobraževanje, kemijski kurikulum, izobraževanje učiteljev kemije, študijski programi za izobraževanje učiteljev kemije

Introduction

According to the latest European Commission report (2019), education quality in Kosovo remains a challenge at all levels. Kosovo is at an early stage of any kind of educational, cultural, scientific and research preparation. There has been no progress in the past years and there is still a need to significantly improve the quality of education and fields of innovation. A lack of qualified teaching staff, teaching materials and supplies, combined with an underdeveloped student evaluation system, undermines the implementation of curriculum reform. Kosovo's teacher training system needs to be strengthened to improve the quality of both pre-university and university level education. It has an education system framework that is still unable to provide young people with the knowledge and skills required to meet labour market demands (UNDP, 2016). Pupovci (2002) found that the traditional education framework was based on teacher-centred learning and memorisation, and this obsolete practice still continues in many cases. As a result, Kosovo is ranked among the lowest of all participating nations in the PISA science test (OECD, 2016). Such concerning data indicate that science teaching in Kosovo is insufficiently effective and may result from the poor performance of inquiry-based teaching and learning and/or active learning.

In an effort to improve the quality of education in Kosovo and harmonise with developed countries, the Ministry of Education, Science and Technology (MEST) approved the New Kosovo Curriculum Framework (KCF) in 2011. This framework is supposed to facilitate a shift from objective and content-based methodologies to contemporary teaching and learning methodologies based on student outcomes and the development of student competencies (MEST, 2016). Furthermore, in 2012, MEST made the choice to reform study programmes for the qualification of subject teachers according to the successive model. Thus, all teachers should complete three years of academic studies for the corresponding subjects in appropriate academic programmes at the bachelor's level and two years at the master's level at the Faculty of Education, where they have specialised instruction in pedagogy content knowledge courses, general pedagogical knowledge and teaching practices. These programmes were offered for the first time in the 2016/2017 academic year. Science educators in Kosovo are therefore expected to make use of the opportunity to enhance teaching practices and student quality outcomes and use the reform to overcome longstanding obstacles. Teaching science through inquiry, argumentation, project-based learning and problem-based learning, as well as using formative assessment purposes and making learning relevant to students' daily lives, is the main goal of the curriculum reforms in Kosovo (MEST, 2016a).

The main objective of the present article is to reflect briefly on the education system, focusing on the current situation, issues and challenges of science education, in particular chemistry education, in Kosovo. Through relevant literature reviews and analysis of the past education system and curriculum, the author would like to identify and understand the obstacles and issues that the current education system faces today. Guidelines that could encourage and meaningfully contribute to future research for the improvement of chemistry education in Kosovo will be discussed. The article should also stimulate debate on the strengths and limitations of chemistry education and science teaching and learning, as well as catalysing further discussion in order to help create a proper system that fits the population and their goals for the future of science development, resulting in economic growth. It should be noted that, due to the lack of previous research on this matter, the article covers a wide spectrum of analysis and it is difficult to support conclusive recommendations. Furthermore, chemistry teaching in compliance with European norms will be discussed as measures needed for the development and improvement of science teaching and learning in the Kosovo education system.

Theoretical Framework

"*Europe Needs More Scientists*" and "*Towards a Sustainable Europe by 2030*" are the headings of European Commission reports on increasing human resources for science and technology in Europe and moving it towards a sustainable future (European Commission, 2004, 2019). The declining interest in studying science is one of Europe's biggest concerns of the 21st century. Osborne and Dillon (2008) state that the current curricula and educational practices around Europe are failing to engage young generations in the study of science. Numerous studies worldwide have examined the declining interest in science education in general (European Commission, 2004; Haste, 2004; OECD, 2006; Osborne, Simon, & Collins, 2003; Osborne, 2007; Osborne & Dillon, 2008; Sjoberg & Schreiner, 2005). According to Rocard et al., (2007) the lack of interest in science studies is due to the way science is taught in schools. This issue should therefore be the main focus of improvement in future science education.

Taber (2017) explains that science education, as a research field, is "concerned with developing knowledge about the learning of science, and the teaching of science", while Cooper and Stowe (2018) give an excellent review on chemistry education, in which they state that chemistry education research is mainly "concerned with teaching and learning in chemistry, investigated through a variety of qualitative and quantitative methods". Researchers in chemistry education are exploring a wide variety of areas of teaching and learning chemistry, including the processes by which learners build knowledge and understand chemistry, as well as the obstacles that hinder construction. Chemistry education research concerns the development of tools that measure knowledge, attitudes, identity and other affecting constructs, such as how student learning can be integrated into curriculum design and the impact of curricular revolutions.

According to Shulman (1987), one of the core competencies that all pre-service science teachers should build in order to achieve any reform objectives in their schools and classrooms is an understanding of pedagogical content knowledge (PCK), which has been proven to be a challenging task for science teacher educators. In addition, Shulman (1986) states that, although PCK is essential to teachers' knowledge, content knowledge (CK) is a requirement for the development of PCK. Bucat (2004) explains that PCK refers to an understanding of the teaching and learning of specific subjects, taking into account the specific learning requirements essential in that subject matter, whereas CK refers to one's knowledge of the subject, and pedagogical knowledge (PK) refers to one's knowledge of teaching and learning independent of the subject matter. Every chemistry teacher has a distinctive understanding of chemistry, but they all share the same role as teachers: repackaging and representing their knowledge of chemistry in a way that ensures the students' understanding of the subject. It is very important that teachers of chemistry not only know the subject matter, but also know the subject in terms of knowledge transfer through teaching and learning (Bucat, 2004).

Ensuring that all young people are taught by highly qualified educators is viewed as a key target for overall training frameworks for teacher preparation. The European Commission's Strategic Framework for Education and Training 2020 (European Commission/EACEA/Eurydice, 2013) points out that high-quality "pre-primary, primary, secondary, higher and vocational education and training" is central to Europe's success. Similarly, for Kosovo, the newest country of Europe, the quality of teacher preparation is essential to the quality of teaching. Teacher preparation in Kosovo should provide balanced and consistent teaching practices with proper access to training and professional development for the improvement of CK, PCK, teaching skills and teaching practices in schools.

Desk literature research on science and chemistry education, along with research on chemistry teacher preparation, and its reforms in Kosovo over the years have failed to yield reliable information. To date, there is no documented research of any kind on science and/or chemistry education in Kosovo. What follows is an attempt to offer information on the current situation of the science and/or chemistry education practices and research in Kosovo.

The Education System and Chemistry Education: The Pre-University Chemistry Curriculum in Kosovo

Several reforms have shifted the direction of education in Kosovo over the years. Consistent information on the general education system in Kosovo before the war of 1999 is hard to find and is not the focus of the present paper. For more information regarding the education system in Kosovo before 1999, please refer to the work of Pupovci (2000), Bache and Tayor (2003), Baliqi (2010) and Bicaj and Berisha (2013).

Immediately after the war of 1999, the United Nations (UN) took over the responsibility to rebuild Kosovo (Vula & Saqipi, 2009). The process of the normalisation of education was assisted by many international organisations. Until 2000, education in Kosovo fought for survival and, as a result, did not inherit any set goals and objectives for the persisting system of education in Kosovo. During the 2000–2001 academic year, many legal and professional preparations were made to generate a new system of education in Kosovo. Education standards, curricula, teacher training, special needs education and vocational education, as well as a statute for higher education and university reforms in alignment with the Bologna Process, were initiated (Vula & Saqipi, 2009).

In March 2002, the Ministry of Education, Science and Technology (MEST) was established in Kosovo, followed by the establishment of the Faculty of Education (FE) at the University of Prishtina (UP) that same year. The MEST took over the education system with the intention of shifting education in Kosovo from the emergency phase to the consolidation phase, and with the goal of achieving European Union (EU) educational processes and trends. Their vision was to build Kosovo into "a democratic and knowledge society", integrated into Europe, and to establish long-term and sustainable social and economic development (MEST, 2007). The education system was the subject of reforms at all levels of education in an attempt to establish a system similar to that of the EU, with 5 + 4 + 3 for primary, lower secondary and upper secondary school education, and the Bologna Process for higher education.

From 2002 to 2017, the curriculum for pre-university education offered a chemistry course from lower secondary school in grade 7 to upper secondary school grade 12 (Figure 1). In elementary primary education, a science education course was offered at grades 3, 4 and 5, for one hour per week. In lower secondary education in Kosovo, chemistry was offered two hours per week in grades 7, 8 and 9. In upper secondary education, natural science gymnasium (grammar) schools (natural sciences, mathematical, general) offered chemistry in grades 10, 11 and 12, with a minimum of two and a maximum of three hours per week (Figure 1). Medical vocational schools offered one hour per week of chemistry for four years, and chemical technology schools offered two hours per week in grades 10 and 11. Other upper secondary schools, such as social sciences gymnasiums (social science and linguistics) and mechanical, agricultural and metallurgy vocational schools offered one year of chemistry during upper secondary education (at least one academic hour per week). On the other hand, economics, engineering, graphics, hotelier/tourism and geodesy/construction vocational schools of upper secondary education did not offer any chemistry courses. In general, lower and upper secondary education in Kosovo offered a respectable number of chemistry hours per week.

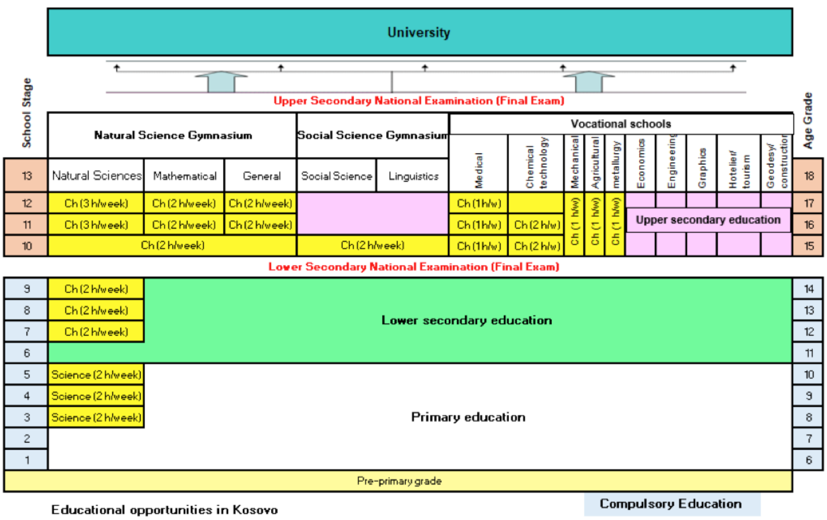

Figure 1. Education pathway and chemistry hours offered by the education system in Kosovo (2002–2017).

With the new KCF implementation as of 2017, there were no significant changes to the number of chemistry hours offered per week. The only significant change was the introduction of science courses starting in the first and second grades in primary education with one hour per week and continuing through the third, fourth and fifth grades with two hours per week (Figure 2). The curriculum for technical/vocational schools has not yet been drafted.

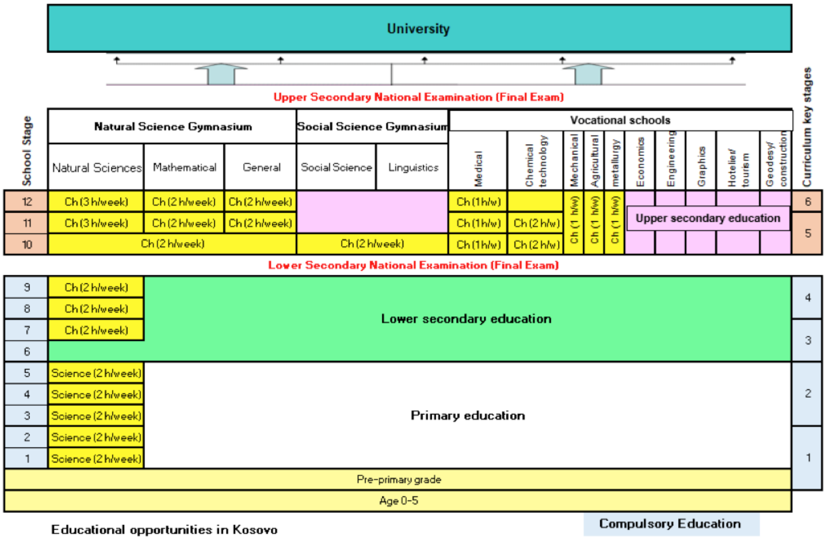

Figure 2. Education pathway and chemistry hours offered by the education system in Kosovo (2017–present).

The new KCF aims to shift central-based teaching and learning towards the competency-based approach. It seeks the development and implementation of learner-centred teaching and learning, as well as inclusion, integrated teaching and learning, flexibility and mobility, in addition to transparency and accountability. The key learning competencies envisioned for the pre-university education system in Kosovo are (MEST, 2016a): communication and expression, thinking, learning, life, work and environmental learning, personal and civic competences. The core curricula (MEST, 2016b, 2016c) provide detailed learning competencies for all six key stages of the pre-university education system.

According to the new KCF (MEST, 2016a), primary education (key stages 1 and 2) nurtures basic learning habits and cognitive and social-emotional development, with special attention devoted to personality development and building a positive attitude towards learning. Lower secondary education (key stages 3 and 4) offers new challenges towards cognitive, physical, personal, social and ethical development. The curriculum for lower secondary education is enriched with broad exposure to learning experiences with the goal of helping students to identify their preferences and areas of special interest. Upper secondary education (key stages 5 and 6) aims for a wider, deeper and more specialised process of learning. Depending on the route, the upper secondary education curriculum orients students toward gymnasium school (natural sciences, mathematical, general, social sciences and linguistics gymnasium), technical/

vocational qualifications and/or the labour market as qualified workers, and is supposed to equip students with lifelong learning skills (MEST, 2016a).

The core curriculum of science for the three pre-university levels of education aims to achieve knowledge, understanding, habits, skills, attitudes and values enabling students to understand the concepts, theories and laws of nature, as well as its fundamental phenomena. The aim of the science curriculum is to contribute to the general growth and development of society, helping to increase the level of technology use and boost economic development, thus enhancing the quality of human life and maintaining health, the living environment and wellbeing. Students should develop a curiosity for the natural environment of scientific research and human-induced change; they should embrace the scientific skills of beginners, acquiring the concepts, tools and procedures required to draw conclusions from data analysis and to present and evaluate results; and they should develop problem-solving skills by using tools when undertaking individual and teamwork tasks. In this way, students will develop critical thinking and will be trained to identify problems, ask questions, formulate hypotheses and draw conclusions based on arguments, as well as to follow the steps of scientific methodology (MEST, 2016a).

In key stages 1 and 2, students learn about the natural and man-made environment, and research methods for studying processes and natural phenomena. In key stages 3 and 4, lessons in physics, chemistry and biology are taught, thus achieving an integrated interdisciplinary approach to teaching sciences. Whereas in key stages 5 and 6, sciences are taught in general upper secondary schools as the separate subjects of physics, biology, chemistry and astronomy, the teaching of technical/vocational sciences is still under development (MEST, 2016a). In the curriculum of lower secondary education, key stages 3 and 4 describe the teaching of sciences as integrated practices. In practice, however, the science courses physics, chemistry and biology are taught as separate courses. According to the lower and upper secondary core curriculum (MEST, 2016b, 2016c), the natural sciences will facilitate the integrated development of competencies aimed at helping students in social, health and economic terms related to various issues at the national and global levels. The general concepts of science in lower and upper secondary education consist of: 1) matter, properties and transformations, 2) physical processes, 3) the living world, and 4) the Earth, the environment and the universe.

The number of hours of chemistry taught in lower and upper secondary education has not changed compared to the previous curriculum. However, an increase in the content and materials that have to be taught during a chemistry course has been noted, but this is not accompanied by an increase in the time allocated for chemistry teaching. Instead, the latter has been fitted into the pre-existing timeframe.

The new KCF teaching goals and objectives have shifted from traditional education to 21st century skills-based education focused on competences, which demands changes to the way science is taught in schools. The teaching of science content has shifted towards a constructive approach and inquiry-based teaching and learning. Scientific literacy and science processing abilities and skills have been moved to the centre of the curriculum, demanding pre-service and in-service science teacher training programmes to promote inquiry-based science teaching and learning. The current curriculum requires that science teachers understand inquiry abilities and skills, and that they use investigation/inquiry methods rather than direct instructions in their schools to educate the future leaders of the 21st century. The curriculum builds on school-based, competency-based, student-centred, research-based, integrated and community-oriented practices.

Chemistry Teacher Education in Kosovo

Until 2002, lower secondary chemistry teachers in Kosovo attended higher pedagogical schools, which offered a two-year study programme to qualify graduates to teach 7th and 8th grade chemistry courses. With the establishment of the Faculty of Education in 2002, the latter took over responsibility for teacher preparation, including that of chemistry teachers for lower secondary education (7th, 8th and 9th grade), offering four-year bachelor studies with 240 ECTS credits. Upper secondary chemistry teachers were prepared at the Department of Chemistry of the Faculty of Natural Science and Mathematics (FNSM) at the University of Prishtina, which offered a four-year programme (Vula, Saqipi, Kraja, & Mita, 2012).

Teacher preparation for lower secondary education offered two subject degrees: Chemistry/Biology and Chemistry/Physics. Until the 2011/2012 academic year, CK and PCK courses were offered equally for the two subjects, in addition to general PK and school practices. Due to limited CK courses on the two major subjects, pre-service chemistry teachers attending the Faculty of Education lacked CK compared to pre-service chemistry teachers attending the Department of Chemistry at the FNSM, while the latter lacked PCK and general PK competencies. The subject teacher preparation gaps created due to the lack of CK, PCK and general PK were evident and were discussed among education stakeholders, who called for immediate reforms. According to Vula et al. (2012), universities faced countless issues in pre-service teacher education, primarily in terms of curricula, teaching methodology, pedagogy, teaching practice and research. Since the Kosovo education system lacked national standards, different curricula offered by different universities have significant pedagogical differences.

In the 2009/2010 academic year, the Accreditation Agency for academic programmes requested that the University of Prishtina and MEST review the model and quality of teacher training and preparation programmes. This was also reflected in the European Commission Progress Reports 2010–2011 (European Commission, 2010, 2011), which recommended reform of teacher training. Eventually, in 2012, MEST decided to reform the preparation of subject teachers according to the consecutive 3+2 model, whereby prospective teachers should complete three years of academic subject/content bachelor studies at the academic units and two years at the master's level at the Faculty of Education with general and pedagogical content knowledge courses offered. The reform advocated by MEST for pre-university teacher preparation was in line with the KCF reforms. The latter has also established coherence in the system of teacher preparation by ensuring that, besides CK courses (180 ECTS), each new teacher also takes appropriate general PK and PCK courses, as well as gaining practice teaching experience in schools (120 ECTS). As a result of the reforms undertaken, the current chemistry teacher preparation programme aims to prepare future chemistry teachers who are competent both in CK and PCK, as well as in general PK and teaching practices. CK is supposed to be refined at the Department of Chemistry of the FNSM through a variety of subject matter courses in a three-year study programme, while PCK is further developed at the Faculty of Education through a variety of educational courses.

According to the European reforms of chemistry education, chemistry students pursuing a bachelor's degree are, upon completion, expected to have developed a range of different abilities, skills and competencies, as outlined by Pinto (2010). The Bologna Process has made chemistry education teaching and learning an active process by using hands-on activities, cooperative learning and technology, and by engaging in problem-based learning, project-based learning, inquiry-based learning, case studies and the environment, as well as other learning strategies that were not present before. Within the Bologna Process, chemistry education has adopted modern pedagogical methodologies taking into consideration all of the competencies (specific, generic and transferable) and skills as a basis of the learning outcomes (Pinto, 2010).

The goal of the chemistry teacher education programme at the Faculty of Education is to equip pre-service chemistry teachers with competencies in both the CK and PCK of chemistry with the ability to teach chemistry. In order to train future chemistry teachers with these competencies, the current practices of chemistry teacher education programmes provide two branches of education and two levels of education: the bachelor's level, where the students obtain CK courses, and the master's level, where they acquire PCK and general PK through educational courses and practice teaching. The general belief behind this type of educational design is that after taking these courses pre-service teachers will be able to integrate the separate knowledge of pedagogy and subject matter and implement this knowledge in classroom teaching.

Issues and Challenges: Time for Action

Obstacles and issues that the current education system faces today

Due to a lack of research on chemistry education, several potential issues and challenges can be raised regarding the future of chemistry education in Kosovo, mainly based on a literature review, the chemistry curriculum and chemistry teacher preparation programmes.

In his study on making chemistry teaching relevant, Holbrook (2005) summarises the results of several studies on the issues of chemistry teaching. The many issues encountered include the fact that chemistry teaching is unpopular and irrelevant to students, that there is a failure to promote higher-order cognitive skills, that gaps are generated between what students want to learn and what teachers teach, and that chemistry teaching is not changing because teachers are afraid of change and need professional development. Similarly, Rocard et al. (2007) claim that science education problems and issues are a reflection of the way science is taught in schools.

This supports the finding of a previous study conducted by Berisha, (2013), which stated that students who entered the Faculty of Education in Kosovo during the 2009/2010 academic year with the intention of becoming chemistry teachers were not prepared for the study of chemistry education at the university level. The indicated study screened first-year students (n = 176) on five chemistry basic knowledge questions. Only 0.6% of the students answered all five questions correctly, 2.8% answered four questions correctly, 8.5% provided three correct answers, 18.2% provided two correct answers, and 27.3% provided one correct answer, while 42.6% did not give an answer or the answer was not correct. On closer examination of their chemistry background based on their upper secondary school, it was found that 46.6% of the students came from gymnasium schools (natural science, mathematics and general) and 6.8%

came from a medical vocational school where they had attended chemistry courses every year of their upper secondary education. The rest of the students came from other technical/vocational schools with no chemistry education or at least one year of chemistry courses taken during upper secondary education. Given that more than 50% of the students had taken chemistry courses in more than two years of high school, the test results were discouraging. The results suggest that chemistry instruction at lower and upper secondary schools in Kosovo is unpopular or irrelevant to students, or that it lacks relevance to chemistry teaching. Furthermore, this finding reflects a lack of interest among students with good results in pre-university studies in becoming teachers, and indicates that the criteria for pre-service teacher selection are not appropriate. Additionally, the teaching of chemistry by in-service teachers often inadequately achieves chemistry learning goals.

The 2015 results of PISA, a test mainly focused on science, listed Kosovo as the third country from the bottom, way below the international average, indicating once more the importance of the emerging science education reforms. The new curriculum reform of the education system in Kosovo, and of chemistry education in particular, advocates competencies that reflect the current developmental needs of the country. However, the reform demands school environment changes and chemistry teacher professional development, as well as the necessary support for quality assurance and capacity building.

A great deal of research has focused on the pre-service and in-service chemistry CK of teachers. The results indicate that their CK is limited and fragmented, and that they lack an understanding of chemistry concepts, which plays an important role in the development of chemistry education (Calik & Ayas, 2005; Cheung, 2009; De Jong, Veal, & Van Driel, 2002; Kind, 2014). This calls not only for improvements in PK and PCK, but also for greater emphasis on CK professional development, which, according to Shulman (1986), is a prerequisite for developing PCK. Studies show that PK had become dominant over CK in trying to advance educational theories, similar to pure subject research that tries to advance their theories (Shulman, 1986, 1987). However, these advances in theory should be used to reflect upon and improve the practices of the discipline through applied subject research, instead of advancing only theoretical knowledge of pedagogical practices (Bucat, 2004).

Thus far, international organisation support has focused mostly on providing general PK training, with little or no training in CK and PCK offered to in-service chemistry teachers practising chemistry in lower and upper secondary schools. It is expected that the lack of CK and PCK will diminish with the current reforms of chemistry teacher preparation programmes in Kosovo.

Prospective teachers of chemistry have enough technical content and pedagogical content courses available, and they should be able to integrate and/or separate pedagogical and content chemistry issues in the classrooms in the future. They are also expected to be skilled in articulating teaching practices in the classroom, as they do have "classroom practice teaching" training to complete throughout their studies. Furthermore, immediate measures should be taken towards the continual professional development of in-service chemistry teachers. According to an EU project report conducted by the Kosovo Education and Employment Network (KEEN, 2019), it is MEST's responsibility to prioritise professional development courses offered based on teachers' needs, not donor priorities, as has been done previously.

Chemistry education in Kosovo should focus on developing programmes for the professional development of chemistry teachers that effectively strengthen CK and PCK, and improve the quality of teaching by encouraging applied research practices. The future of chemistry education depends heavily on the improvement of chemistry teacher preparation in Kosovo, as well as on the training methods used for teacher training. The implementation of the new science curriculum, in particular the chemistry curriculum, may give rise to a number of issues, such as an appropriate classroom teaching environment, laboratory equipment for daily activities, ample textbooks, and trained teachers to implement such activities, as well as many other issues that cannot be solved quickly.

Changing the curriculum is not enough to improve and bring meaningful advancements to chemistry education (Bodner, 1992). In the past decade, intensive efforts have been undertaken with regard to pure chemistry research practices in Kosovo, but chemistry education research has been left aside. Chemistry education research is crying out for studies that test and document qualitative and quantitative data, research the CK and PCK of pre-service and in-service chemistry teachers and examine chemistry content in the classroom. Inter alia, there is a need for applied research studying how chemistry teachers practise chemistry in classrooms and how students learn chemistry.

Another dilemma is that there is no difference reflected in the way lower secondary and upper secondary subject teachers are prepared. A basic assumption is that chemistry teachers are prepared specifically and broadly for teaching chemistry, both at lower secondary and upper secondary schools. Due to the lack of research on chemistry teacher practices in Kosovo, this remains a grey area, thus creating the assumption that there is a need for a distinctive programme requiring separate specialised preparation of teachers for lower and upper secondary teaching.

An analysis of the curriculum reveals the strengths and weaknesses of existing practices of chemistry education. It also creates opportunities to find and analyse threats to future improvements. The science curriculum in lower secondary education stresses the interdisciplinary nature of teaching. This means that university level programmes should include study programmes for interdisciplinary teaching, such as STEM (Science, Technology, Engineering and Math) majors, that will further prepare teachers to teach the lower secondary integrated science curriculum. Such study programmes should consider the consecutive nature of science courses and the interrelationships between the different science courses. In particular, they should provide prospective teachers of integrated sciences with an understanding of the multiple angles of science.

Developing the abilities and competencies of future chemistry teachers and science educators will positively influence the contributions to the development of the country that science will make. The latest education system reforms in Kosovo aim to fulfil these norms with the harmonisation of the education system with most European countries. However, as the reforms to chemistry teacher preparation in Kosovo are new, their implementation having commenced only in the 2016/2017 academic year, it is too early to judge the quality of the reform.

Time for Action

In this emerging world of innovations and global warming, the current teacher preparation programmes focusing on the scientific teaching of subjects is limiting teachers' understanding and practice of interdisciplinary teaching. This is a major concern and an objection that could be raised regarding the teaching of subject courses, particularly the way chemistry is taught in Kosovar schools. If teachers have been educated in a system of subject-specific teaching, then their teaching will be the same as they have been taught. As a result, teachers often fail to conceptualise science and make it interdisciplinary. The emphasis on conceptual understanding of student learning and the relevance of science in daily lives has been discussed by several studies (De Jong, 2008; Holbrook, 2005; Mahaffy, 2004), which state that knowledge of concepts themselves, such as atomic structure or chemical bonding, tends to be emphasised more by teachers, rather than daily-life topics, such as improving air quality for our health, which is potentially a much more relevant starting point to teach. The findings are also in line with Osborne and Dillon's (2008) concerns that science curricula in Europe and other regions have failed to respond to the rapid changes to student needs. A new vision of science education issues is therefore needed immediately. Science teacher preparation, especially chemistry teacher preparation, and in-service teacher training programmes in Kosovo have to reflect upon the way chemistry is being taught in schools and respond by adapting changes to student needs.

Chemistry is not a static subject. A stunning growth of knowledge of the field has taken place, which leads to an increase in the quantity of material to be taught (Sheppard & Robbins, 2005). The current curriculum time allocated to chemistry in Kosovo has led to chemistry courses saturated with content in comparison to other natural science subject courses offered at lower and upper secondary schools. Not surprisingly, chemistry is becoming a less favoured subject among students. This dislike also limits the ability of teachers to do what they are being asked to do: to perform their principal objective of teaching future generations.

Science subject courses in Kosovo are taught as distinct, unrelated courses. As a result, a thorough analysis of the natural science curriculum in terms of content, time allocation and teaching sequence could have a huge impact on chemistry education. As indicated by Sheppard and Robbins (2005), in order to build a world-class science education system and training framework for the 21st century, one has to rethink and reconsider, not only what chemistry content is taught, but also how chemistry is taught, when it is taught and how much curriculum time is dedicated to it.

Conclusion

The present article provides an overview of the chemistry education system, as well as chemistry teacher preparation, in Kosovo over the years. It aims to draw attention to science education in general, and particularly to chemistry education, the chemistry curriculum, chemistry teacher preparation and research.

Kosovo, the newest country in Europe, faces the prospect of joining the EU, which will open all sorts of opportunities and challenges for its population. These opportunities can be tapped into and the challenges overcome only with a well-established and resourceful education system in practice. Science education, particularly chemistry education, is an important component in the development process and needs considerable attention. Moreover, science education in Kosovo should fit the modern world while at the same time meeting the demanding developmental needs of Kosovo's population. Having the youngest population in Europe, Kosovo must restore, rebuild and practise a well-organised education system. This is an important step for Kosovo's development.

With the implementation of the Bologna Process in Kosovo, it is expected that universities, the overall education system, as well as future outcomes, will harmonise with European countries. Furthermore, it is expected that science education in Kosovo will take advantage of the opportunity to enhance teaching practices and student quality outcomes, and use the reform to overcome obstacles that have been part of a long-lasting process. In order to move forward, the Kosovo education system needs to close the gap in the professional development of teachers and student achievements, and to prepare a generation of university learners prepared for university studies and the labour market.

Education reform needs to improve the quality of education that will support economic development and help address inequalities. Particular attention should be paid to avoiding courses that produce knowledge that cannot be applied to real-world problems. Special focus should be given to fostering learning through facilitating, spending less time instructing and more time listening. Chemistry teacher education programmes need to provide teachers with knowledge and experience that foster the cultural significance of science, relating it to other subjects that apply multidisciplinary approaches to studying and solving problems.

The present article could be considered as a catalyst that stimulates the research community to focus on research on the chemistry curriculum and teacher development programmes, while analysing the pre-service and in-service teacher base CK and PCK and teacher education programmes, particularly chemistry education. However, such research alone will not bring meaningful changes if chemistry instruction in the classroom does not receive attention.

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Challenges and Recommendations for Improving Chemistry Education and Teaching in the Republic of North Macedonia

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The study aims to present the development of education in North Macedonia from the country's independence to the present day, as documented in several national reports and other official documents. The focus is on development and changes in chemistry education throughout the years of primary, secondary and higher education. Particular attention is devoted to the introduction of the new curricula of natural sciences courses in primary education, which is an adapted curricula of the Cambridge International Examinations, and the use of information and communication technology in increasing the efficiency of the education system. Despite numerous reforms over the years, the country is still faced with various challenges and issues regarding chemistry teaching. Investment in education is constantly decreasing and no notable improvements in conditions for teaching chemistry are being made. Recommendations are made regarding the need for appropriately educated, qualified and motivated teaching staff, well-equipped laboratories and teaching resources, continuous professional development of teachers, mutual cooperation of all stakeholders in the educational process, and continuous support from the authorities and policy makers for gifted pupils and chemistry teachers at all levels.

Keywords: chemistry teaching, curricula, education reforms, natural sciences

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Izzivi in priporočila za izboljšanje kemijskega izobraževanja in poučevanja v Republiki Severna Makedonija

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Namen prispevka je predstaviti razvoj izobraževanja v Severni Makedoniji od osamosvojitve države do današnjega dne na podlagi številnih nacionalnih poročil in drugih uradnih dokumentov. Poudarek je na razvoju in spremembah v kemijskem izobraževanju v osnovnem, srednjem in v visokošolskem izobraževanju. Posebna pozornost je namenjena uvedbi novega učnega načrta za poučevanje naravoslovnih predmetov v osnovni šoli, ki je prilagojen učni načrt Cambridge International Examinations, in uporabi informacijsko-komunikacijske tehnologije z namenom povečanja učinkovitosti izobraževalnega sistema. Kljub številnim reformam v zadnjih letih se država še vedno spoprijema s številnimi izzivi in z vprašanji, povezanimi s poučevanjem kemije. Vlaganje v izobraževanje se nenehno zmanjšuje in ni izvedenih nobenih vidnih izboljšav v pogojih za poučevanje kemije. Oblikovana so priporočila glede na potrebe po primerno izobraženih, usposobljenih in motiviranih učiteljih, dobro opremljenih laboratorijih in virih za poučevanje, programih strokovnega izpopolnjevanja učiteljev, skupno sodelovanje vseh deležnikov v izobraževalnem procesu ter nenehno podporo avtoritet in odločevalcev za nadarjene učence in učitelje kemije na vseh ravneh.

Ključne besede: poučevanje kemije, kurikulum, reforme na področju izobraževanja, naravoslovje

Introduction

Quality education and teaching is a prerequisite for the successful formation of pupils' knowledge. Therefore, different ways of improving the quality of education and teaching are constantly sought. A number of measures are taken to improve the quality of teaching and the overall development of the educational process in schools: improvement of the curriculum (Metz, 1997), continuous professional development of teaching staff through in-service education, training and advisory work (Watson, Steele, Vozzo, & Aubusson, 2007; Wilson, 2000), introducing information technology in teaching (Ardac & Akaygun, 2004; Barbour & Reeves, 2009; Carvalho-Knighton & Keen-Rocha, 2007), improving textbooks and other literature, improving working conditions and providing teaching and learning resources and other equipment (Vosniadou, Ioannides, Dimitrakopoulou, & Papademetriou, 2001), extending the duration of regular institutional education, as well as empowering pupils and developing self-education habits (Demirdogen & Cakmakci, 2014). Certainly, the teacher has a key role in overall educational work, especially in the planning, organisation and realisation of teaching, and thus in the process of forming conceptual, quality knowledge among pupils. This can be achieved through the teacher's professional preparedness and competences (Watson et al., 2007), the application of adequate methods, forms and techniques of work, the teacher's ability to teach and transfer knowledge, as well as by encouraging interactive pupil collaboration in thinking and in understanding learning and applying the acquired knowledge to solving problems in specific situations (Tytler, 2002).

The education system in North Macedonia acknowledges the need for and importance of 21st century skills within the context of science education, in order for pupils to be adequately prepared to participate in and contribute to today's society. Science education is therefore of tremendous importance for the country.

The aim of this study is to present the development of chemistry curricula in primary (6–14 years old), secondary (15–18 years old) and higher education (18+ years old) in North Macedonia throughout the years from its independence to the present day. Particular attention is devoted to the introduction of the new curricula of *natural sciences* and *chemistry* in primary education, which is an adapted curricula of the Cambridge International Examinations (CIE). Challenges and recommendations for improving chemistry education and teaching are ascertained.

General Overview of Education in North Macedonia

North Macedonia is trying to develop and implement the measures mentioned above for improving the quality of education and teaching in schools. The education system in North Macedonia is structured through different levels depending on the age, necessities and affinities of the pupils. The first level is preschool, which is optional, while primary education lasts for nine years. There is also primary music and ballet education, as well as primary education for pupils with special educational needs. The International Baccalaureate programme has been implemented in several primary schools, as well. Secondary education includes gymnasium (grammar school), vocational education, sports gymnasium, sports academy, secondary music and ballet education, and secondary art education. All of these are four-year models, although vocational education can last two, three or four years. Since 2007, secondary education has been compulsory for every citizen under equal conditions, as determined by the Law on Secondary Education (2017). Adult education is also available. Education at university level is the highest level in the education system.

Since primary education in Macedonia remained the same for more than a decade after the country's independence, it seemed appropriate to create and implement a new concept for primary education. The main goal was to improve the content, organisation and quality of education. According to the National Programme for the Development of Education in Macedonia for 2005–2015 (Geramitčioski et al., 2004), a new concept for nine-year primary education was developed and introduced in 2007 (Concept for Nine-Year, 2007). In the development of the primary education system in Macedonia, it was deemed appropriate to learn from the Slovenian experience, in view of the latter's long tradition and experience, as well as the similar principles in the development of education shared by Macedonia and Slovenia. Many research projects have been undertaken aimed at the introduction of interactive teaching and active learning in schools, based on the experience from descriptive assessment and from the introduction of the national assessment of pupils in our country. There are compulsory and elective courses in the teaching process, which create opportunities for individualised approaches in certain courses. The compulsory courses in primary schools are from the area of language and literature, social sciences, mathematics, natural sciences, technical education, technology, information technology, arts, sport and health education. Moreover, the school has the responsibility to plan and organise additional lessons both for pupils who progress at a slower pace and for those who achieve outstanding results and have shown special skills and talents in certain courses.

During the past years, the concept for nine-year primary education has been continuously improving in various segments. Therefore, new courses and syllabi have been introduced or revised according to the needs of pupils and modern educational trends. One of the most prominent reforms is the introduction of the Cambridge International Examinations curricula for mathematics and science courses.

Secondary schools are organised as public or private schools, and the educational process is carried out according to the respective curricula and syllabi adopted by the Minister of Education and Science on the proposal of the Bureau for the Development of Education – BRO (https://www.bro.gov.mk/) and the Vocational Education and Training Centre – CSOO (http://csoo.edu.mk/), in accordance with the Law on Secondary Education. Secondary education in Macedonia underwent major changes in the period after 1980. With the introduction of the Concept for Specialised Secondary Education, gymnasium programmes were replaced with specifically tailored curricula for cultural enlightenment and natural science and mathematics disciplines. This concept was applied until 1990, when, due to extensive criticism, amendments were introduced to the Law on Secondary Education and immediate preparations started for returning the curricula and syllabi for the gymnasium, the implementation of which commenced in the 1991/92 school year.

After the break-up of Yugoslavia, a system of three- and four-year secondary vocational education and gymnasium education remained. There were three types of gymnasium education: general gymnasium, natural sciences and mathematics gymnasium, and linguistic gymnasium. In the 2001/02 school year, the gymnasium curriculum was reformed (Analysis of Gymnasium Education, 2008; Đeladini, Stojanovski, Mitrevska, & Andreevski, 2004), and it has not been changed to this day.

Since 2001, there have been three gymnasium areas: natural sciences and mathematics – combination A and combination B (combination B is chosen by pupils who plan to study at chemistry or biology-related faculties), linguistics-arts – combination A and combination B, and social-humanities – combination A and combination B. The gymnasium curriculum is structured by three types of courses: compulsory courses, optional courses and project activities. *Compulsory courses* represent the core knowledge for all pupils and are a prerequisite for providing a general education standard. The number of such courses gradually decreases from the first (10–11) to the fourth year (5–6). *Optional courses* differentiate pupils according to their orientation towards certain areas and combinations. These courses are aimed at deepening and expanding the knowledge of pupils and are represented by two or three school hours per week each, from the second to the fourth year. Obviously, each area contains two combinations of optional courses, on the basis of which each pupil is prepared for appropriate studies. *Project activities* are selected by the pupils.

Three-year vocational education was reformed in the 2000s, according to the PHARE programme (Poland and Hungary: Assistance for Restructuring their Economies), followed by reforms for certain profiles in 2013. In 2017, coordinated by the CSOO, two-year and three-year vocational education was reformed and, in 2018, four-year vocational education was also reformed. A methodology for the development of modular curricula based on competences has recently been introduced, in some cases related to labour market demands. This was initially a pilot in three vocational disciplines, but continued in the 2019/20 school year in all vocational disciplines, resulting in new chemistry curricula being prepared for certain profiles/qualifications.

A more significant reform (Ministry of Education and Science, 2018) is the introduction of the concept of dual education in secondary vocational schools, following the German model, which will hopefully enable an easier transition of pupils from the educational process to work. Dual vocational education involves greater cooperation between schools and the business sector, and includes more practice for pupils, under the mentorship of employees in companies. In this way, pupils will acquire the necessary competencies and skills to hopefully enable them to work immediately after completing their education.

It was initially planned to introduce new curricula and syllabi in 2017/18 for mathematics, biology, chemistry and physics, based on adapted curricula of the CIE, in gymnasium education and vocational three- and four-year education, as a continuation of the curricula in primary education. However, in 2017, it was decided to postpone the implementation of these programmes for secondary education (Trajkovska et al., 2019). It is believed that long-term solutions for secondary education will emerge from the Strategic Plan on Education 2018–2025 and the Action Plan (2018), on the basis of which a new concept for secondary education will be developed, educational standards will be defined, and the projected solutions will be implemented in schools.

The roots of higher education in Macedonia stretch back seven decades. In 1946, the first faculty using the Macedonian language was founded, the Faculty of Philosophy, with two departments: (1) Natural Sciences and Mathematics, and (2) Social Sciences and Humanities. In subsequent years, several more faculties emerged, so in 1949 the first Macedonian university, the Ss. Cyril and Methodius University (UKIM), was founded (Manevska & Fotinovska, 2019).

The University currently represents a functional community of 23 faculties, 5 research institutes and 12 various associate members. Its activities are stipulated by the Law on Higher Education and the Statute of the University. The UKIM develops study programmes in all scientific fields: natural sciences and mathematics, engineering sciences, medical sciences and health, biotechnical sciences, social sciences, humanities and arts. In addition to research at the faculties, research work is also carried out in independent research institutes, which form an integral part of the university.

An illustration of the UKIM today through figures is as follows: over 60,000 students from North Macedonia enrolled in undergraduate and master's studies, as well as over 700 foreign students. The number of students enrolled in undergraduate studies at the Faculty of Natural Sciences and Mathematics in the current year is 305 (48 at the Institute of Chemistry) from a total of 5,614 at the UKIM. Doctoral studies are realised within the Doctoral School (2008), with a total of 655 students. Over 3,100 teaching, research, associate and administrative staff participate in delivering the teaching and scientific process at the faculties and institutes. The University has produced around 150,000 graduated high-level professional staff (with a bachelor's degree), including 10,000 graduates with an MSc degree and around 4,000 with a PhD.

Undergraduate studies last six or eight semesters (180 or 240 ECTS points). Upon graduation, the student may be obliged to submit a graduation thesis, but not in all cases (depending on the details of the specific curriculum). Master's studies last for two or four semesters (60 or 120 ECTS points). A master's thesis is a compulsory part of completing the studies at all faculties. Doctoral studies last six semesters (180 ECTS points) and are organised by the Doctoral School, at the university level. Two generic courses and three seminars are compulsory, together with a large number of elective courses. This cycle is completed by the defence of a PhD thesis.

Chemistry Curricula in Primary Education

The focus of the primary school teaching process is the BRO approved curriculum (Table 1) and syllabi (Tables 2–4) for natural sciences courses, with a particular emphasis on chemistry (Stojanovski, Andreevski, & Spasovski, 1995). In the 2014/15 academic year, BRO introduced new curricula for *mathematics* and *natural sciences courses*, based on adapted CIE curricula. With this reform, the science course is differentiated as a separate subject from the first to third grade and, according to the curricula, the scope of natural sciences content is broader than in previous curricula. The programme is characterised by scientific investigation intended to encourage pupils to focus on problem-solving skills and to develop a scientific point of view, thus helping them to solve problems in everyday life. In this way, pupils have an opportunity to acquire broader, deeper and more significant knowledge in the field of natural sciences, as well as to develop practical skills for research. Furthermore, content domains, cognitive domains and practices in the curricula are comparable to international standards of learning, such as those set in TIMSS (Centurino & Jones, 2017).

Table 1

Curriculum overview of natural sciences courses

Course	Number of classes per week								
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Introduction to Nature and Society	2*	2*	3*						
Introduction to Nature				2*					
Introduction to Society				2*					
Introduction to the Environment	2**	3**	3**						
Nature				2**					
Science					2**				
Science and Engineering						3**			
Science (Cambridge)	2***	2***	2***	2***	2***	2***			
Biology					1*	2*	2* 2**	2* 2**	2**
Biology (Cambridge)							2***	2***	2***
Chemistry							2*	2* 2**	2**
Chemistry (Cambridge)								2***	2***
Physics							2*	3* 2**	2**
Physics (Cambridge)								2***	2***

Note. * 1994–2007 curriculum; ** 2007–2014 curriculum; *** 2014–2019 curriculum (2016–2019 – Biology, Chemistry and Physics).

Table 2

Thematic overview of 2007–2014 science-related syllabi

Introduction to the Environment		
1st grade	**2nd grade**	**3rd grade**
Me and Others My School My Home The Place Where I Live I Am Part of Nature Traffic	Me with Others Life and Work at School My Place My Home I Am Part of Nature I'm Exploring Traffic	Me with Others and Others with Me School and Knowledge Family Relationships My Birthplace Exploring Nature Environmental Features Orientation in Time and Space Traffic
Nature	**Science**	**Science and Engineering**
4th grade	**5th grade**	**6th grade**
Nature Materials and Energy in Nature Planet Earth is a Variable System The Living World in Nature Ecology	Nature and Natural Sciences Planet Earth Matter and Energy on Earth Earth's Orientation Ecology and Diversity of Wildlife	Planet Earth in Space The Earth is a Dynamic System Features of Wildlife Ecology Natural Sciences in Everyday Life

Table 3

Thematic overview of 2014–2019 science syllabi (Cambridge)

1st grade	**2nd grade**	**3rd grade**
Us What is it made of? Living and Growing Push and Pull Making Sounds Plant Cultivation	Light and Darkness Electricity Change of Materials Investigating Rocks The Universe Plants and Animals around Us	Life Processes Materials Plants that Blossom Introduction to Forces Senses Keeping Up Good Health
4th grade	**5th grade**	**6th grade**
Habitats Solid Matter, Liquids and Gases Making Circuits How do magnets work? Skeleton and Muscles Sound	Evaporation and Condensation How We See Things around Us Earth Movement Shadows The Life Cycle of Flower Plants Investigating Plant Growth	Reversible and Irreversible Changes Organs and Systems in the Human Body Conductors and Insulators Environmental Care Growing Food Chains Forces and Movement

The chemistry curricula were implemented in the 2016/17 school year for both 8th and 9th grade pupils. The learning content for chemistry (as well as for biology and physics) were reduced compared to that covered by the previous syllabi, but the number of classes for pupils' research activities was increased, thus fostering experimenting in the learning process. For this generation of nine-graders, some topics were repeated from the previous year, others were missing and few were added, as pupils were starting the programme for the first time and had studied according to another curriculum the previous year. Thus, for example, atomic structure and periodic table concepts were present both in the 8th grade syllabus of the old programme and in the 9th grade syllabus of the new programme. This step caused numerous reactions, as the curricula were adapted over a very short period of time and without discussion with stakeholders.

Table 4

Thematic overview of 2009–2019 chemistry syllabi (with the recommended number of hours)

8th grade	9th grade
Chemistry	
Chemistry as a Part of Science (10) Substances (26) Atomic Structure, the Periodic Table of Elements and Chemical Bonding (16) Oxides (5) Acids (4) Hydroxides (4) Salts (7)	Oxidation and Reduction (6) Simple Chemical Calculations (8) Metals and Non-Metals (14) Hydrocarbons (16) Organic Compounds Containing Oxygen (10) Biocompounds (14) (Additional 4 hours, where necessary)
Chemistry (Cambridge)	
States of Matter (5) Metals and Non-Metals (11) Elementary Substances, Compounds and Mixtures (16) Chemical Reactions (31) Introduction to Organic Chemistry (9)	Atomic Structure and the Periodic Table of Elements (13) Valences and Formulas (5) Rate of Reaction (14) Ionic Bonding and Balancing Chemical Equations (7) Reactivity Series (12) Making Salts (10) Exothermic and Endothermic Reactions (11)

By comparing the chemistry syllabi before and after 2016 (Table 4), it can be noticed that the old syllabus differs from that of the "Cambridge" programme, although there are certain topics in common. Thus, organic chemistry topics in the new curriculum are very limited. Only the first four representatives of the alkanes are mentioned, without going more deeply into nomenclature, isomerism and reactions. Other classes of organic compounds and bio compounds are not introduced at all. In addition, no chemistry calculations are included in the current chemistry syllabi. On the other hand, the Reactivity Series topic is present in current syllabi, thus providing a better approach to gaining preliminary knowledge about oxidation-reduction reactions. The Rate of Reaction topic, which is a novel one, correlates with the secondary education chemistry syllabus, so it eases further learning. These two topics also focus on experimenting, thus ensuring the acquisition of sound long-lasting knowledge instead of just theoretical and unessential knowledge.

Chemistry Curricula in Secondary Education

From 1991 to 2001, chemistry was taught for two school hours per week in all four years in the general and linguistic gymnasium. In the natural sciences and mathematics gymnasium, there were three school hours per week in the first and third year and two school hours per week in the second and fourth years. One school hour per week (out of a total of three) was planned for experimental work. Since 2001, chemistry teaching in gymnasium education has been carried out for two school hours per week in the first, second and third year, as a compulsory course for all areas. It is represented by three school hours per week only for the natural sciences and mathematics gymnasium area, combination B in the final year. With the reform in 2001, there are no more classes for experimental work in gymnasium education. A thematic overview of the chemistry courses in gymnasium education is given in Table 5.

Table 5
Overview of the 1991–2019 chemistry syllabus in the gymnasium (with recommended number of hours)

1991–2001	2001–2019
I	
Introduction (3) Chemical Measurements (5) Chemical Symbols, Formulae and Equations (5) Simple Chemical Calculations (5) Structure of the Atom and the Periodic Table (7) Molecules, Ions and Crystals (7) Classification of Chemical Compounds (4) Chemical Processes (10) Disperse Systems (6) Electrolytes (4) Proton Transfer Reactions (5) Oxidation-Reduction Reactions (6) Chemical Reactions and Electricity (3) Chemical Information (2)	Introduction to Chemistry (18) Structure of Matter (28) Inorganic Compounds (10) Disperse Systems (16)

1991–2001	2001–2019
II	
Introduction (1) Structure of Organic Molecules (7) Hydrocarbons (27) Haloalkanes (3) Alcohols (6) Phenols (3) Ethers (2) Aldehydes and Ketones (8) Carboxylic Acids (9) Nitro-Compounds and Amines (4) Heterocyclic Compounds (2)	Introduction to Chemistry Processes (9) Chemical Kinetics (7) Chemical Equilibrium (6) Proton Transfer Reactions (14) Oxidation-Reduction Reactions (8) Electrochemical Processes (9) Chemical Reactions in Industry (19)
III	
Structure of Matter (22) Introduction to Inorganic Chemistry (1) *s*–elements (11) *p*–elements (26) *d*–elements (10) *f*–elements (2)	Introduction to Organic Chemistry (8) Hydrocarbons (28) Organic Compounds of Oxygen and Nitrogen (30) Reactivity and Types of Organic Reactions (6)
IV	
Chemical Reactions (21) Chemistry in Us (28) Chemistry around Us (17)	Learning through Investigation (10) Biochemistry Basics (26) The Elements and their Compounds (36) Stoichiometry (21) (Additional 6 hours, where necessary)

Chemistry is studied as a compulsory and/or optional course for many educational profiles in vocational education, usually for two school hours per week, except in the chemical-technology discipline, where various chemistry courses are offered.

Chemistry Curricula in Higher Education

The "centre of chemistry events" within the university is located at the Institute of Chemistry, which is part of the Faculty of Natural Sciences and Mathematics. All fundamental chemistry courses are taught at the Institute. More specialised courses, such as Biochemistry, Spectroscopy, Radiochemistry, and Instrumental Methods in Chemistry, are also taught. There are several disciplines around which the studies are organised: Applied Chemistry, Analytical Biochemistry, Environmental Chemistry, and Educational Chemistry (see Table 6). All chemistry studies at the undergraduate level last for eight semesters. A BSc graduate in chemistry can work in industry and in various laboratories, while Graduate Professors of Chemistry (BSc) are qualified to work in all primary and secondary schools. Master's studies last two semesters and are composed of several compulsory courses (Methodology of Research, Computers in Chemistry, etc.) as well as a number of elective courses. Doctoral studies are integrated within the university's Doctoral School.

Table 6
Detailed curriculum of educational chemistry undergraduate studies

Course	Lectures	Problem-Solving	Experimental Work	ECTS Points
Semester I				
General Chemistry – A-level	4	2	3	10
Mathematics I	4	3	0	8
Psychology	2	2	0	4
Macedonian Language	2	2	0	4
Safety and Protocol in the Laboratory	2	0	2	2
Sport and Health – UKIM				2
Semester II				
Inorganic Chemistry – A-level	4	2	3	8
Mathematics II	4	3	0	8
General Physics – B-level	4	2	2	8
Pedagogy	2	2	0	4
Foreign Language - UKIM	0	4	0	2
Semester III				
Inorganic Chemistry – selected topics	3	1	3	6
Organic Chemistry I	4	1	5	10
Analytical Chemistry I – B-level	2	1	4	6
Communication Skills	2	1	0	2
History of Chemistry	2	1	0	4
Elective Course – UKIM				2
Semester IV				
Organic Chemistry II – B-level	3	1	4	8
Physical Chemistry I – B-level	3	0	3	6
Analytical Chemistry II	3	2	4	8
Chemistry in Practice	3	1	0	4
Computers in Chemistry	2	1	0	4
Semester V				
Biochemistry I – B-level	3	1	3	8
Physical Chemistry II – B-level	3	0	3	8
Instrumental Analytical Methods – B-level	3	1	3	6
Environmental Chemistry	2	0	4	6

Course	Lectures	Problem-Solving	Experimental Work	ECTS Points
Semester VI				
Physical Chemistry – selected topics	3	1	3	8
General Methods of Chemistry Teaching	3	2	2	8
Experimental Organic Chemistry	2	0	5	6
Biochemistry II	3	0	3	6
Elective Course – Chemistry				4
Semester VII				
Methods of Experimenting in Chemistry Teaching I	3	1	5	10
Special Methods of Chemistry Teaching	3	2	2	8
Modern Technologies in Chemical Education	2	2	0	4
Elective Course – Chemistry				4
Elective Course – Chemistry				4
Semester VIII				
Methods of Experimenting in Chemistry Teaching II	3	1	5	10
School Practice	2	4	0	6
Elective Course – Chemistry				4
Elective Course – UKIM				2
Graduation Thesis	0	2	6	8

Chemistry courses are of fundamental importance for other students, too. Unfortunately, at the Faculty of Technology and Metallurgy, many of the chemistry courses are taught by non-chemists. The situation is similar at the Faculty of Pharmacy. A number of other faculties (Medicine, Dentistry, Veterinary Medicine) deliver chemistry courses for students using experts without specific competencies (experts in other fields, not chemistry). It must be said that this long-term practice is contrary to the Law on Higher Education (2018), both in its present form as well as its previous guises.

In fairness, however, it should be noted that there are other faculties (the Faculty of Forestry, and the Faculty of Agricultural Sciences and Food) where chemistry courses are taught by chemists, in complete accordance with the Law. A few decades ago, a general chemistry course was taught at the Faculty of Civil Engineering. Unfortunately, no chemistry is being taught there today. This course was important, in our opinion, as it gave students at least some insight into the complex processes occurring during the preparation of concrete and similar important materials used in civil engineering.

Finally, it should be mentioned that there are five other public universities and some twenty private universities. The State University of Tetovo offers Educational Chemistry and Educational Physics studies, and both primary and secondary school teachers of chemistry and physics are educated there.

Challenges Regarding Science Teaching

North Macedonia has dealt with numerous reforms over the years, affecting all levels of education. Despite this, the country is still faced with various challenges and issues regarding education overall. There has been an awareness of the poor situation regarding equipment in natural sciences workrooms for a long time (Stojanovski et al., 1995), and the introduction of modern teaching technology in education has not been implemented systematically and is inadequately coordinated. Investment in education is constantly decreasing and no notable improvements in conditions for chemistry teaching are being made.

This is confirmed by the project "One Computer Per Pupil", which was initiated back in 2007 and is a very controversial investment. It has been criticised by the public and educators as so-called "make-up", a bad picture of reality. A lot of equipment was provided (Jašari, 2010), but it turned into a source of problems for school principals and teachers because a sizeable part of the equipment appeared to be missing. There is no official information about the exact price of this global project. Some estimates claim that the project met only 20 percent of the real needs; at least 30 percent of the educational process is supposed to be performed using computers. In short, the project was governed by the goodwill of its architects, but was not realised to the necessary extent. The problems persist.

As mentioned earlier, one of the biggest reforms was the introduction of the CIE curricula for mathematics and natural sciences courses. Regarding chemistry, the curriculum requires a well-equipped laboratory for the successful performance of inquiry-based activities, which is a positive feature of this programme. Unfortunately, the situation is ideal only on paper. In North Macedonia, the equipment in many schools is not at the desired level and not all of the experiments can be performed. Moreover, experiments usually take place in traditional classrooms and are carried out without the help of an assistant. Thus, one of the biggest problems when it comes to chemistry teaching is to equip school workrooms and laboratories (providing they exist!). This is essential for both schools and faculties. Unfortunately, pupils and students are deprived of the most beautiful and most interesting parts of chemistry, the parts that enable them to learn the most and develop their critical and creative thinking, and from which they can acquire the practical skills needed for their future life, irrespective of whether or not they choose chemistry for their future profession.

Another problem is the lack of handbooks for pupils and teachers, which are required by the CIE curricula in addition to textbooks. Together with lab equipment and competent teachers, this is the key to the programme's success. In North Macedonia, the application of this curriculum has been reduced because teachers lack appropriate settings and resources, and are forced to improvise to obtain the minimum necessary results. They are often forced to use video experiments and presentations, which can by no means replace the experiment and the teacher's spoken word.

The CIE curricula, as well as the syllabus itself, subsequently provoked many reactions, and there were doubts about their implementation, particularly with regard to the rapid changes in the curricula and the even faster introduction of new (translated) textbooks without consulting all stakeholders. The implementation of such programmes without providing serious prior analyses will unavoidably cause a decrease in the level and quality of the acquired knowledge, and will have long-lasting consequences. This is already reflected in the lack of continuity in the teaching content, as well as the omission of entire thematic units or crucial concepts (such as calculations and organic chemistry concepts). Simply mirroring foreign systems without providing the necessary preconditions for implementation is problematic and counterproductive.

As previously stated, in the first six grades, natural sciences are studied in an integrated form. Unfortunately, the education system in North Macedonia does not prepare teachers for the integrated teaching of natural sciences. In their initial education, teachers of grades 1–4 are not educated for specific teaching methods in biology, chemistry and physics. On the other hand, teachers of grades 5 and 6 are graduates of two-course (biology-chemistry) or single-course studies (biology, chemistry, physics). The fact that in-service teachers are not prepared for integrated teaching is confirmed by the teachers themselves. In an article by Spasovska (2017), the author interviews a primary school teacher, who states:

> We are not biologists, chemists, or physicists. We need to have a lot of specific knowledge to put it into practice. A two-day training certainly cannot do a lot. Neither do we have equipment and resources to deliver the material to pupils. The number of pupils is too big in the classes to do any research-like activity. (We are not Ready for Cambridge Education, para. 7)

In recent years, career advancement of teachers has been proposed, and there have been efforts to support the continuous professional development of teachers in key areas such as pupil assessment techniques. However, these efforts are not sustainable and a merit-based career system has not yet been implemented. From 2013 to 2017, a nationally standardised assessment was conducted in North Macedonia to compare grades given by teachers with pupils' results in standardised assessment, and to rank teachers in terms of objectivity in assessment, with the highest ranked to be rewarded. However, the reward system was never implemented, a lot of pressure was put on teachers, and this kind of assessment was terminated. In North Macedonia, a new national assessment is now planned. If devised well, this assessment could provide useful information to monitor pupils' results in the key stages of their education in relation to national goals.

To date, North Macedonia, via the Ministry of Education and Science (MON), has been involved in three testing cycles of the Programme for International Student Assessment (PISA) of the Organisation for Economic Cooperation and Development (OECD), in 2000, 2015 and 2018. These activities have been implemented by the State Examination Centre (http://matura.gov.mk/) and the BRO. The results of the 2000 PISA tests, which were held in 41 countries around the world, ranked Macedonia 38th, suggesting that a large percentage of pupils who have completed primary education have not achieved high levels of competence. Such results are a serious indicator of the questionable quality of teaching and highlight the need to introduce systemic changes to increase the level of literacy (Report on the Progress, 2009). At the 2015 PISA testing (OECD, 2019), 15-year-olds showed that they lag nearly four years behind peers from OECD countries. North Macedonia participated in PISA again in 2018 and the results of this assessment are due to be published in December 2019 (European Commission, 2019). The country has also participated in four cycles of TIMSS, in 1999, 2003, 2011 and 2019.

With regard to vocational education, previous reports (Report on the Progress, 2009) state that it does not fully meet the needs of the labour market and does not offer sufficient opportunities for rapid and effective training of pupils for practical occupations. For these reasons, the programmes have been reformed, starting from 2017 (Trajkovska et al., 2019).

Recommendations and Conclusions

For the continuous development of education, there is a permanent need to take measures to develop appropriate curricula, improve working conditions, provide equipment and teaching resources, increase financial support, and improve the care and maintenance of facilities and equipment, as well as other activities in schools. Without lab materials and other resources, quality teaching is not possible, and thus acquiring solid knowledge, work habits and skills becomes a delusion (Vosniadou et al., 2001). It is therefore necessary to provide an annual fund for teaching resources in natural sciences courses. It is also necessary to modernise and maintain schools and student laboratories, as well as sustaining other important activities for the smooth functioning of the teaching process. Insufficient funding and a lack of transparency in the allocation of funds results in most schools not having adequate resources to cover basic costs, let alone to invest in improving the conditions for learning and teaching (OECD, 2019).

In addition to revising curricula for individual courses, a correlation with the curricula of other courses is needed, especially those in mathematics, physics, chemistry and biology. More attention should be paid to this in future reforms. As an example, in the current programme in secondary education, pupils are required to calculate a pH value, but they have not yet learned logarithms in mathematics. When speaking of correlation, it seems important to note that, although the idea of the curriculum is to provide continuity in studying natural sciences from the 1st to the 9th grade, only biology is present in 7th grade.

As mentioned in the previous section, in-service teachers do not have adequate initial education to teach natural sciences in an integrated form. This is due to the lack of a strategic perspective and the illogical sequence of events. The new science curricula are implemented without appropriate education of the teaching staff and teacher students/future teachers, as well. Furthermore, in North Macedonia, there is an "option" for pedagogical-psychological-methodical post-qualification for graduates. Offering such education as an option reflects a failure to take into account the need for one-semester pedagogical content knowledge, which is a key competence for future teachers. This practice must end, and the criteria for teachers' employment must be accepted and adhered to. Accredited preservice studies include general methodical and psychological preparation, as well as specific methodical courses, which are especially important for the natural sciences.

In North Macedonia, the admission of students to teaching faculties is not selective, and almost all applicants for initial teacher education programmes are accepted, which means that newly enrolled candidates have a range of academic knowledge and motivation. The interest in these studies is directly affected by the status of the teaching profession in the country. Therefore, policy-makers must find a mechanism to attract and select talented and motivated candidates for the teaching profession, and to further provide them with appropriate training in initial education, so they can develop the competencies required to be an effective teacher.

When it comes to in-service teachers, taking into account the recommendations regarding evaluation and assessment in education obtained from a recent analysis (OECD, 2019), substantial and consistent support to teachers through formative assessment and professional development resources is needed, as well as initiatives to reinforce the practical implementation of these measures. For this, it is necessary to overcome the systemic obstacles that prevent teachers from using the results of assessment to adapt their teaching to the needs and interests of the pupils. The main issues in this regard are the compact and inflexible curriculum and external inspections in schools in which the assessment is aimed at verifying the extent to which schools adhere to the curriculum. This discourages schools from adapting the curriculum to the specific context. Continuous professional development of teachers, mutual cooperation of all stakeholders in the educational process, and continuous support from the authorities and policymakers are of utmost importance (Watson et al., 2007; Wilson, 2000).

Vocational education reforms are of particular importance for the development of the economy in North Macedonia, because they will help companies to recruit professional staff among pupils during their secondary education. The final goal is to educate pupils who will be ready to enter the labour market after graduation.

Another problem that needs to be resolved in the near future is the adoption of a general strategy for working with gifted pupils, ensuring their support and motivation. At this point, very little has been done in this respect. Thus, there is no support for associations that organise competitions for pupils and prepare them for International Olympiads. The MON should finally find a solution and fully fund the associations for organising competitions, as well as covering the costs for preparation and participation in International Olympiads for pupils and leaders. An attempt has been made to improve the situation for both the pupils and associations involved in working with gifted pupils in the new Law on Primary Education (2019). Time will tell whether and how these legislative changes will be implemented in practice.

In general, the introduction of educational reforms, including those that concern teaching chemistry in primary, secondary and higher education, should be a strategic process that necessarily involves analysis, clearly set goals, systematic work and the involvement of all relevant stakeholders. Stronger interconnection between all levels of education is also needed, and special attention should be paid to preservice teacher education.

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Business School Teachers' Experiences with a Student with Autism Spectrum Disorder

Jaka Vadnjal*[1] and Darinka Radoja[2]

Autism has become an increasingly relevant topic in the research of neuroscience with the objective of enabling people with this condition to become equal opportunity members of the society; this includes an exploration of the benefits of the public education system. However, the science and knowledge in this field have thus far been limited, and the results of scientific findings have been very rare. The objective of the study was to explore primarily the first experiences of higher education teachers dealing with a student with an autism spectrum disorder. The aim was to learn lessons and contribute to some new understanding of special and adapted pedagogical approaches. The methodology of the study is qualitative, using (i) a case study as an objective of the researchers, and (ii) in-depth interviews with the twelve teachers about their experience with (for them) the new demanding assignment to teach a student with an autism spectrum disorder. The case study is about three years of undergraduate studies of a student with autism spectrum disorder who, in the end, obtained a bachelor's degree in the field of business. The findings reveal that teachers generally viewed the experience as very positive and found teaching to be a challenge. For success, cooperation with experts and parents is crucial, but the education institution (of which all are stakeholders) could and should have done more. However, taking into account that the challenge is new, this study may contribute to some further development.

Keywords: autism, business school, students, teachers, programme adaptation, parents

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Izkušnje učiteljev poslovne šole s študentom z motnjo avtističnega spektra

Jaka Vadnjal in Darinka Radoja

Avtizem postaja vse pomembnejša tema raziskovanja v nevroznanosti s ciljem omogočiti ljudem s to boleznijo, da postanejo enakopravni člani skupnosti z enakimi možnostmi uživati ugodnosti javnega izobraževalnega sistema. Znanstvene raziskave na tem področju so zelo omejene in redko uporabljene v praksi. Namen študije je bil raziskati večinoma prvo izkušnjo visokošolskih učiteljev v poučevanju študenta z motnjo avtističnega spektra. Cilj članka je spoznati nekatere ključne ugotovitve in prispevati k razumevanju namenskih pedagoških pristopov. Uporabljena je bila kvalitativna raziskovalna metoda, in sicer: i) študija primera študenta kot glavni objekt raziskovanja; ii) poglobljeni intervjuji z dvanajstimi visokošolskimi učitelji o njihovih izkušnjah z za njih novo in zahtevno nalogo poučevati avtističnega študenta. Študija primera govori o triletnemu študiju študenta z motnjo avtističnega spektra, ki je na koncu diplomiral s področja poslovnih ved. Ključne ugotovitve raziskave so, da so učitelji v splošnem zadovoljni z novo izkušnjo in da jo ocenjujejo kot velik izziv. Za končni uspeh je ključno sodelovanje z drugimi strokovnjaki in s starši, vendar bi uradni izobraževalni sistem na tem področju lahko in moral storil več. Po drugi strani pa je treba priznati, da gre za nov strokovni in znanstveni izziv; upamo, da bo ta članek prispeval k njegovemu nadaljnjemu razvoju.

Ključne besede: avtizem, poslovna šola, študentje, učitelji, prilagoditev programa, starši

Introduction

Autism encompasses a spectrum of disorders, ranging from classic autism, high-functioning autism, Asperger's syndrome, and atypical autism, to other unspecific pervasive development disorders. In all cases, problems occur in three fields: social interaction, communication, and stereotypic behaviour. The cognitive status of the person with autism spectrum disorder is dependent upon the severity of the disorder. In addition, people with autism spectrum disorder tend to have more heightened senses, thus receiving many more information/stimuli from the environment than an average person does. Sensory hypersensitivity is commonly accompanied by a different sensory integration, thus making the reception of a large amount of information even more difficult, and thus the environment may become unbearable for the person with an autism spectrum disorder. To defend themselves from such disturbing influences of the environment, people with autism spectrum disorder create a 'defence mechanism' (stereotypic games) in order to help themselves 'erase' or alleviate the world and build their own, which is more comprehensive and acceptable: a world in which they have complete control over the stimuli, and which is predictable (Autism Treatment Centre Ljubljana).

Asperger's syndrome is classified as a high-functioning form of autism, lacking development disorders, yet characterised by difficulties in social interaction, communication, and a restricted range of interests that is seen in play, imagination, and behaviour. People with Asperger's syndrome are described as being more socially motivated but very sensitive. This syndrome has been commonly used as a conceptual bridge between autism and the general population (Jurišič, 2012; Klin, McPartland, & Vokmar, 2005). Asperger commented about children with autism spectrum disorder never being 'on the same wavelength' as their neurotypical peers in any group activities (Frith, 1989).

Autism is categorised under the Pervasive Developmental Disorders (PDD) category as described by the American Psychiatric Association. It is marked by deficits in reciprocal social interaction, communication (verbal and nonverbal), and a restricted repertoire of activity and interest (American Psychiatric Association, 2000). Children with autism spectrum disorder have a relatively limited prognosis and usually require special care (Attwood, 1998). The nature of autism usually requires a wide range of services (e.g., health and medical, rehabilitative, and educational). These services might require parents to interact with multiple providers, try different types of services or treatments, and dedicate their time, money, and energy (Goin-Kochel, Mackintosh, & Myers, 2009). Providing formal support for them and their parents is essential to improving children's abilities and enhancing the capabilities of parents. Once it was believed that children with autism were not able to learn anything, so they did not deserve any special attention. In the past, many adults with autism did not learn to read or count above the level of the early years of primary school, although there are some rare individuals with autism spectrum disorder who achieved a high level of education (Volkmar, Reichow, & McPartland, 2014).

The motivation for this study was the very first experience of one of the two researchers with autism spectrum disorder or, more precisely, with the organisation of pedagogical work at a small college for business studies at which a student with autism spectrum disorder enrolled for the first time. For the majority of teachers and study support staff, this was a new direction, and the challenge for the college was to react accordingly to this new professional issue. The study was conducted when the student had already passed all the exams and other formal learning obligations and was working on the preparation of his graduate thesis.

The present paper, which has the objective of both giving some theoretical background and sharing some findings of teachers has the following structure. After the introduction and theoretical background with the research questions defined, the methodology, which is qualitative, is presented. The methodology has two components: first, the case study on the student and his launch of the study; second, the research conducted among teachers. Next, some results and findings are given, and some discussion and implications are provided in the conclusion.

Theoretical background and research questions

Because autism encompasses such a wide spectrum, the symptoms tend to appear in different ways and at different ages. The symptoms most commonly show up in the second or third year, when a neurotypical child becomes progressively sociable, and starts to talk and play with their parents and peers. In contrast, children with autism spectrum disorder tend to withdraw into their own world and do not seek social contact. The parents are usually the first to notice their distinctive reactions. Autism may lead to a decline or loss of previously acquired skills, such as speaking, walking, etc. The symptoms of autism are sometimes noticed as late as in primary school (Društvo za avtizem DAN).

The symptoms of disabilities of the autism spectrum are highly heterogeneous due to the complexity of interactions among genes, brain, and behaviour throughout development (Pelphrey, Shultz, Hudac, & Vander Wyk, 2011). Differences in cognitive abilities contribute to the heterogeneity of autism while serving as a kind of predictive factor of later development result of each individual (Kuhl, Cofey-Corrina, Padden, Munson, Estes, & Dawson, 2013). A study that examined the relationship between the age of language acquisition and later functioning in children with autism spectrum disorder showed that meaningful language use by the age of five seems to be a powerful indicator of a positive outcome (Mayo, Chlebowski, Fein, & Eigsti, 2013).

Cognitive Theories on Autism Spectrum Disorder

The cognitive and social symptoms of autism may overlap and are highly interconnected. The social deficits of individuals with autism spectrum disorder may be directly related to the degree of their general cognitive functions (Richardson, 2008). The four cognitive theories dealing with the alternative cognition of autism are as follows.

The theory of 'mind-blindness' (Baron-Cohen, 1997) states that individuals with autism spectrum disorder cannot tell what others are thinking, which is the critical factor for appropriate social reasoning and communication. However, they may learn to interpret the mental states, understanding of emotions, facial expressions, and empathy very well (Howlin, Baron-Cohen, & Hadwin, 1999).

The 'executive dysfunction' theory (Hill, 2004) states that individuals with autism spectrum disorder have problems with planning, organisation, controlling attention, inhibition of impulses, updating of information, and working memory. This theory attempts to explain the repetitive stereotypic behaviour and socio-communicative difficulties in autism (White, 2012).

The 'weak central coherence' theory (Happe & Frith, 2006) is defined by problems with the perception of the whole or inability to see the big picture, the lack of an ability to process information globally. Some resemble the clinical picture of autism as submitted by Kanner and Asperger: limited interests, resistance to change, individual above-average abilities, excellent orientation memory, and obsession with details (Lawson, 2011).

'Enhanced Perceptual Functioning' (Mottron, Dawson, Soulieres, Hubert, & Burack, 2006) is the latest cognitive theory, and thus the least studied. The theory proposes that the excessive brain function, i.e., processing of different sensory and motor information act in a manner as to enable a different perception. The individuals with autism spectrum disorder are thus believed to learn in a different manner: more spontaneously and implicitly, which is not necessarily bad (e.g., a combination of narrowly focused attention and reinforced senses can yield amazing results). The theory serves to explain why some individuals with autism spectrum disorder are remarkably successful at certain tasks (Lawson, 2011).

Cognitive Functions and Autism

Information Processing and Encoding

Autism represents an obstruction that exists between the senses and the mind (Waleski, 1997 in Bryson, 2005). Thus, the incoming information may be incomplete or distorted. Different types of sensory stimuli may be unusually intense (Grandin, 1995) as to cause an excessive arousal state, in which the senses block the mind; the reception of information is thus incomplete and distorted. Excessively focused attention in autism appears to be associated with the analytical method of processing information, which enables higher performance in the tasks of reconstruction. Such an approach to the world seems to be associated with a higher propensity to sequential processing of information rather than parallel, due to the excessive orientation of attention to detail, which inhibits simultaneous processing of multiple sources of information. As a result, the information is stored in separate 'folders', rather than by their conceptual or semantic relations, which results in a high level of accuracy, but comes at the expense of lacking categorisation and generalisation (Bryson, 2005).

Emotions and Mindset

Autism is characterised by a lack of emotional expression; however, this is not equal to being indifferent to emotions. Kanner (1943) believes that people with autism experience a range of emotions, but they do not always know how to express them. In autism, the emotions are expressed atypically (e.g., flapping hands or movement). Extreme emotions may cause catatonic-like freezing in individuals with autism spectrum disorder (Wing, 2000 in Bryson, 2005). Controlling emotions by thinking is problematic due to weaker self-awareness. An individual with autism spectrum disorder has problems interrupting an important event or thought, which may become a source of obsessive attention, controlled by anxiety. Withdrawal from such emotional events is very difficult, as they cannot think of anything else (Rothbart et al., 1992 in Bryson, 2005).

Language and Communication

Individuals with autism spectrum disorder encounter delays and deficits in language acquisition, ranging from complete absence of functional communication to nearly adequate speech. About half of individuals with autism spectrum disorder never adopt functional language (Bailey et al., 1996 in

Tager-Flusberg, 2005). Parents of children with autism often report that the first sign of trouble became apparent by the absence or loss of speech at around two years of age (Kurita 1985; Lord and Paul, 1997 in Tager-Flusberg, 2005). Some children with a milder form of autism regain the ability to communicate and acquire a certain degree of functional language around the age of five, which proved to be the most predictive factor for a favourable developmental outcome of the autism spectrum (Rutter, 1970; Ventner et al., 1992 in Tager-Flusberg, 2005). Kanner (1946) first noticed that children with autism often only repeat words, phrases or sentences, as a kind of echo. This feature of autism is called echolalia and is typical in children who have very little productive speech. Currently, echolalic speech is considered to have functional value, as it enables them to preserve some sort of role in the conversation, even if they do not understand or have not mastered the skills necessary for an appropriate response.

Executive Functions and Memory

The executive functions disorders are associated with all three categories of behavioural symptoms of the autism spectrum, with impairments of reciprocal social interactions, communication, and stereotypic behaviour (Kenworthy, Black, Harrison, Rosa, & Wallace, 2009). Some of the symptoms of autism may be explained by memory deficits, for example, inappropriate comments of a person with autism spectrum disorder might be attributed to the fact that he or she cannot remember the topic of the conversation. Similarly, the repetitive movements can be explained by the inability to retrieve the memory of the previous activity. A quite probable explanation may lie in the fact that what looks like the deterioration of memory functions in persons with autism spectrum disorder could be a consequence of a different type of information processing and organisation, thus leading to poor performance on memory tests (Killiany, Moore, Rehbein, & Moss, 2005).

Peculiarities in learning with autism spectrum disorder

Bogdashina (2005) suggests that the 'triad of impairments' (social interaction, communication, and imagination), which is the main feature of autism, would be better described as qualitatively different modes of interaction, communication and information processing, which do not overlap with conventional methods. People with autism may also have other problems, such as sleeping problems, eating problems, fears and phobias, problems with motor skills, and others (Hannah, 2009). All this has a strong influence on the course of their learning. There is a strong correlation between autism and various learning difficulties. Two-thirds of people with autism have profound learning difficulties. Learning difficulties are a risk factor for the development of behavioural disorders (Dobnik-Renko, 2009). Autism has a high comorbidity with attention deficit and hyperactivity disorder (ADHD), which has a negative impact on individuals' intellectual development (McTighe, Neal, Lin Hughes, & Smith, 2013). The lack of attention often leads to difficulties in understanding longer texts and instructions.

A typical problem in autism is learning abstract concepts. The ability to learn abstract rules from specific experience is crucial for a wide range of areas, including categorisation, language and social behaviour. Individuals with autism show difficulties in learning, application and flexibility of abstract rules. This affects their ability to respond appropriately in social situations (Jones, Webb, Estes, & Dawson, 2013). Many things that people usually learn spontaneously and intuitively as social skills, people on the autism spectrum have to learn as a special subject in school. Grandin (2013) says that over the years she learned some basic emotions, often in the form of mathematical equations. She describes her social learning as 'a strictly logical process'. Some never understand such acquired social skills in their true sense, but they know how to use them effectively enough. Individuals with high-functioning autism and Asperger syndrome often develop compensatory strategies to conceal their inability to understand social situations.

Autism in the formal education system

Today, children with autism can be and are mostly included in society with adequate professional help and support. They often attend mainstream schooling with individually adjusted programmes according to their needs so that they can participate in the educational process (Dobnik Renko, 2009). Working with children with autism represents a challenge for those who are engaged with them (e.g., teachers, paraprofessionals, primary health providers and parents). The challenge emerges from

> […] the heterogeneity of students' characteristics and needs, the idiosyncratic and occasionally severe nature of the students' behavioural challenges, the dramatic increase in the prevalence of autism spectrum disorders, the strongly held and diverse opinions regarding appropriate intervention and the litigious atmosphere engendered by these opinions. (Dunlap, Iovannone, & Kincaid, 2008, p. 111)

In Slovenia, children with autism spectrum disorder are included in the mainstream schooling system as children with special needs according to the Law on the Placement of Children with Special Needs (Ministry of Education and Sport, 2011). They are addressed as children with autism spectrum disorders. They are placed in programmes with adapted implementation and additional professional assistance, adjusted programmes with lower educational standards or special educational programmes. It is possible to switch between programmes. An individualised educational programme is prepared, which details the objectives and methods of work for each child. To enable the successful inclusion of children with autism spectrum disorders, more attention should be paid to the field of socialisation, communication and functional objectives in the cognitive domain (Working Group of the Ministry of Health, 2009). It appears that inclusion does not work for children with autism spectrum disorder as it should (Harvey, 2011). In education, there is currently a trend to place all students with disabilities in mainstream education settings or so-called mainstreaming. As the number of students with autism spectrum disorders in mainstream classes is increasing, so are the challenges for educators. Due to the very nature of autism spectrum disorders, mainstreaming may result in 'exclusion' of the student if his social needs are not being met by the environment (Little, 2017).

In the past, the term 'inclusion' was used interchangeably with 'integration' to refer to the location in which a child was educated (Warnock, 2005). Today, these two concepts are distinguished based on the course of involving children with special needs in mainstream education. 'Integration' implies that a child with special needs will adapt to the environment of mainstream education with no additional support. 'Inclusion', in contrast, is not simply about where an individual is educated: it is about the quality of the support he receives. It involves the restructuring of the curriculum and classroom organisation (Barnard, Prior, & Potter, 2000).

At the beginning of the educational path, there is more focus on early intervention and special education with a team approach to educating students with autism spectrum disorder and a role for parents as equal partners in the planning for an individual child. This model promotes education in the least restrictive environment. The objective is to place students in as natural a learning environment as possible, within their home community, to the greatest extent possible. The participation of students with autism spectrum disorder in the general education environment is often called 'mainstreaming' or 'integration'. A variety of supports is provided to create a successful environment and experience for everyone involved. Careful planning and training are essential to provide the right modifications and accommodations. Supports might include a specially 'trained' classroom or one-on-one paraprofessional, altering testing environments or expectations, adapting curriculum, visual supports or adaptive equipment, etc. Educating students with autism spectrum disorder is usually an intensive undertaking, involving a team of professionals and many hours each week of different instruction and therapies to address a student's behavioural, developmental, social, and academic needs (Autism speaks, 2012).

The transition into adulthood is very hard for somebody on the autism spectrum, mostly because of the loss of structure that school provided for six hours a day as well as the loss of contact with people he saw every day for years. For individuals on the spectrum, every transition is difficult, whether transitioning from one place to another, one activity to the next, or from one major life event to another, such as from secondary school to college (Sicile-Kira & Sicile-Kira, 2012). While in the past individuals with autism spectrum disorder were considered to be unlikely to have the academic potential to pursue higher education, the landscape has dramatically altered as interventions have improved and as our understanding of the spectrum has been modified to include a broader range of behaviours and disabilities. Today, the majority of young adults identified with autism spectrum disorder intend to go to college with a goal of achieving higher-level employment and independent living (Wagner, Newman, Cameto, Levine, & Marder, 2007). Researchers have suggested that high functioning students with autism spectrum disorder will achieve optimal results in an integrated, support-based system, as opposed to separate, self-contained programmes (VanBergeijk, Klin, & Volkmar, 2008). These programmes use peer mentors or facilitators, often specifically trained fellow students majoring in social science graduate or undergraduate programmes, who can support students in an unobtrusive manner. Fellow students act as 'social navigators'. Their role is to alter the student's outsider status by introducing them to their friends.

Many individuals with autism spectrum disorder have significant academic strengths, often in the technological, mathematical, and mechanical fields (Wagner, Newman, Cameto, Levine, & Marder, 2007). Although there is a growing demand for students to enter science and technological fields, employment prospects for people with autism spectrum disorder remain poor, often because of general social deficits (Turnbull, Turnbull, Wehmeyer, & Park, 2003). A study on the participation among college students with autism spectrum disorder suggest that they had the highest science, technology, engineering, and mathematics participation rates although their college enrolment rate was the third lowest among eleven disability categories and students in the general population (Wei, Yu, Shattuck, McCracken, & Blackorby, 2013). The cost of losing the contribution of this unique population will be borne by both the individuals affected and by the rest of society. Students with autism spectrum disorder may be assisted to productive, creative adult lives or face more limited futures surviving on benefit payments. Existing programmes have demonstrated what is needed so that these students need not fail, but flourish. These programmes should be publicly funded and developed and should be considered not as a cost but as an investment for a better future for everybody.

The two research questions can, therefore, be derived from the literature review and some of the experience and subjective views of the researchers:

1. What was the level of awareness on autism among the college teachers and possible readiness to learn more in order to adapt their pedagogical activities with the student?
2. Is there any room for improved action on the side of the institution for more efficient and effective inclusion of the student with autism spectrum disorder into the teaching/learning process?

Method

The methodology of the study can be explained in two parts. The first part (called 'the case study' in section 3.1 of this paper) is the story of a student with an autism spectrum disorder diagnosis, which caused some serious challenges to the management and organisation of a business college. He enrolled with the assistance of his parents and solely on the basis of the formal administrative requirements (finished secondary school). It seems that everybody involved in the process of enrolment (i.e., parents, medical doctor(s) and school) were fully aware of all the potential risks and challenges that would arise once the student became a full part of the study process. Practically no preparations were taken, neither with the teachers, nor the administrative staff. It seemed that the biggest burden of dealing with specific learning issues and requirements of the particular student was placed on the shoulders of the teachers.

Thus, in the second part of the study (titled 'the interviews' in section 3.2 of this paper), teachers were asked about their (in most cases) first professional experience with a student with autism spectrum disorder. For the first part of this paper, the case study method was used, involving mostly a method of description combined with some secondary data (Weiss, 2010), because the study on the same student's evolvement through the first and secondary levels of the school system has previously been published. Therefore, the presented story is based on the synthesis of the description and secondary source utilisation. In the second part, teachers were interviewed regarding their experience with the student. The semi-structured interview was the method utilised on the sample of teachers, who took active pedagogical roles in the student's study process.

The case study

The story of the case study was rather simple. A male student ('Peter', a pseudonym) with the diagnosis of Asperger's syndrome enrolled at the age of 19 in the undergraduate business studies programme run by a relatively new independent business college. Known from the personal relationship of the researchers with Peter's parents, his particular case study was described before in some earlier work aiming to explore the role of the schooling system in the social development of children with autism spectrum disorder (Weiss, 2010). There are certain general legal regulations on the level of the country concerning the treatment of children and students with special needs in the education system.

These regulations, which are frequently more like directions than specific requirements, do pass a substantial level of proactive responsibility to the institutions to organise their teaching and learning processes so that children and students with disabilities are not placed into an (even) more unequal position compared to their classmates. Unfortunately, although there are quite high requirements from the government, there is little or no assistance offered. 'Autism' is a new term in the field of the discussion and planning pedagogical treatments influenced by the 'special-need' requirement in comparison to some other conditions for which there has traditionally been much more knowledge and experience (e.g., physical disabilities, deafness). Therefore, the ways of tackling these new issues faced by the schools are to a great extent left to the management of the education institutions. Very often there are severe constraints in the field of knowledge, experience, expertise, staff and, in higher education, additional limitations of academic freedom, which give teachers the right and responsibility of practically everything that is happening in the classrooms but, also regarding the workload and understanding of expected achieved competencies and learning goals.

In the letter of recommendation issued by the national education authority, which is based on Peter's medical documentation, it is stated, that 'inclusion in the education is very important for his personality development and mental health, however there is a need for methodological and time adaptations'. The specific recommendations in the letter include: (i) avoiding stressful situations like suddenly asking the student questions; (ii) assistance in providing study materials; (iii) close cooperation with his parents as mentors; (iv) short and clear instructions with repetition of those if needed; (v) more time available for written examinations and oral examinations when this is possible; and (vi) avoiding exposure to classmates when this is possible and, some others, which are in compliance with listed above. Peter started attending classes, but only the teachers were notified that they had 'a different guy' in the classroom.

Peter's classmates were not prepared for this (for them) new situation, and very soon a couple of conflict situations evolved. Some students started to make jokes triggered by some of Peter's unusual behaviour mostly expressed with extreme politeness to other people, verbalised in highly artistic phrases that are not common (even archaic) in everyday conversations; moreover, they sometimes were accompanied some explicit facial gesticulations. Only a couple of weeks after the start of the study year, a workshop was organised by the college management and was run by Peter's specialist doctor. Teachers and classmates were invited to have Peter's special condition explained by an expert and discussed. Most probably, for the majority of the workshop participants, this was their first formalised contact with autism.

From what is described, it is very obvious that the requirements of Peter's enrolment were heavily underestimated by all stakeholders: the parents, the doctor, and the school management. The reasons for this may be multilayered. On the one hand, one cannot blame the school for lack of experience in the field. Similarly, the doctor should have given some professional input before the process was started, but it seems that this was limited to administrative and legislative details. On the other hand, the parents are not to be expected to reduce their wish to do the best for their child. In the end, it all seems the situation was to a great extent delegated to teachers who, one by one, tackled the situation according to their best professional judgement.

The interviews

Sixteen teachers were invited to give an interview regarding the proposed issue on working with the student. Eleven teachers who taught the student agreed to participate in the study and to provide feedback through interviews. Additionally, a teacher who was not actively teaching but was intensively involved with the approach to this new challenge for the academic staff was willing to provide insights from his side. There were five other teachers involved in teaching the student. One of them rejected an interview because she thought that the topic was too personal to be researched in this way and argued this point with the fact that they had a similar issue in her extended family. One teacher retired after teaching the student and replied: 'I have nothing to do with this issue anymore.' Two teachers repeatedly ignored emails with the request for interviews. Derived from the personal acquaintance with both teachers there is a strong belief that because of certain personal reasons (in one case, a conflict between the teacher and Peter's father in the role of his mentor) they did not feel comfortable participating in the study.

Table 1
Some demographics on study participants

Teacher	Gender	Age	Own Children	Discipline taught: Soft/ Hard	Number of hours taught	Additional hours spent	Educational background Social/Technical
T1	Male	57	3	Soft	150	30	Social
T2	Male	54	1	Soft	96	10	Social
T3	Male	52	0	Soft	60	5	Social
T4	Female	32	0	Hard	60		Technical
T5	Male	56	2	Hard	35	3	Technical
T6	Female	33	0	Soft	40	3	Social
T7	Female	55	2	Hard	150		Social
T8	Male	54	2	Soft	30		Social
T9	Male	57	3	Soft	60		Social
T10	Female	43	1	Hard	150	15	Social
T11	Male	39	0	Hard	60	20	Social
T12	Male	49	3	Hard	0	30	Social

Some demographics on the study participants are presented in Table 1. Four women and eight men gave interviews. This is somewhat comparable to the gender ratio of people teaching at the college. Regarding age, two women were in their thirties, one woman in her forties, and remainder in their fifties. The two youngest women did not yet have children and, additionally, two men were without children. The taught disciplines were robustly differentiated as (i) hard ones, which are more based on numbers (i.e., economics, statistics, accounting, finance) and (ii) soft ones, which are more essayistic or narrative (i.e., management, entrepreneurship, marketing, human resource management). Six teachers came from the hard side of business studies, and the remaining six from the soft side.

Regarding educational background, two teachers were from a technical background while the rest mostly had different level degrees in business-related fields. The lowest level of formal education was a master's degree while seven study participants held doctoral degrees. All the study participants have the length of their teaching experience in correlation with their age, and nobody had less than five years of teaching experience. The number of hours they taught Peter was very different, ranging from 30 (one teacher did not teach at all) up to 150 hours. The reason for this is that different courses consisted of different numbers of contact hours in the classroom and some teachers were teaching more than one course. In total, Peter had to pass 22 exams, and he wrote and successfully defended his thesis.

The majority of the interviews were conducted in written form (questions sent through email) with some later clarifications by phone or at the meeting when this was necessary in a couple of cases in which, surprisingly, study participants were not comfortable providing written answers. The period of conducting the interviews was late 2014, but no findings were revealed before Peter successfully graduated in the same period. Total confidentiality was promised to study participants with the objective of personal data and opinion protection. However, from the demographics displayed in Table 1, there is a slight chance that someone who knew the situation and people involved in the research well could make a good guess who the study participants were. However, no personal opinions are revealed in the study. Additionally, there is a certain time difference between the study and the date of possible publication. Therefore, it is believed that anonymity is entirely assured.

Results

There were in total twenty questions asked to participants of the study. It turned out that two questions were asked too directly to evaluate some personal abilities of the student, which probably led to a certain reluctance on the side of teachers to frankly and openly respond to these questions. For this reason, the analyses of these two questions were omitted from the study, leaving eighteen questions for the further discussions. The summary and some quantifications of responses are displayed in Table 2.

Nine teachers were informed about Peter's special learning needs from the college's management before the lectures started. This was more a brief note rather than in the form of clear instructions and directions for the upcoming work and interactions with the student. Furthermore, some formal notice including a copy of Peter's medical report was sent to all the teachers just before they started their classes. The first workshop with the expert (doctor) was only organised after a couple of weeks of the ongoing lectures and after the evolution of some communication problems with Peter and his parents in the role of his mentors had already started. Also, some conflict situations arouse in the relation between Peter and some other fellow students who found Peter's unusual behaviour childish and sometimes even mocking to other people. Other students began to mock him back. In the opinion of the majority of the teachers, the college should have done much more to prepare teachers for this issue, for them mostly new professional challenge. They were missing more detailed and specific directions, and some of them even expressed doubt how appropriate this level of formal studies was for somebody with a medical condition like Peter's. Only three teachers felt that the college had performed adequately.

In the case of Peter, the majority of teachers encountered autism for the first time in their pedagogical careers. One person had never heard about this mental health issue before. Half of the teachers did some research on their own, using the internet, books, discussing experiences with colleagues and even by getting some opinions and advice from external experts. The majority of teachers never discussed Peter's issues with his classmates (with one exception) because they thought there was no need for this. The majority of teachers thought that the classmates accepted Peter very well after some initial hesitation and prejudices. The meeting with the expert was found to be very useful. Some students even tried to assist Peter while others, according to some observation from teachers, were avoiding interfering with him.

There were only three teachers who claimed that they felt no need to make any particular adaptations to their courses. In the majority of other courses, there were some modifications introduced for Peter: oral instead of written examinations, different design and form of the same exam questions (larger font, every question on separate page and no tricky word games), additional explanations and consultations regarding the content, more repeating and more time for examination. The majority of problems occurred in communication, the ability of explanation, linking different pieces of content and cooperation with parents. Other students generally did not mind the slightly different approach for Peter. The majority of teachers cooperated with Peter more intensively in comparison to other students. The majority of teachers evaluated Peter's progress to be comparable to that of other students.

Table 2
Quantified responses to questions

Question	Answers summary
Where and how were you acquainted with Peter's special needs?	Ten out of twelve received information from the institution.
Have you heard about this handicap before? Where and how did you get additional information?	Eight teachers heard and two were a little familiar with the issue. Half of them searched for some additional knowledge.
Did you discuss Peter's situation with other students?	Generally, without exception.
Were there any special adaptations of your course needed? How were those adaptations understood by other students?	Three teachers did not need to make any changes. Other made adaptations according to recommendations. Other students did not mind those course adaptations.
How did, in your opinion, other students accept Peter?	Generally, very well with some drawbacks and some avoidance of any contact.
Did Peter rely for help mostly on classmates, teachers, or somebody else?	In most cases, teachers felt that Peter mostly relied on his parents for the help.
What kind of behaviour particularities did you notice and how did you encounter those?	Majority of teachers reported typical autism behaviour characteristics.
Who did you address when you encountered problems in communications with Peter?	Majority of teachers who followed the expert's instructions had no problem.
To what extent did you cooperate with Peter's parents.	Majority of teachers cooperated with Peter's father.
To what extent did you individually cooperate with Peter?	Majority of teachers cooperated with Peter much more than they cooperated with other students.
How would you evaluate Peter's progress?	Majority of teachers thought that Peter's progress was comparable to other students.
Do you think you are adequately professionally trained for work with students with this type of special needs?	Majority of teachers responded negatively to this question.
In what area did you experience most problems in your work with Peter?	Communication, explanation, linking different pieces of content and communication with parents.
How would you describe your experience in teaching Peter? Did you learn anything?	Half of teachers evaluated the experience as a positive one and learned something. Others are more indifferent.
To what extent will experience with Peter be useful for your future work?	Majority of teachers felt that this teaching experience would be useful.

Generally, the teachers did not report any particular problems encountered in doing their jobs with Peter. The assistance of the doctor was very useful, and so was the communication and cooperation with the parents. Some teachers mentioned some useful discussions with the student's office, dean, other colleagues, and the parents. For some teachers, the cooperation with parents was somewhat ambiguous. This communication was most intense before examinations, and some teachers reported feeling some unpleasant pressures from the side of parents, and there were even a couple of minor conflicts reported that were later resolved with some mediation from the side of the college's dean.

Although teachers generally agreed that there were no major problems with Peter, they mostly felt that they were not adequately trained to work with students with an autism spectrum disorder. For the majority of them, this was their first experience in which they had to include the reality of the disorder in their curricula. More information and clearer instructions would have been very useful. There were a couple of individuals who felt more confident than their colleagues regarding their competences to work with Peter. These were mostly teachers with some previous experience in working with people with special needs. In one case, more openness for the issue was, as expected, demonstrated by a teacher with an educational background in psychology. Seven teachers expressed that this particular experience would enrich and enhance their views of their pedagogical work in the future while the other seven skipped answering this question.

The quite detailed data on study participants were given in an attempt to indicate some pattern of opinions with the connection to certain demographic characteristics. After several trials using qualitative cluster methods, no patterns (or clusters) were identified based on age, having children, the discipline taught, or the number of taught and spent hours. The two possible patterns are that (1) female teachers tend to be more empathetic towards the student and that, (2) teachers with social science educational backgrounds had more understanding of the student's health condition.

To address directly the second research question, teachers' answers reveal several opportunities to improve further activities on the level of the institution for further improvement of the teaching/learning process. It is believed that these suggestions for improvement may be generalised to other higher education institutions with possible similar challenges in the future. First, teachers should be informed well in advance about the presence of students with special needs in the study process. Classroom activities may have to be adapted accordingly. The learning progress of a particular student may have to be different from the mainstream for other students, as well as the examination process. Second, a training meeting with direct suggestions on the possible special methods should be organised for all teaching staff with the goal of preparing the participants for possible unfamiliar situations. Third, different forms of consultation should be provided to teachers during the courses to assist them in making often difficult decisions about study process adaptations. Fourth and finally, one of the members of the teaching staff should be appointed to direct and facilitate the communication among all the stakeholders on this very specific topic.

Conclusions and implications

The field of autism remains a somewhat grey area. Most probably, the reason lies in the fact that until recently autism was a very rare disorder, and not many researchers showed interest in it. However, the sudden and unexplainable dramatic increase in the occurrence of autism in recent years has stirred interest in the media and professional circles. The short history of autism has seen a significant turnaround: from interpreting this disorder with psychogenic theories, to claiming that autism is caused by an error in the operation of certain biological processes. The adoption of empirical research methodology in order to explain the problems in the field of mental health has allowed for such changes in theories (Schopler, 1994). However, the neurobiological bases of changes in cognition in relation to autism are still not well understood. The ultimate objective is a complete characterisation of the origin and extent of changes in all areas of behaviour, including the processing of language, social skills, and all aspects of cognitive functions (Killiany, Moore, Rehbein, & Moss, 2005).

There has also been significant progress regarding the inclusion of people with autism spectrum disorder into the formal education system, taking into account the necessary adaptations in teaching methods, pedagogical aids, and examination. Although there has been some evidence on the inclusion of children with autism spectrum disorder into primary schools, less has been said about their involvement in secondary programmes and very little, apart from some anecdotal evidence, about people with autism spectrum disorder studying at the higher education level.

Therefore, this study aims to be among the first contributions in the unexplored field of people with autism spectrum disorder studying on a higher educational level, at universities or colleges. Due to the academic freedom and independence paradigm, the work on this educational level is almost entirely left in the hands of teachers. Thus, the approaches in the cases of special needs students are essentially left to their own judgment, which cannot be based on anything else but their very limited experience in working with, in our case, students with autism spectrum disorders. No practical experience of any formal training on working with students with autism spectrum disorder has been found in the scientific literature thus far.

The main finding of this study can be summarised as follows. There is absolutely no need or excuse for any fear about not being able to deal with very often not understandable issues that accompany the diagnosis of autism. There is an urge for very strong connections between the different internal stakeholders (students, teachers, parents, university management) and the external expertise providers. The body of knowledge on pedagogical best practices needs to be developed and constantly upgraded in order to develop a flexible, but still sustainable pedagogical model. This would leave enough space for both prerequisites that need to be taken into account before somebody is awarded a degree and specific academic feature that remain essential to higher education. Thus, it should be strongly encouraged that every new case and experience is carefully studied and examined. The objective of doing so is the creation of best practices and constant improvements for everybody involved in professional work with people with autism spectrum disorders. It is about helping the people with autism spectrum disorders to reveal all their hidden potentials and to assist their parents and families, who very often devote their entire lives to being able to understand this life, still full of secrets.

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Advancing the Scholarship of Teaching and Learning using Learning Theories and Reflectivity

Lester Brian Shawa[1]

The Scholarship of Teaching and Learning (SoTL) remains a mostly elusive notion. For universities to genuinely contribute to SoTL, they must delineate clear parameters of engagement. For example, while some engage SoTL at the academic level, others examine it from an institutional policy perspective. Others view it from national and international frameworks that impact teaching and learning in universities. Engaging SoTL at the academic level, this article uses a postgraduate diploma module, Higher Education Context and Policy (mostly attended by university academics from South African universities) to show how a facilitator could draw from learning theories and reflectivity to teach and advance SoTL. More specifically, it demonstrates how a facilitator could mediate the module utilising a social constructivist learning theory perspective.

Keywords: scholarship of teaching and learning, postgraduate diploma in higher education, learning theories, reflectivity, social constructivist learning theory

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Spodbujanje dodelitev štipendij za poučevanje in učenje z učnimi teorijami in refleksivnostjo

Lester Brian Shawa

Štipendija za poučevanje in učenje (SoTL) večinoma ostaja nedorečen pojem. Univerze morajo jasno opredeliti parametre delovanja, če želijo resnično prispevati k SoTL. Nekatere ustanove sodelujejo pri SoTL na akademski ravni, druge jo preučujejo z vidika institucionalne politike, tretje pa jo obravnavajo z vidika nacionalnih in mednarodnih okvirov, ki vplivajo na poučevanje in učenje na univerzah. Za prikaz dodelitve SoTL na akademski ravni so v članku uporabljeni: modul diplome na podiplomskem študiju, Kontekst in politika visokošolskega izobraževanja (večinoma so se ga udeležili univerzitetni akademiki z južnoafriških univerz) in način, na katerega bi spodbujevalec poučeval in spodbujal dodelitev SoTL na osnovi učnih teorij in refleksivnosti. Prav tako članek podrobno opisuje, na kak način lahko spodbujevalec posreduje modul ob uporabi socialno-konstruktivistične teorije učenja.

Ključne besede: štipendija za poučevanje in učenje, diploma na podiplomskem študiju, teorije učenja, reflektivnost, socialno-konstruktivistična teorija učenja

Introduction

While much attention has been paid to the notion of the Scholarship of Teaching and Learning (SoTL) since its first use by Boyer in his 1990 publication, *Scholarship Reconsidered: Priorities for the Professoriate*, the meaning of this term remains elusive, and it is used differently by different scholars. For example, some perceive SoTL as the work of academics in their pedagogical and research activities with their students, others as institutional policies that support activities such as staff development and promotion, and still others as the national and international frameworks that impact a university's scholarship (Fanghanel, Pritchard, Potter, & Wisker, 2016).

This article engages with the understanding of SoTL as the work of academics in their pedagogical work with their students. While much has been written on academics and their engagement with teaching (see, Flint, 2016; Hằng, Bulte, & Pilot, 2017), few studies share how academics could draw on both learning theories and reflectivity to advance SoTL. This article, therefore, uses a postgraduate diploma in a higher education module, Higher Education Context and Policy, to show how a facilitator could draw on both learning theories and reflectivity in mediating a university module while advancing SoTL. More specifically, it demonstrates how a facilitator could mediate the module by utilising the social constructivist learning theory and reflectivity.

One of the significant problems associated with university academics is a lack of the pedagogical training that is necessary for the mediation of subject content as expertise in subject matter does not necessarily mean that an academic can teach effectively. The combined use of learning theories and reflectivity could provide academics that have limited pedagogical knowledge with fundamental resources to deepen their contribution to SoTL. While universities worldwide have introduced short staff development programmes or induction courses that contribute to developing SoTL in Higher Education (HE) (see Reddy et al., 2016; Remmik et al., 2011; Subbaye & Dhunpath, 2016), these are not usually sufficient to have an impact. There is thus a need for continuous learning of the 'art and science' of teaching and learning in order to improve academics' praxis (theory and practice merged). The postgraduate diploma in a higher education programme discussed in this article is designed to stimulate a continuous reflective, critical, and innovative spirit among university academics in the field of HE to make a sustained contribution to SoTL.

This article thus adds to conceptualisations of SoTL by arguing that both learning theories and reflectivity should be employed in advancing it and that experiences need to be shared. A reflective understanding of SoTL that draws on learning theories advances the notion that academics need to use learning theories in their teaching, to reflect on what they do, and to share their experiences. Leibowitz and Bozalek (2016, p. 110) contend that 'SoTL is distinguished from other forms of higher educational development in that it involves a degree of reflection, research or scholarship which is usually achieved in the process of academics researching their own teaching and learning contexts'. This article is in line with such a concern.

The article is presented in seven sections. The first is the introduction while the second section briefly explains learning theories and elaborates on the social constructivist learning theory that provides the article's theoretical point of view. The third section briefly examines reflectivity in teaching and learning while the fourth discusses the elusive nature of SoTL and argues for the need to use learning theories and reflectivity in enhancing SoTL. The fifth section describes the postgraduate diploma in higher education programme – the Higher Education Context and Policy module – and the pedagogical activities as well as the nature of assessment for the module, all of which are framed within the social constructivist view. The sixth section applies the social constructivist learning theory's view to the mediation of the module and draws conclusions on how a facilitator could use this view and reflectivity to advance SoTL. Finally, the seventh section presents the article's conclusions.

Learning theories

This section briefly examines the major learning theories (behaviourist, cognitive, constructivist, and social constructivist) from which facilitators could draw their pedagogical knowledge in advancing SoTL. Learning theories in HE help immensely in guiding and developing academics' pedagogical knowledge (Fry et al., 2009; Kay & Kibble, 2016; Shunk, 2012; Taylor & Hamdy, 2013).

Behavioural learning theories came to the fore after the publication of Watson's *Psychology as the Behaviourist Views It* in 1913 (Schunk, 2012). Proponents of the behaviourist learning perspective, such as Pavlov (1849-1936), Watson (1979-1958), and Skinner (1904-1990) argue that learning is manifested by a change in behaviour (Peel, 2005). They argue that the environment is critical in stimulating student responses and that the primary role of the teacher is to introduce such stimuli and reinforce student responses (Schunk, 2012). In this approach, behavioural objectives are fundamental, and academics employing such an approach need to pay sufficient attention to the way they reinforce student behaviours.

Cognitive learning theorists are concerned with how the mind operates to store and remember knowledge acquired from the environment (Schumm & Bogner, 2016). They posit that learning is a mental activity and, as such, teaching methods should focus on understanding how students learn cognitively. In his social cognitive theory, Bandura (1998) expounded the view that people not only use cognition in learning, but learn from others in a social setting. He referred to this as 'observational learning', which is made up of four components: attention – 'what people observe from modelling influences and what they retain'; retention – the 'active process of transforming and restructuring the information conveyed by modelled events […]'; behavioural production – 'translating symbolic actions into an appropriate course of action'; and motivation – whether or not one is incentivised to exhibit an acquired behaviour. Cognitive theories thus show that, while the environment is important as claimed by the behaviourists, learning chiefly depends on how students use the mind to engage with their own learning. In enhancing SoTL, academics drawing on cognitivism thus need to seriously reflect on how they assist students in harnessing cognition in learning.

In contrast to the behaviourists and cognitivists, constructivists take a different ontological stance that sees reality not as a "given" but as constructed. In providing an example of advancing SoTL based on learning theories and reflectivity, this article draws on the social constructivist theoretical point of view.

The social constructivist learning theory point of view

The social constructivist view is mainly associated with Vygotsky (1886-1934), who viewed reality as socially constructed. He argued that learning is a social process that is useful in developing cognition (Shunk, 2012; Subban, 2006). Viewed this way, learning is a process of enculturation or appropriation, in which learners gradually internalise the knowledge and skills learnt through social interaction (Kay & Kibble, 2016). Subban (2006) states that this view of teaching and learning regards the social context as vital in the development of higher order functions in learners.

Vygotsky (1978) posited that learning occurs at the interaction of two related aspects: the interpsychological (interpersonal) and the intrapsychological (internal), with the former a necessary condition for the latter. This means that an external experience (at the external level) is internalised by the learner into an intrapersonal experience. Thus, for Vygotsky, learning started at the social level.

John-Steiner and Mahn (1996) argue that semiotic mediation is the key to fostering the connection between the social level and the individual in

Vygotsky's social constructivist learning theory. Vygotsky himself listed a number of examples of semiotics. Kay and Kibble (2016) state that semiotics can include a range of factors, such as cultural tools, language, symbols, calendars, processes, art, maps, writing, writing tools, technology, and machinery. For Vygotsky, semiotics enables human beings to understand or master nature and, in so doing, they begin to master or know themselves (John-Steiner & Mahn, 1996). Thus, semiotic mediation is powerful in the learning process as it assists the learner's mind in internalising the external into the internal in a process Vygotsky termed 'appropriation' (John-Steiner & Mahn, 1996; Kay & Kibble, 2016).

Vygotsky introduced the notion of the Zone of Proximal Development (ZPD) to the learning process to explain the knowledge attained by learners within the social context. He defined it as the 'distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978). This suggests that the learner has the potential to learn more from an adult or knowledgeable other. As such, teaching entails purposeful instruction that allows the learner to achieve his/her ZPD in an on-going process (Subban, 2006). Although not directly introduced by Vygotsky, this process has been referred to as 'scaffolding' (Shunk, 2012). Paying attention to the ZPD is very useful in enhancing SoTL as it enables academics to understand the level of knowledge students bring to a course, to design appropriate learning activities, and to enhance their reflectivity. It should be noted that while the concept of ZPD is applied to university learning, Vygotsky applied his understanding to children (Fani & Ghaemi, 2011).

In summary, the social constructivist perspective posits that reality is socially constructed and that the social context is vital for higher order learning; learning involves a process of appropriation or enculturation of the external into the internal; semiotic mediation is vital; teaching requires an understanding of learners' ZPD, and that scaffolding is important in enhancing learners' ZPD. As a result, particular teaching and learning methods are preferred. Academics are thus called on to adopt particular methods and strategies in their classrooms. Among others, these include working in teams (to facilitate social learning), attention to diversity in engaging with participants (to facilitate learning from different perspectives), understanding students' prior knowledge (to promote appropriation and the ZPD) and reflecting on experiences (to facilitate one's construction of reality). This theoretical point of view guides the analysis of how the module under consideration could be mediated.

Reflectivity in teaching and learning

For Schön (1983, 1987), reflectivity or reflective practice occurs in two ways: reflection-in-action and reflection-on-action. The former refers to the thinking that academics employ to deal with unexpected situations in the classroom in order to improve the learning experience while involved in actual teaching, while the latter involves reflecting on what happened in the classroom so as to improve practice in the future. Thus, reflectivity happens both at the time of teaching and in reflection on lessons that have been delivered (Shannon & Fells, 2016; Tajik, 2016).

At both levels, reflectivity goes beyond mere thinking and involves an inherent quest to find solutions. It thus necessarily involves a sound understanding of what is being taught, what will be taught, or what has been taught in order to enhance future engagements (Scanlan & Chernomas, 1997). Reflectivity calls for academics to be self-aware and confident in engaging with their teaching so as to be critical of their activities (Quin & Vorster, 2015).

A SoTL that is framed within an understanding of learning theories and reflectivity means that academics draw on learning theories to improve their pedagogical practices, while reflectivity helps them to critically engage with how these practices could be effective and improved for future engagement.

Conceptualising SoTL

In advancing SoTL, academics, policy-makers, university administrators and other stakeholders should pay careful attention to its conceptualisation in order to delineate the parameters of engagement. This section demonstrates the contested nature of SoTL and clarifies the understanding of SoTL proposed in this article.

Boyer (1990, 1996) espoused four interrelated meanings of scholarship: as discovery, as integration, as application, and as teaching. The scholarship of discovery encompasses the university's role in contributing to human knowledge through research, while that of integration demands an interdisciplinary praxis (Boyer, 1996). The scholarship of application calls for reflective praxis, 'moving from theory to practice and from practice back to theory' (Boyer, 1996, p. 17) and, finally, the scholarship of teaching projects the desired impact on others; as Boyer posits, 'the work of the professor becomes consequential only as it is understood by the other' (Boyer, 1990). Scholars note that Boyer's meanings of scholarship are interrelated, with each contributing to the others (Glassick, 2000).

However, Boyer's concepts have not gone unchallenged (see Boshier, 2009; Glasssick, 2000). For example, the difference between scholarly teaching and the scholarship of teaching was not clearly delineated by Boyer, as remains the case. Nonetheless, he provided a locus of intellectual debates surrounding the term SoTL that remain ubiquitous. Many authors have sought to elaborate on the 'ambiguous' terms. In seeking to differentiate between good teaching, scholarly teaching, and SoTL, McKinney (2003), cited by Maurer (2016), argued that good teaching is that which enables students to learn. In contrast, scholarly teaching uses evidence on the teaching-learning connection and SoTL as the production and dissemination of new evidence about teaching and learning, in peer-reviewed fora from which other teachers may learn.

McKinney (2006, p. 39) further conceived SoTL as a 'systematic study of teaching and/or learning and the public sharing and review of such work through presentation, performance or publications'. Earlier, Shulman contributed to the debate by positing that for work to qualify as SoTL, it must be public, available for peer review, and critiqued according to accepted standards and be able to be reproduced and built on by other scholars (Glassick, 2000).

Commenting on the elusiveness of SoTL, Boshier (2009) contends that it is problematic in five senses. The first is that it is used as a synonym for other activities, such as the notion of scholarly teaching. According to him, such usage is problematic in that the scholarship of teaching does not mean the same as scholarly teaching. Secondly, he argues that the definitions provided by Boyer remain conceptually confused. Third, he posits that SoTL is difficult to operationalise. Fourth, Boshier argues that much discourse concerning SoTL is anti-intellectual and located in a narrow form of neoliberalism. In this regard, he points to a very relevant issue that hinges on a culture of measuring teaching and learning. A case in point is the lack of clarity in the measurement of how academics achieve the aspects of SoTL espoused by Boyer in their teaching. Finally, Boshier states that uncritical dependence on peer review to measure scholarship means that if a piece of work does not pass peer review, it lacks scholarship. All these critiques underline the need to delineate carefully the parameters within which to engage with SoTL.

More recently, scholars have analysed SoTL as applied at the institutional level (see Boose & Hutchings, 2016; Vithal, 2018; Timmermans & Ellis, 2016) and how it contributes to a community of scholars (Boose & Hutchings, 2016).

Reacting to the limited, evidence-based conceptualisation of SoTL, Kreber (2013) posits:

> […] knowing what strategies to use in particular situations to enhance students' learning is an important aspect of the scholarship of teaching,

> yet deciding what to do in particular situations cannot be based exclusively on evidence yielded on studies on what works. (Kreber, 2013, p. 860)

In framing an understanding of SoTL in this article, it is argued that, as stated by Kreber, rigid adherence to evidence-based teaching or 'what works' could limit the reflectivity required to interrogate one's own practice. It is in the spirit of reflectivity that this article shares at a personal level how a facilitator could mediate a module by drawing on learning theories. The article was also motivated by Huber and Hutchings's suggestion in the 2005 Carnegie report on SoTL cited by Kreber and Kanuka (2006) that one important aspect of SoTL hinges on small-scale efforts to reflect on one's classroom teaching and share what is learned. As noted earlier, Leibowitz and Bozalek (2016) also highlight the importance of reflection and scholarship premised on academics researching their own teaching and learning contexts.

Given that one of the ultimate objectives of SoTL is to enhance the student learning experience, excellent knowledge of subject matter is not sufficient: academics also require pedagogical knowledge (Kreber & Kanuka, 2006). This entails an understanding of teaching and learning as praxis, one that could be enhanced by understanding learning theories and their application. The following sections turn to the programme and the course.

The postgraduate diploma in the higher education programme

The postgraduate diploma in higher education is an honours-level equivalent programme offered in the School of Education of the College of Humanities at the University of KwaZulu-Natal. The courses towards the programme are run by a unit in HE, a directorate under the Deputy Vice-Chancellor: Teaching and Learning Portfolio that plays multiple roles in implementing university-wide staff development programmes, conducting institutional research and promoting the field of HE as an area of scholarship. Students register for eight modules pegged at 16 credits each. This programme attracts academics in different disciplines in universities, most of whom have no prior training in the field of education.

The programme aims to contribute to the professional development of HE practitioners with a focus on teaching and learning. By the end of the programme, participants are expected to:

- demonstrate critical awareness of the local current HE contexts and policies, with particular emphasis on teaching and learning,

- access and critically review local and international literature pertinent to teaching and learning,
- explain and critique their own practices in relation to teaching and learning in HE,
- plan innovative practices to promote professionalism in teaching and learning,
- demonstrate competent and ethical practices to enhance teaching and learning in the institution.

In line with the expectations of the university, the programme aims to contribute to the strategic goal of promoting excellence in teaching and learning and to the vision of the university, which is to advance African Scholarship, interpreted in the following ways:

- Local literature, policies, and resources are sourced and prioritised.
- In assignments and class interaction, participants are required to integrate their knowledge and experience of the local context with local and global HE theories and literature.
- The participants are diverse in terms of disciplinary background, personal characteristics such as race and age, and the nature and length of their experiences in HE. Such diversity is valued and used constructively in the programmes' teaching and learning activities.
- Priority is given to collaborative and critical reflection among the programme participants on their knowledge, experiences, and values.

The programme has three core modules: Higher Education Context and Policy; Practice, Reflection and Portfolio Development in Higher Education; and Research in Higher Education. Participants are offered the following six electives: Designing and Evaluating Curricula in Higher Education; Teaching and Learning in Higher Education, Assessing Learning in Higher Education; Supervising Research in Higher Education; Diversity and the Student in Higher Education; and Technology for Higher Education Pedagogy.

The Higher Education Context and Policy module

The Higher Education Context and Policy module was selected because the author has more knowledge of its pedagogical underpinnings. The module is a 16-credit-bearing one, which focuses on broad issues in HE and introduces participants to a range of trends, debates, and policies that affect the sector, both internationally and nationally. It enables the achievement of the programme's first learning outcome – *to demonstrate a critical awareness of the local current*

HE contexts and policies, with particular emphasis on teaching and learning.

More importantly, the module invites participants to reflect on their everyday practices as HE practitioners. At the end of the module, participants are expected to:

- articulate diverse views of the purposes and values of HE,
- describe and critically engage with trends in HE,
- relate the impact of trends, debates, and policies to teaching and learning in HE in South Africa,
- critically engage with the HE policy context in South Africa,
- reflect critically on their professional practice in relation to the HE context in South Africa.

Facilitation of the module

The module is usually presented under five broad topics:

- Topic 1 conceptualises HE policy praxis;
- Topic 2 examines the roles/purposes/values and functions of HE;
- Topic 3 discusses the global issues and trends in HE;
- Topic 4 examines these issues and trends from a South African perspective;
- Topic 5 critically engages with transformation in South Africa and the policy context.

The discussions continuously feed into the teaching and learning focus of the programme.

Pedagogical approach of the module

The postgraduate module template for the Higher Education Context and Policy module vividly captures the pedagogical philosophy of the module:

> The pedagogical approach underpinning the teaching in this module is one of active learning. The students, who are practitioners in the Higher Education sector, are viewed as "participants" in the learning process. They are believed to develop understanding through integrating existing knowledge and beliefs with new knowledge and experience. This is viewed as a developmental process. Participants are invited to share their experiences, to reflect on and interrogate their current practice, and juxtapose this with alternate practices and theories. The module teacher, thus, assumes a role as facilitator, charged with eliciting and respecting participants' existing understandings, modelling various pedagogic

> approaches and ensuring access to learning resources. In these ways, participants in the module are encouraged to participate actively, to develop critical reflexivity and to work collaboratively. (O'Brien, 2013, p. 3)

This approach shapes the activities and assessments.

The nature of pedagogical activities

Pedagogical activities for the module are carefully designed based on the social constructivist view and include group work, individual write-ups, guest speakers, oral presentations, case studies, and oral and written assessments. For example, in conceptualising policy praxis (Topic 1), participants are asked to interrogate their understanding of policy and their practice in HE and are provided with readings to broaden their understanding. They work in heterogeneous groups to share their understanding of the concepts, make oral presentations and interrogate what a policy praxis might mean for South Africa. The facilitator then asks participants to submit brief individual write-ups that further probe their general understanding and practice in the sector. This assists content planning and mediation especially in identifying guest speakers who offer presentations on the South African HE context, providing participants with opportunities for further critique and engagement.

In presenting Topic 2: The role/purpose/values and functions of HE, participants are provided with pre-readings that hinge on the functions of higher education. They prepare presentations in heterogeneous groups on the functions of HE as presented in the literature. Later, they consider the South African context given the challenges of access and social injustice that are part of the apartheid legacy and reflect on how these could be challenged through a policy landscape. As practitioners, they share their experiences and plans to contribute to resolving these challenges as agents of change through their teaching and general practice in the sector.

In facilitating the topic on global trends, participants are given prescribed readings that they engage with prior to class. They employ a case study approach to examine the trends that have impacted a particular region or country. For example, participants might want to look at the impact of the Bologna process, neoliberalism, internationalisation, decolonisation, Africanisation, globalisation, transformation, modularisation, and funding on a specific region or country. In this way, they begin to see the connection between the global and the local. Participants are encouraged to critically engage with such discourses and begin to find their own informed voices.

In Topic 4, participants are required to engage with the trends in HE, drawing on their own experiences in South Africa. This requires reflective activities in which they share with the whole class how they experience the impact of trends in their universities, how these affect (or might affect) teaching and learning in the sector, and how they could mitigate some of the negative aspects in their spaces.

Transformation is very topical in South Africa. While this topic starts with conceptualisations of transformation in general and in South Africa, participants are invited to explain their own understanding of transformation and how they have experienced it in their institutions. They read and discuss a range of policies such as White Paper 3: A programme for the Transformation of Higher Education (1997), the National Plan for Higher Education (1997), the Transformation and Restructuring: A new Institutional Landscape for Higher Education document (2002), the Higher Education Qualifications sub-Framework (A sub-framework of the National Qualifications framework) (2013), the White Paper for Post-School Education and Training: Building an expanded, effective and integrated post-school system (2013) and some institutional policies from South African universities. This helps the participants to situate government policy within HE policy discourses and allows for critique.

The facilitator takes time to clarify, brings to the fore prevailing contradictions, and allows genuine critiques to prevail. Participants respond by constructing their views from an informed social constructivist learning perspective.

The nature of assessment for the module

The module is assessed using three assignments: an oral presentation or a short written assignment (20%), a mid-length written assignment (30%), and a comprehensive article (50%). Cumulatively, the assignments aim to assist participants to reflect on teaching and learning by drawing on their own practice to explain the policy landscape; critiquing articles relating to policy and change; discussing how the South African HE policy landscape responds to global as well as local trends; and examining how transformation in South Africa is presented in policy documents and what this might mean in their everyday practice.

Application of the social constructivist view and reflectivity

This section explains how the facilitator employs the social constructivist view in the module's pedagogical activities and the nature of the assessments and reflectivity to enhance SoTL. The mediation of the module adheres to the many assumptions propounded by Vygotsky's social constructivist learning theory.

Mediation of the social constructivist view

In interrogating their own experiences and practice in HE, the participants can reflect on such experiences and develop cognition. In this way, they tap into the external or the social level influences to elucidate their individual actions. For Vygotsky, this is the interaction between the interpsychological (interpersonal) and the intrapsychological (internal) – learning viewed as starting from social interaction.

The write-ups that participants provide to the facilitator inform the way the facilitator re-organises lessons and the selection of special guests or presenters. In other words, the write-ups help the facilitator to determine the participants' ZPD level. Thus, assessment of write-ups and group presentations enable participants to learn from knowledgeable adults – the facilitator as well as the guest speakers, a process referred to as scaffolding.

Using heterogeneous groups enables participants to learn from varied viewpoints. Group work and presentations promote interaction that facilitates a social learning environment that contributes to participants' understanding of the content and enables them to critique their assumptions. This indicates the importance of the social context for higher order learning as espoused by Vygotsky.

Case study approaches are useful in enabling the participants to learn from what is happening elsewhere and compare this with their own experiences. This assists their construction of knowledge that helps them to critique their own situation and improve their practice. Here participants tap into semiotic mediation and improve their appropriation of knowledge.

Sharing with the whole class is an excellent way of assisting the participants to learn to substantiate their arguments and learn to listen and be attentive to others' opinions. This facilitates learning together, in which the facilitator and the participants are involved in learning and re-learning. It offers an excellent social context that Vygotsky regards as vital to higher order learning.

Reading and critiquing policies enable the participants to actualise the semiotic mediation that is necessary for appropriation. They learn to construct their own voices to help improve their praxis. This is also achieved when critiquing journal articles on policy praxis.

The assignments are crucial as they help the facilitator to assess participants' ZPD so as to scaffold their learning. Furthermore, they help participants to construct their views and learn to substantiate them. For example, a comprehensive article allows them to draw on what they have learnt from their social context: others' experiences, policies, and their own experience and practice and thus form an informed view of the praxis. This exercise helps the participants to fully develop their critical mind and contribute to debates within the field.

Reflectivity on the application of the social constructivist view

As argued by Schön (1983, 1987), the facilitator for this module draws on both reflection-in-action and reflection-on-action in enhancing learning experiences and contributing to SoTL.

Drawing on the social constructivist view, the facilitator's reflectivity concerns how the participants interrogate their experiences in HE; the quality of their write-ups in showing evidence of learning; the benefit of working with heterogeneous groups; the way they utilise case studies in understanding the field; the way they read policies and actualise semiotic mediation, and the way they engage with assignments.

The facilitator asks critical and probing questions such as: In what way did I utilise Vygotsky's view that learning ought to start from social interaction? How did I determine the participants' ZPD through their presentation and assessments to facilitate learning? How did I help the participants to actualise the semiotic mediation that is necessary for learning? In general, how did I help the participants to construct their own arguments within the field? Each question is approached with an openness to critique oneself to improve one's practice.

Depending on the circumstances, these questions may apply to one level of reflection or to both reflection-in-action and reflection-on-action. The questions aim to assist the facilitator in rethinking how to improve the planning, design, and execution of the learning experiences by drawing on the social constructivist learning view and reflectivity.

Numerous studies demonstrate how the social constructivist view helps to improve classroom experiences. Flint (2016) shows how a social constructivist approach assisted students in improving their learning and facilitators in exploring future course designs based on student feedback and instructor experience in diverse learning environments. Hsueh and Lan (2015) used a social constructivist approach to web-based English as a Foreign Language (EFL) learning and found that collaborators performed better than individuals in terms of vocabulary gain. Similarly, Hằng, Bulte, and Pilot (2017) show how a social constructivist approach helped them to improve the curriculum as teachers became more open-minded, friendly, equitable, engaging, and collaborative.

Conclusion

Amidst contested conceptualisations of the notion of SoTL, this article engaged the view that concerns the pedagogical activities of academics, advancing a view that draws on learning theories and reflectivity for academics to reflect on what they do and to share their experiences. It used a postgraduate diploma in a higher education module, Higher Education Context and Policy, to show how a facilitator could draw on learning theories and reflectivity in mediating learning, thereby contributing to SoTL. More specifically, the article has shown how a facilitator could use the social constructivist learning theory advanced by Vygotsky to facilitate learning in contributing to SoTL. The social constructivist theoretical view helped to explain the facilitation of the module, its pedagogical approach, and the nature of pedagogical activities as well as assessment. Finally, the article presented the probing questions that a facilitator needs to ask of themselves in relation to the social constructivist theory in order to achieve reflectivity that could facilitate improved learning.

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Biographical note

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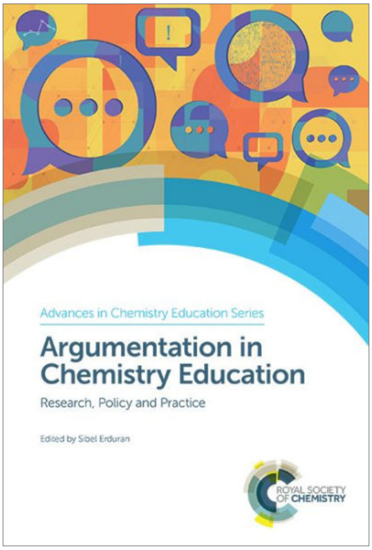
Reviewed by Lilith Rüschenpöhler[1]

Johnstone's triangle and the role of arguments in the chemistry class



Multilevel thinking is an essential feature of talking about chemistry. When chemists and chemistry teachers talk to each other about chemistry, they switch from a description of observed phenomena (macroscopic level) to explanations on the molecular level (submicroscopic level) and merge this with symbolic representations in the language of chemical equations and the 'alphabet' of the periodic table of elements (symbolic level). This complexity challenges both teachers and learners of chemistry, as Johnstone (1991) pointed out almost 30 years ago. Students have to make sense of communication in chemistry, in which the three aforementioned levels are often difficult to distinguish. Furthermore, for constructing their own arguments in the chemistry class, they have to build connections between the different levels of communication in chemistry. Chemistry teachers, on the other hand, need to guide their students in these processes: in the development of an understanding of these levels and in the students' construction of scientifically sound arguments from the perspective of chemistry.

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The book *Argumentation in Chemistry Education*, edited by Sibel Erduran, is positioned in this context. Erduran points out that building connections between the different levels of the triangle (macroscopic, symbolic, submicroscopic; see Johnstone) requires arguments. Chemistry teachers can show an observable phenomenon and present an explanation for it on the symbolic or the submicroscopic level, but the connections between the two levels are made with arguments, as Erduran argues in the first chapter of the book. This is the framework in which Erduran's book provides insights into one of the central aspects of chemistry education: argumentation. Chemistry education seeks to empower students to construct chemical arguments and to provide evidence for the claims they make, instead of merely believing the teacher. This is a highly complex issue in the chemistry class.

A combination of theoretical perspectives and concrete teaching resources

The book *Argumentation in Chemistry Education* approaches the topic with an interesting mixture of articles about argumentation in the chemistry class. It contains chapters that present the theory of argumentation in chemistry education, providing an overview of the field today. This is done, for instance, in a literature review by Aydeniz covering advances in research about argumentation in chemistry education (Chapter 2). In addition, insights into the integration of argumentation in pre- and in-service teacher training are presented by Zembal-Zaul and Vaishampayan (Chapter 7). However, the book's great strength is its strong focus on application to chemistry teaching practice. Chapter 6, by Ng, constitutes a bridge between theory and practice. The author presents an analysis of the place of argumentation skills in the school curricula of the UK and Australia. In an exemplary fashion, she shows the divide between curricula that demand the teaching of argumentation skills in the chemistry class and the assessment of such skills, which remains only partially resolved. Rather than measuring argumentation skills, assessment tools often measure factual knowledge, and thus lag behind the demands of the curricula. For chemistry teachers and teacher educators, this shows the place of argumentation in education policy.

The most interesting chapters for teachers are probably those that provide practical resources. Many chapters contain a box with a 'practical digest'. Here, the authors show the impact of their research on teaching practice in chemistry, in some cases using concrete examples with teaching material. Moreover, Cullinane and O'Dwyer (Chapter 4) give an overview of teaching approaches that can support teaching argumentation in school, for instance, evidence-based reasoning. They review established tools, such as concept cartoons or frameworks that support students linguistically in the construction of arguments. Henderson and Osborne (Chapter 5) concentrate on the potential of online applications in teaching argumentation. In both chapters, teachers find a multitude of very helpful references to concrete teaching material, in some cases as open educational resources that can be easily accessed. Hofstein, Katevitch and Mamlok-Naaman (Chapter 8) propose inquiry-based learning as a means to develop students' argumentation skills in laboratory work. Christodolou and Grace (Chapter 9) expand the notion of argumentation from scientific reasoning to the more comprehensive way of reasoning that is necessary in socio-scientific argumentation. Integrating ethical, socioeconomic and scientific reasoning in nuanced argumentation is a task that differs from the basic model of linking the macroscopic, submicroscopic and symbolic levels. The authors show that argumentation in the chemistry class can reach beyond chemistry itself, an argument underlying Chapter 3 by Crujeiras-Pérez and Jiménez-Aleixandre about interdisciplinarity, as well.

Research about argumentation in concrete contexts is presented in Chapters 10–12. Pabuccu (Chapter 10) shows how argumentation tasks can lead to conceptual learning in organic chemistry, instead of simply memorising reaction mechanisms, as is very common in organic chemistry in higher education. Concrete examples of teaching practice in higher education, accompanied by a report on the experiences gained by the author using them, make this chapter very useful for teacher educators. Chapter 11, by Towns, Cole, Moon and Stanford, covers argumentation in physical chemistry. It is more research-focused than Chapter 10 and presents a method for analysing argumentation in chemistry classrooms in higher education. It is, therefore, more interesting for researchers working in the field of argumentation, and less germane for chemistry teachers and teacher educators. Chapter 11 shifts the focus to the socioeconomic and socio-cultural context in which argumentation occurs in chemistry education. The authors, Msimanga and Mudadigwa, present the results of research conducted in South African classrooms. In this context, many students learn chemistry in English despite speaking other languages at home. Integrating other languages is crucial for the students to develop arguments in chemistry.

A valuable resource for teacher educators

The book covers a broad range of perspectives on argumentation in chemistry education. Different groups of science educators can profit from this wealth: some chapters are interesting mostly from a chemistry education research perspective (e.g., Chapters 2 and 11), while others are very application-focused and could therefore be interesting for chemistry teachers, as well (e.g., Chapters 4, 5 and 8). The audience for other chapters could be researchers in chemistry who would like to improve their courses in organic chemistry at the university level (Chapter 10). This diversity in the collection of articles constitutes an honest account of what has been achieved and what still needs to be done in the field of argumentation in chemistry education. The book therefore provides a high-quality overview of the research field.

Chemistry teachers could, of course, learn from the book via self-study. However, working with the chapters in a group of chemistry teachers, possibly under the supervision of a chemistry teacher educator, could increase the learning output even more. Since the book is based on educational resources from the English-speaking world, application of the material is easy only for teachers working in English-speaking countries or in bilingual chemistry classes. These teachers will certainly profit from the open educational resources and the teaching material referenced or included in the book, which they will be able use in their chemistry classes. For those chemistry teachers who teach in other languages, however, the application is not as straightforward, as the material would need to be translated. Working in a group of teachers could facilitate the process of translation and ensure that the intended content is captured. Moreover, the teaching material can probably unfold its full potential if teachers know the theoretical basis of argumentation (which is provided in the book), and if they have the craft knowledge of putting the theory into practice. Working in a group of chemistry educators could be a great opportunity for developing this craft knowledge, as this setting allows for discussions about adequate applications of the theory to the design of practical teaching material and sequences. In the sense of continuous professional development, chemistry teachers could benefit greatly from the resources presented in Erduran's book.

Chemistry teacher educators could profit from the book, as well. For those who already teach argumentation in classes for pre- and in-service teachers, the book provides knowledge about the latest advances on the topic and can be used to stay up to date in the field. On the other hand, for those who have not yet taught argumentation to chemistry teachers and who wish to introduce the topic into their teaching, the book can serve as a basis for the construction of a specific course for pre- and in-service teachers. It is interesting in this context because it unites theoretical, practical and policy-oriented perspectives on argumentation in chemistry education.

Using Erduran's book, teacher educators could, for instance, (i) first cover some fundamental knowledge about the status of argumentation in the chemistry class. This can be done to sensitise teachers to the challenges posed by argumentation in chemistry education, especially if Johnstone's concept is covered in the course, as well. In the next step, (ii) teacher educators could, together with chemistry teachers, analyse the place that local policy allocates to argumentation in the school curricula. In the last phase, (iii) the teachers could be guided in the development of concrete teaching materials that help students in the acquisition of argumentation skills. Existing material that can be found in the book or its references could be adapted, as well. This third phase is crucial for the development of the teachers' craft knowledge about argumentation in chemistry. Here, discussions with the other teachers in the course, as well as supervision by the teacher educator, will be necessary in order to introduce the theory into teaching practice in chemistry education in local school settings. Erduran's book represents an excellent resource for designing this type of course.

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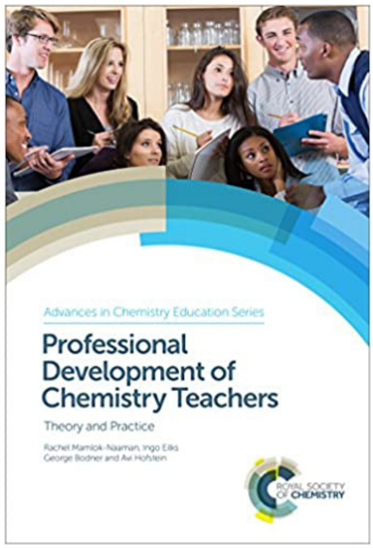
Rachel Mamlok-Naaman, Ingo Eilks, George Bogner and Avi Hofstein: *Professional Development of Chemistry Teachers – Theory and Practice*, Royal Society of Chemistry: Croydon (UK), 2018, 203 pp.: ISBN: 9781782627067

Reviewed by Silvija Markic[1]



In recent years, the focus in science education research in general, and chemistry education research in particular, has shifted from students to teachers. This is reasonable, since teachers are the key factor for changes in the classroom. Thus, the professional development of teachers in general and chemistry teachers in particular is an essential element, if not the key element, for effective and improved chemistry teaching and learning. As written on the cover of the present book, "Professional development aims to keep chemistry teaching up-to-date and to make it more meaningful, more educationally effective, and better aligned to current requirements".

The authors of the book have extensive experience working as science/chemistry teachers in school, but all four of them are also successful chemistry education researchers who have been working on the topic of professional development for a long time in their careers.

First, it must be said that this book is not a collection of different chapters written by different scholars and edited by the four persons named in the tittle of this review. The four authors wrote the book based on their own experience and research, while also undertaking a thorough international literature review.

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In general, the book presents different models and examples of professional development for chemistry teachers that stem from different countries, and thus from different cultures and education systems. Furthermore, the authors present both theory and practice, focusing on current issues in modern chemistry education. When talking to chemistry teachers about their professional development, they usually mention the obstacles involved. In this book, the authors also focus on issues that can have a negative impact on successful professional development, providing ideas and advice on how to manage these issues.

The authors begin with an explanation of the need for the book. The first chapter is called *Introduction – Issues Related to the Professional Development of Chemistry Teachers.* In this part, different fields of chemistry teaching are presented, as well as approaches to the preservice education of chemistry teachers. From here, the consequences for continuous professional development are drawn.

The second chapter, *Understanding the Cognitive and Affective Aspects of Chemistry Teachers' Learning and Professional Development*, presents the theory of this topic. The chapter is based on studies on teachers' knowledge, skills, attitudes and beliefs, starting from the three professional knowledge domains: pedagogical knowledge (PK), content knowledge (CK) and pedagogical content knowledge (PCK). The domains of professional growth (personal, practical, external and domain of consequences) are also discussed.

Each of the subsequent chapters has a similar structure. First, the theory related to each approach is discussed, followed by two examples from different countries.

The third chapter is entitled *Top-Down Approaches for Chemistry Teachers' In-Service Professional Development – From Basic to Advanced.* It presents different sources of information resources for chemistry teachers, such as traditional media, online courses and workshops. Challenges and resources for professional development from the point of view of the USA are presented, as well as a top-down, long-term approach in three cases from Israel.

The following chapter focuses on *Cases of Bottom-up Professional Development for Chemistry Teachers.* The idea is to encourage chemistry teachers to develop ownership of curriculum innovation. After presenting the theory, the practice is illustrated by the example of the PROFILES project and teachers' professional learning communities.

The fifth chapter discusses *Action Research as a Philosophy for Chemistry Teachers' Professional Development and Emancipation.* The examples report on action research work in Israel, and on twenty years of a curriculum development project by a group of chemistry teachers in Germany, based on the participatory action research model.

Starting with the following chapter, Mamlok-Naaman, Eilks, Bodner and Hofstein focus on modern issues and topics concerning the professional development of chemistry teachers.

The next chapter (Chapter 6) is based on theory regarding *Teacher Professional Development for Society, Sustainability, and Relevant Chemistry Education.* The authors present the roots of society-oriented secondary chemistry education and discuss three dimensions of relevant science education. Issues related to the "chemistry for all" approach are discussed, and the importance of including social views on chemistry teaching and teacher education are presented. An example of a lesson unit on sustainable development is described.

Chemistry teaching and learning is not possible without a laboratory and practical work. Chapter 7, *Professional Development of Chemistry Teachers to Teach Effectively in the Chemistry Laboratory*, focuses on and discusses this topic. The authors present certain skills that chemistry teachers need to possess in order to teach chemistry effectively in laboratory settings. One of the foci is the development of inquiry-type high-order learning and thinking skills. In the last part of the chapter, the authors present an example of professional development of teachers to teach in the inquiry chemistry laboratory.

Chapter 8 is about the *Continuous Professional Development of Chemistry Teachers to Incorporate Information and Communication Technology* in their teaching. The chapter first reflects on the influence of modern ICT on chemistry teaching and learning, drawing implications for chemistry teacher education and professional development.

The penultimate chapter (Chapter 9) gives advice on *How to Educate Chemistry Teachers to Become Leaders.* A programme aimed at the long-term development of teachers is presented. The authors give guidance on how to prepare chemistry teachers to become educational leaders.

The last chapter (Chapter 10) summarises the general ideas of the book and points out further directions on the topic of the professional development of chemistry teachers. In addition, for "quick readers", the authors provide a summary after each chapter.

The book is intended for researchers and educators, to help them better understand the teachers' role in good and effective chemistry teaching. Although I agree with this, I would like to add that I see the value – and also importance – of this book for chemistry teachers, as well. While reading this book, I think teachers will be able to understand and reflect on the importance of their work and its influence on students, and thus on our future generations. Furthermore, it can be informative for chemistry teachers to see the different models of professional development, which most of them are probably unfamiliar with. As well as providing a good overview, it offers teachers an opportunity to choose a suitable model for themselves. Thus, I would highly recommend that chemistry teachers, too, read this book.

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