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Secondary-school chemistry textbooks in the 19th century

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Abstract: The teaching of chemistry in Serbia as a separate subject dates from 1874. The first secondary-school chemistry textbooks appeared in the second half of the 19th century. The aim of this study was to gain insight, by analysing two secondary-school chemistry textbooks, written by Sima Lozanić (1895) and Mita Petrović (1892), into the amount of scientific knowledge from the sphere of chemistry was presented to secondary school students in Serbia in the second half of the 19th century, and the principles textbooks written at the time were based on. Within the framework of the conducted research, we defined the criteria for assessing the quality of secondary-school chemistry textbooks were defined in the context of the time they were written. The most important difference found between the two textbooks under analysis pertained to the way in which their contents were organised. Sima Lozanić's textbook is characterised by a greater degree of systematicness when it comes to the manner of presenting its contents and consistency of approach throughout the book. In both textbooks, the authors' attempts to link chemistry-related subjects to everyday life, and to indicate the practical significance of various substances and their toxicity can be perceived.

Keywords: chemistry teaching; chemistry textbook; structural components of textbooks; textbook quality.

INTRODUCTION

Textbooks are representative samples of the time in which they were written, for they reflect the trends and principles that existed in a particular area of education.[1] In a way, the books are built into the generations of students after which they were taught, for it is through them that a certain way of thinking, a strategy of learning, general intellectual skills and habits, ones attitude towards that which is being learnt, towards science and knowledge in general are cultivated.[2] A review and analysis of various chemistry textbooks from their beginnings to the

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present day affords insight into the development of ideas about chemistry and the intellectual achievements of many generations of students in the realm of this science.[3] A textbook reflects the characteristics of the context that it was created in, as well as the academic knowledge and beliefs of its author(s), reflecting their views of what science is or what it should be.[4] It may be viewed as a conversation between chemistry as a scientific discipline, the context for teaching/learning, the author's personal characteristics and the burden that each society imposes upon one.[5] Textbook writers are confined to the margins of scientific communities, they share various cultures and they are under strong social, economic, and political pressures.[6] Moreover, textbooks are read and used by a great variety of audiences with different aims, expectations and reading practices. Scientific textbooks are, therefore, at the crossroad between disciplines such as the of science, the history of education and the history of books and reading.[7] By analysing textbooks that were used in the past, one can form a picture of the quality of teaching at that time can be formed. Insight can be gained into the relationship between science and education, into how fast scientific knowledge was built, into the process of education and the extent to which they represented a response to the needs of society at the time. It could be said that textbooks are sorts of archaeological traces of former regimes of knowledge.[6] Textbooks can be viewed as focal points for many of the historical contingencies that shape not only scientific practice, but also the roles of science and scientists in society. Although most easily treated as part of the history of the book, they also carry historical significances that transcend that genre.[8]

Textbooks turned into an independent and characteristic genre of scientific publication in the 19th century when science education became compulsory in a number of European universities as well as in primary and secondary education. A reason for the rise of the textbook was its instrumentality in the development of the national structures of education, in particular, the nineteenth-century implementation of secondary education.[9]

The teaching of chemistry as an independent subject in secondary schools in Serbia dates back to 1874.[10] Prior to that, chemistry was studied within the framework of physics and mineralogy. It was taught in the fourth grade, four classes per week. In the guidelines sent to teachers in 1874, it is stated that inorganic and organic chemistry with experiments should be taught. Of the four classes per week, one had to be dedicated to conducting experiments, which is indicative of the significance attached to experimental work in the course of teaching chemistry.

By analysing two secondary-school chemistry textbooks written by Sima Lozanić (1895) and Mita Petrović (1892), the aim of this study was to gain insight into the amount of scientific knowledge from the sphere of chemistry

presented to young people in Serbia in the second half of the 19th century, and into principles on which textbooks written at the time were based.

Sima Lozanić (1847–1935) was a chemist, scientist, Professor, Chairman of the Academy of Sciences, the first Rector of Belgrade University, Ambassador to London, Minister of the Economy and Minister of Foreign Affairs, a diplomat. In the mid-1880's, at the time of a reform and modernisation of grammar schools, Lozanić worked on compiling a modern chemistry curriculum and introducing teaching through experiments in secondary schools.[11] Apart from chemistry, Sima Lozanić also studied pedagogy (1868–1870) at the well-known school of pedagogy in Küsnacht near Zurich. At Zurich University, Lozanić studied chemistry under Johannes Wislicenus (1835–1902), and subsequently spent one year at the August Wilhelm von Hofmann's (1818–1892) laboratory for organic chemistry.[12]

For many years, Mita Petrović (1848–1891) worked at the Serbian Teacher-training School in Sombor, where he taught mathematics and natural sciences. He had organized and equipped a chemical laboratory in Sombor where he did research in the sphere of natural sciences, especially physics and chemistry. He also wrote a large number of textbooks on all subjects he taught. These were mainly based on contemporary German language textbooks which Petrović translated and adjusted to the level and needs of his students. He was a correspondent member of the Serbian Academy of Science, and member of numerous other learned societies. Mita Petrović received many accolades for his work.[13]

The rules on writing secondary-school textbooks in Serbia were passed in 1895. A commission was formed the task of which was to establish whether suitable textbooks existed for all the subjects taught at school. In March 1895, the commission informed the Board of Education that there was no suitable chemistry textbook for the fourth grade of grammar school. Within one year, Lozanić wrote a textbook and submitted it for publication in March 1896 (although on the cover 1895 remained as the year of publication). In March 1896, Lozanić sent the textbook to the Minster of Education and to the Board of Education for review. The reviewer Marko Leko submitted a negative review, containing 36 objections, of the textbook to the Board.[14]

The Board of Education, which was composed of secondary school teachers who opposed Lozanić's terminology, decided not to accept Lozanić's book as an official textbook. It was in vain that Lozanić tried to respond to the criticisms addressed to him.[15–19] Through the Board of Education, the polemic between him and Leko continued throughout 1897, until *The Ed ucational Gazette* announced that the editorial board would accept no further correspondence pertaining to the said polemic. Lozanić's textbook was only recommended for use in secondary schools at the beginning of the 20th century. Until then, Mita Petrović's textbook was used.[11]

THE METHODOLOGY OF THE RESEARCH

The textbook sample analysed within the framework of this research was the first edition of Sima Lozanić's textbook *Chemistry for Secondary Schools*, dating from 1895, and the third edition of Mita Petrović's textbook *Chemistry for Secondary Schools, based on Prokop Prohaszka and Others*, dating from 1892. Sima Lozanić's textbook had a total of five editions (1895, 1897, 1903, 1910, and 1925). For the purpose of this analysis, the first edition was chosen in view of the above-mentioned criticism, which reflects the context in which the textbook was created.

Mita Petrović's textbook, despite the fact that it was not in accordance with the curriculum dating from 1881, was used in schools with the permission of the Ministry of Education until the beginning of the 20th century, even after the publication of Sima Lozanić's textbook.[12] The first edition of this textbook came out in 1883, but herein, the third edition, dating from 1892, was analysed as the preceding two editions were not available.

In order to achieve the set goal, first a methodology for analysing and evaluating the quality of these textbooks within the context of the period when they were created required development.

Some characteristics of a textbook can be quantified, whereas others require a qualitative analysis. The main purpose of the qualitative approach is to understand and interpret various meanings that the textbook being analysed carries, following which the elements of the meanings are established.[20] The present analysis of the selected secondary-school chemistry textbooks dating from the 19th century was supposed to provide answers to the following questions:

1. What contents were presented in the chemistry textbooks from the second half of the 19th century?
2. To what extent were the contents presented in the examined textbooks in keeping with the then current level of knowledge in chemistry?
3. What experiments are presented and described in the textbooks?
4. To what extent did the textbooks analysed establish a connection between the textbook contents and everyday life?
5. To what extent does the textbook caution the students to take care when dealing with certain substances?
6. To what extent were the contents of the textbooks in keeping with the chemistry curriculum then in effect?
7. To what extent did the textbooks deal with events from the history of chemistry?
8. How were the analysed textbooks supported in terms of graphic design and illustrations?
9. What were the structural and organisational components of the analysed textbooks?
10. How were the contents of the textbooks shaped in terms of didactics?

The chemistry-related contents of the analysed textbooks were followed through the following: the themes, the index, the symbols and names of the elements mentioned in the textbook, the formulas of chemical compounds and their names, the equations depicting particular chemical reactions. With the exception of the themes reviewed, all the other parameters monitored within the framework of this part of the research were quantified. The degree to which the contents of the analysed textbooks were in keeping with the current level of knowledge in chemistry was assessed based the presence of current discoveries in the sphere of chemistry in the text (for example, the discovery of the periodical system of the elements, the Arrhenius theory of acids and bases, *etc*.).

The extent to which the students' understanding of chemistry was supported through experiments was also monitored. The experiments described in chemistry textbooks brings the question whether laboratory techniques can be appropriated by students when reading textbooks and provide information about the teaching practices in the context of the local resources.[6] The possibilities for developing meanings on the basis of the textbook (the meaningfulness of the textbook material) and insight into the practical importance of the knowledge of chemistry were monitored on the basis of the existing links between the chemistry-related contents and their application in everyday life, and also on the basis of indicating the toxicity of certain substances, their influence on human health and precautions to be taken when dealing with such substances.

The contents of the analysed textbooks were compared with the chemistry curriculum from 1881, the latter being closest in time to their publication dates.

On the basis of the presence of contents related to the history of chemistry, we reviewed the extent to which the textbooks supported the development of an appropriate idea of this science in the students' minds.[21,22] Furthermore, we monitored the ways in which the analysed textbooks were supported in terms of illustrations and graphic design and what kind of information was supplied through the illustrations, *i.e.*, what was their purpose, were monitored. One of the ways of checking the extent to which textbooks achieve their aims is to evaluate the questions that they contain.[23] In the textbooks analysed, the thought processes that they initiated, *i.e.*, the form of learning they initiated, were evaluated.

The structural and organisational components that were monitored within the framework of this analysis are given in Table S-I of the Supplementary material to this paper.

The content of a textbook should be didactically shaped in such a way that it ensures the students' minds are activated, that the basic structure of knowledge is accepted by those for whom the textbook is intended.[20] The indicators of didactic organisation that were followed in the analysed textbooks were as follows: I) the existence of scientific terms, II) the functional use of pictorial means of expression, III) the diversity of the examples provided, IV) the meaningfulness of the organisation of the textbook contents and V) whether the textbook material has any connection with everyday life out of school.

Whether the language of the textbook in question was compatible with the current language of the science of chemistry at the time when the textbooks analysed were written was also monitored during the analysis of the textbooks.

RESULTS AND DISCUSSION

From the introductory statements of both textbooks, their intentions and views on how the study of chemistry should be organised could be seen.

In the preface to the first edition of his textbook, Sima Lozanić pointed out that students found it easier to understand the formulation of the laws of chemistry based on experiments conducted in class. He was of the opinion that it was easier for beginners to learn about general terms in the sphere of chemistry in a separate section of the book and that by doing so enabled the presentation of this part in a systematic manner, thus forming a basis for understanding inorganic and organic chemistry. The method of "placing the general part within the framework of a special part", which was included in the curriculum, could lead to learning without real understanding. In his introductory statement, Sima Lozanić explained that his approach to organising the contents of organic chemistry was

through homologous series. He stressed that he paid greater attention to applied chemistry and to interpreting chemical phenomena in nature, for he was of the opinion that in this way "young men were not only enriched through knowledge but also developed a greater interest in science".

At the beginning of the third edition of Mita Petrović's textbook *Chemistry for Secondary Schools, based on Prokop Prohaszka and Others*, dating from 1892, the preface to the first edition of this textbook, dating from 1883, is included. In this preface, Mita Petrović states that the presentation of the contents of chemistry, the body of knowledge of which has greatly increased, in a manner suitable for beginners to this area, while at the same time including its development as a science, is a problem. He indicated that the organisation of the textbook material was such that the theoretical explanations provided by chemistry were not given in succession, but alternated with experimental parts, and were placed so that the students should be able to understand them when they reached them. In his opening statement, the author pointed out that, when deciding on the scope of the textbook material, he was guided by the curriculum prescribed for grammar schools in the Kingdom of Serbia.

The quantitative data on the analysed textbooks are presented in Table S-II of the Supplementary material. The scope of the textbook material in the analysed textbooks differs: Sima Lozanić's textbook has 163 pages, whereas Mita Petrović's textbook has 110 and is smaller in format. In Sima Lozanić's textbook, the table of chemical elements, containing their symbols, names and atomic mass, comprises 68 elements, of the 70 that were known at the time. The table presented in Mita Petrović's textbook contains such data for 36 elements. In Sima Lozanić's textbook, there are a greater number of chemical formulas. Those are, for the most part, molecular formulas, whereas the number of structural formulas is small in both textbooks.

Both textbooks comprise contents related to general, inorganic and organic chemistry. In Sima Lozanić's textbook, the contents are organised into three sections: general chemistry, inorganic chemistry and organic chemistry. Following a brief opening part, explaining several fundamental terms in the sphere of chemistry, the contents of Mita Petrović's textbook are organised into two sections: inorganic chemistry and organic chemistry.

These two textbooks differ in how their contents are organised. Sima Lozanić's textbook first explains the basic concepts, principles and laws in the sphere of chemistry, and only then proceeds to consider inorganic chemistry through the families of elements, and organic chemistry through the classes of compounds and homologous series. In Mita Petrović's textbook, the material related to inorganic chemistry, within the framework of which chemical elements are considered individually, is interspersed with segments of material in which general chemical

principles and laws are reviewed (which is referred to as "placing the general part within the framework of a special part").

In the general section of Sima Lozanić's textbook, the fundamental concepts and laws in the sphere of chemistry, the division of elements into metalloids and metals, and the nomenclature of chemical compounds are explained. The following fundamental chemical laws are discussed: the law of constant mass ratio, the law of multiple proportions, the law of conservation of mass, and Avogadro's law. The material is conceived in such a way that the corresponding experiments, or the results of experiments that preceded the discovery of the law in question are first presented, followed by the formulation of the law. At the end of the general section, the author explains how the remainder of the textbook is organised, announcing that the most important elements and compounds are discussed, that carbon compounds are especially emphasised because they are so numerous, and thus, that the entire sphere of chemistry is divided into two parts: inorganic chemistry, within the framework of which elements and their compounds are presented, and organic chemistry, within the framework of which carbon compounds are studied.

As opposed to the general section of Sima Lozanić's textbook, which contains 28 subtitles, in the opening section of Mita Petrović's textbook, there are four subtitles. In the section entitled *Things change*, various kinds of physical and chemical changes known from everyday life are presented (changes in the aggregation state of water, sliding a bow across a string, charging a resin bar with electricity, sliding a magnet across steel, the dissolution of sugar in water, the burning of wood and the fermentation of grapes). In the section entitled *Transient and essential changes*, differences between the types of changes are presented, which is followed by their classification into two groups and finally their definition as physical and chemical changes. In the section entitled *The directions of chemical changes*, some experiments are presented, following which the meanings of the terms analysis and synthesis are defined. The last section in the introductory part of the textbook is entitled *The difference between a mixture and a compound*, in which the difference between the two is defined.

In the section of Sima Lozanić's textbook that deals with inorganic chemistry, the chemical elements are presented based on the family of elements to which they belong, They are considered in the following order: the hydrogen family (H), the halogen family (F, Cl, Br and I), the oxygen family (O, S, Se and Te), the nitrogen family (N, P, As, Sb, Bi, B, V, Nb and Ta), the carbon family (C, Si, Ge, Sn, Ti, Zr and Th), the alkali family (Li, Na, K, Rb and Cs), the earth alkali family (Ca, Sr and Ba), the magnesium family (Be, Mg, Zn and Cd), the mercury family (Hg, Cu, Ag and Au), the lead family (Pb), the aluminium family (Al, Ga, In, Tl, Ce, La, Di, Sm, Y, Er, Yb and Sc), the iron family (Fe, Co, Ni, Cr and Mn), the platinum family (Pt, Pd, Ir, Rh, Ru and Os) and the molybdenum

family (Mo, W and Ur). A consistent manner of presentation was used for each of the above families of chemical elements. First the name of the family is given, followed by an enumeration of all elements belonging to it, together with their valences, and then the elements are studied individually. The organisation of the presentation of material when considering each individual element is as follows: after the section title, which contains the name of the element in Serbian and, in most cases, in Latin, its atomic mass, as well as molecular mass if the element occurs in nature in molecular form, the author proceeds to speak of the forms in which it occurs in nature, both in its elementary state and as part of compounds, then of the ways in which it can be obtained, its physical and chemical properties, and finally of its use, that is, its practical application. The physical properties include the state of aggregation, colour, taste, solubility in water and less polar solvents, for example, alcohol and CS_2. The chemical properties include the reactivity of the given element with some other element or compound. Concerning the use of elements, first their use in everyday life is presented, be it in their elementary state or in compounds. This order of presentation of the material is retained when considering the important compounds of the elements previously presented. In the case of compounds where characteristics analogous to those of previously presented compounds featuring elements of the same family can be observed, the similarity in their physical and chemical characteristics are emphasised. At the beginning of the presentation of the majority of the elements, the year when a particular element was discovered and who discovered it are briefly mentioned. In the section dealing with nitrogen, a three-atom molecule of nitrogen, N_3, referred to as argon, as an allotropic modification of nitrogen, analogous with oxygen and ozone, was mentioned (which was deleted from the next edition of the textbook, published in 1897). The mention of N_3 as an allotropic modification of nitrogen was criticised by Marko Leko, and constitutes one of his objections contributing to his negative review of the textbook.

A lot of attention is paid to ores and minerals that contain certain elements and to where they can be found, and the most important mines are enumerated, both in Serbia and outside its boundaries at the time. This points to the significance of mineralogy and to the importance that was attached to it in the sphere of education in the 19th century.

As was already stated, the contents of the inorganic chemistry section of the textbook *Chemistry for Secondary Schools, based on Prokop Prohaszka and Others* are organised based on the principle of "placing the general part within the framework of a special part", which was applied in the chemistry curriculum dating from 1881. This textbook contains separate sections for studying metals and non-metals. The section dealing with non-metals includes a lot of subjects from the sphere of general chemistry, alternating with segments wherein the characteristics of individual elements and their compounds are considered. The

textbook section entitled *Metals* deals with individual metals and their characteristics. The presentation of the contents related to inorganic chemistry begins with the section entitled *On air*. At the very beginning of this section, the following experiment is described – the heating of tin inside a closed vessel, along with measuring the mass of the solid substances before and after the reaction, identical to the one on which Lavoisier (Antoine Laurent Lavoisier, 1743–1794) established the Law of conservation of mass. However, Lavoisier's work is not mentioned here, nor is the law that he discovered; the latter is subsequently explicitly stated within the framework of the section entitled *The quantitative ratios of compounds*. There follows a description of experiments for obtaining nitrogen and oxygen. After this, the characteristics of oxygen and nitrogen are discussed individually, primarily the physical ones, and when considering the characteristics of oxygen, the process of oxidation and the creation of oxides are explained. The next section is entitled *On water*, and it considers hydrogen. The author expounds on the dilemma of whether hydrogen should be classified among non-metals or metals. There follows a general part again in which the following are defined: chemical affinity, atoms and molecules. After neutralisation, there is a detailed presentation of chlorine and sulphur (the way they appear in nature, how they are obtained, their properties, use, *etc*.). Within the framework of the section entitled *The quantitative ratios of compounds*, for the first time an equation of a chemical reaction is presented, namely, the one depicting the creation of water, wherein the reactants are presented in their atomic form. Within the next section, entitled *The important compounds of the elements considered so far*, the following compounds are presented: HCl, H_2S, HNO_3 ($HO{\cdot}NO_2$), NO_2, NO, H_2SO_4 and $(HO)_2SO_4$. Described is how they occur in nature, how they are obtained, their properties and their use. The next element to be considered is carbon, its allotropic modifications, and the types of coal. Particular attention is paid to the sites of coal deposits and the sources of mineral water in Serbia. Together with carbon, its compounds are considered, which was not the case for the preceding elements. *Valence*, as a topic belonging to the general section, is introduced after carbon. There follows a section entitled *On flame and burning*, wherein the last considered non-metal, phosphorus is introduced.

At the beginning of the section dealing with the study of metals, it is stated that metals are divided into light and heavy ones. The light metals are: K, Na, Ca, Mg, Ba, Sr and Al. The others are heavy metals. What is presented next is the division of metals based on valence follows: one-valence metals (K, Na and Ag), two-valence metals (Ba, Sr, Ca, Mg, Zn, Cd, Pb, Cu and Hg), three-valence metals (Bi and Au), four-valence metals (Al, Mn, Fe, Co, Ni and Cr). It is pointed out that some metals, as well as some non-metals, have more than one valence, that they form two lines of compounds, but that it is still not known

what valence depends on and how it changes, except that it often occurs at high temperatures. Subsequently, the important metals and metal compounds are studied individually, and it should be noted that the "*affinity*" of certain metals is stressed. The section of Mita Petrović's textbook dealing with inorganic chemistry ends with an explanation of the spectral analysis method and a description of the main parts of the spectroscope. As opposed to Mita Petrović's textbook, spectral analysis is not dealt with in Sima Lozanić's textbook, even though in the general section of the textbook, the author did mention the importance of this method and said that he would discuss it later.

At the beginning of the section dealing with organic chemistry, Sima Lozanić states that organic chemistry studies carbon compounds, whether those in the "*kingdom of life*" or those artificially produced in laboratories. Then he presents a classification of organic compounds based on their composition: hydrocarbons, halogen derivatives of hydrocarbons, alcohols, aldehydes, acids, carbohydrates, nitro compounds, amines, amides, nitriles, unstudied compounds (terpenes, camphors, resins and caoutchouc, natural colours and the like, alkaloids, proteins). When speaking of a class of compounds, it is stated whether a particular compound exists in nature, whether it is extracted from certain plants or animals, and how this is realised, whether such compounds exist in the human body and what sort of function they perform. Along with homologous series of carbohydrates, the text presents the boiling and melting temperatures of various elements of the series, on the basis of which conclusions may be draw about their state of aggregation under the same conditions. The importance that was attached to fuel is evident from the amount of space dedicated to oil, the way it is obtained, its refining and various fractions. When considering proteins, the molecular formulas of albumin, haematin and haemoglobin are presented ($C_{72}H_{112}N_{18}SO_{22}$, $C_{68}H_{70}N_8Fe_2O_{10}$ and $C_{600}H_{960}N_{154}FeS_3O_{17}$), but it is stressed that these are their presumed formulas, and that the exact composition of these compounds is still unknown, except that they are characterised by a high molecular mass. The ensuing section contains detailed descriptions of various types of fermentation that contribute too many important processes unfolding in nature, and to processes for producing various compounds. Within the framework of the section entitled *The processes inside an animal organism* , there is a description of the composition of blood and urine, of the process of breathing and digestion. This chapter also contains advice for healthy eating and presents information on the daily needs of the human organism for various kinds of food in order to function properly.

In Mita Petrović's textbook, the first section dealing with organic chemistry, entitled *The ingredients of organic compounds* , contains an explanation of the elements that are part of the composition of organic compounds, while organic chemistry is determined in the following way: "If we heat wood, a feather, paper,

cotton, egg-white, etc. in a glass tube which is heated at one end, after a while they will all turn black and turn into coal. All organic matter contains carbon without exception. An object that does not contain carbon is not organic. We can therefore say that organic chemistry is the chemistry of carbon compounds." Paraffins are considered first, of which methane is presented in some detail, as are its halogen derivatives, along with four equations depicting chemical reactions for its gradual chlorination. After that, cyan compounds, alcohols, ethers, aldehydes and acids are described. Not much attention is dedicated to aldehydes, while acids are considered individually and in more detail within the framework of two sections. Regarding carbohydrates, the following are described individually: plant fibre (cellulose), starch, dextrin, grape sugar, cane sugar (sucrose) and milk sugar. Their occurrence in nature and the method of their extraction from natural products are described, and an experimental method of distinguishing between reducing and non-reducing sugars (Fehling's test) is presented. Within the section entitled Alcohol fermentation, the processes of producing wine, beer and various kinds of brandy are described in detail. A significant amount of attention is dedicated to tannin, in order to indicate its use for tanning leather, making ink, *etc*. Subsequently, aromatic compounds are considered, i.e., how to obtain benzene and its nitro and amino derivatives, and their characteristics. Several alkaloids are enumerated, and their physiological effect on man is indicated. The penultimate section is dedicated to natural colours, and the final one to proteins.

Sima Lozanić's textbook contains the descriptions of 13 experiments, while that of Mita Petrović contains 29 descriptions. A list of experiments featured in the textbooks is given in Table S-III of the Supplementary material. Some of the experiments are featured in both textbooks. The experiments are not individually marked and separated from the main text. From the manner of the presentation of the material, it could be concluded that the authors intended them for demonstration in class, and having presented them, both authors subsequently referred to the experiments already presented when considering new material.

All the experiments featured in Sima Lozanić's textbook pertain to the contents related to general and inorganic chemistry, whereas in Mita Petrović's textbook, two of the experiments belong to the sphere of organic chemistry.

In both textbooks, one can observe the connection between the textbook material and everyday life outside school, be it when it comes to the practical application of certain elements and compounds, or the occurrence and function of organic molecules in the human organism, plants or animals. There are 158 such examples in Sima Lozanić's textbook and 174 examples in Mita Petrović's textbook.

In both textbooks, apart from pointing out the practical use of various substances, the authors stress that certain substances have a toxic effect on human

health. These include not only substances that can be found in a chemical laboratory, but also substances that are encountered in everyday life, or those that easily occur as a result of processes unfolding in the surroundings (such as carbon monoxide gas). In Sima Lozanić's textbook, there are 14 examples testifying to the toxicity of certain substances and their harmful effects on humans, although, there is no direct reference to precautions that should be taken or first-aid measures to be applied if any accident should happen, which is a shortcoming of this textbook. In Mita Petrović's textbook, there are 34 such examples, and in some cases the author points to precautions that should be taken when handling such substances, as well as first-aid measures to be applied.

Sima Lozanić's textbook contains 43 illustrations, whereas that of Mita Petrović contains 10. All the illustrations featured in both the analysed textbooks follow the main text and contribute to a better understanding of chemical concepts and processes. The illustrations in both textbooks are numerically marked, but contain no captions explaining their contents. The main text contains references pointing to a particular illustration through its number. In Sima Lozanić's textbook, the illustrations are used to present apparatuses (ten illustrations), experiments (two illustrations), industrial plants or their segments (nine illustrations), various types of furnaces (eight illustrations), crystallographic structures (two illustrations), structures seen under a microscope (two illustrations), certain processes or parts of them (seven illustrations), chemical vessels and equipment (three illustrations). The first four illustrations are featured in the general section of the textbook, 36 illustrations are to be found within the framework of the inorganic chemistry section, whereas only three illustrations are included in the section of the textbook dealing with organic chemistry. In Mita Petrović's textbook, the illustrations are used to present apparatuses (two illustrations), experiments (four illustrations), processes (two illustrations), laboratory vessels (one illustration) and instruments (one illustration). All the illustrations are included in the textbook section dedicated to inorganic chemistry, specifically, in the part dedicated to studying non-metals.

Contents pertaining to the history of chemistry, mention of essential discoveries in the sphere of chemistry and names of great chemists are to be found in Sima Lozanić's textbook, 27 cases in all, whereas in Mita Petrović's textbook, there are only two references to the historical development of chemistry. In his textbook, Sima Lozanić points to turning points in the development of the science of chemistry (disproving the phlogiston theory, disproving the vitalist theory by means of the Wöhler synthesis of urea), and also to the development of certain production processes that have a broad scope of practical usefulness (the production of ceramic dishes, the production of glass), from time immemorial to the period when the textbook was written, based on which conclusions could be

draw about the development of science through history and its beneficial effect on mankind.

Concerning the monitored structural components in the analysed textbooks, both of them contain: the main text, illustrations and questions. Apart from the three components, Mita Petrović's textbook also contains instructions and references to other parts of the text. Concerning the organisational components, the following were observed in both textbooks: a table of contents, an introductory explanation of the textbook structure as part of the preface, an index of terms arranged in alphabetical order, tables of chemical elements. In Mita Petrović's textbook, there is a brief note on the author, consisting of a few sentences included on the title page. Neither textbook contained a separate list of the literature used in compiling the books, but in their prefaces both authors refer to the authors on whose books they had relied when writing their textbooks. Sima Lozanić states that when writing the present textbook, he had relied on his own textbooks of inorganic and organic chemistry that he had previously written for the High Schools, while Mita Petrović explains in the introductory section that his role model for writing the present textbook was the book written by Prokop Prohaszka, professor of the Czech High School in Prague, entitled *Chemie učebna kniha pro čtvrtu tridu škol realnih, založena na pokuseh* , and that he also relied on Sima Lozanić's inorganic and organic chemistry textbooks for the High Schools.

Indicators of the didactic organisation of a textbook, such as explanations of scientific terms, a functional use of illustrative means of expression and variety of the examples used are for the most part similar in these two textbooks. In both of them, when a term is mentioned for the first time, it is printed in bold letters, and immediately next to it there is an explanation. In both textbooks, definitions of a certain concept, process or phenomenon are supported by diverse specific examples, before or after the formulation of the definition.

In the general section of Sima Lozanić's textbook, there are five questions, followed by answers, whereas in Mita Petrović's textbook, in the course of studying inorganic chemistry, 12 questions are posed, but no specific answers to them are provided. The questions and instructions found in both textbooks analysed are presented in Table S-IV of the Supplementary material.

In Sima Lozanić's textbook, a uniform manner of presenting the material contained in the textbook is consistently applied almost throughout the book (the only exception being the section entitled *Unstudied compounds*, which encompasses terpenes, camphors, resins and caoutchouc, natural colours, alkaloids and proteins), which is not the case with Mita Petrović's textbook.

The contents of both textbooks to a large degree cover the chemistry curriculum of 1881. Both authors observed the recommendation from the curriculum on what should be taught about an element, *i.e.*, how it is obtained, its physical

and chemical properties, how it occurs in nature, its use. Even though Sima Lozanić's textbook covers the contents relating to inorganic chemistry prescribed by the curriculum, there is a difference between the textbook and the curriculum concerning the organisation of the contents. Mita Petrović's textbook follows the organisation of the contents prescribed by the curriculum more closely ("placing the general part within the framework of a special part"). The essential difference between the 1881 curriculum and the organisation of the contents in both textbooks lies in the way organic compounds are systematised. The curriculum, which was actually based on Sima Lozanić's textbook for the High School, systematised organic compounds according to the number of carbon atoms they contain, whereas in the textbooks, the compounds are systematised in accordance with homologous series. In Sima Lozanić's textbook, much emphasis is placed on this particular way of systematising compounds, whereas in Mita Petrović's textbook, the compounds are systematised in this way without defining the notion of homologous series.

One characteristic of textbooks is the translations from the language in a scientific discipline into the local or national language[7]. A difference was observed concerning the terminology used between the curriculum and Sima Lozanić's textbook, whereas the terminology used in Mita Petrović's textbook is in keeping with the curriculum. In Mita Petrović's textbook, the scientific terms used are adjusted to the Serbian language, that is to say, they are "Serbianised". In Sima Lozanić's textbook, the scientific terminology corresponds to the terminology that we still use today, with minor changes. The names of compounds in Sima Lozanić's textbook are mainly in the nominative case (for example, potassium chloride), while in Mita Petrović's textbook the names of compounds are given in the genitive case (for example, chloride of potassium).[24] At the time, a discussion between scientists (not exclusively chemists) was ongoing – should science terminology be "Serbienisied" or not.

Sima Lozanić's textbook also contains topics that go beyond the curriculum contents, mainly related to organic chemistry, whereas Mita Petrović's textbook does not cover several topics from the sphere of inorganic chemistry, nor does it cover the topics contained in the curriculum supplement relating to: the chemical difference between plants and animals, breathing and life-giving heat, and the feeding of plants. Furthermore, it contains no topic beyond those prescribed by the curriculum.

In the major part of both textbooks, the knowledge available at the time is accurately presented, with the exception of the valences of some elements, the symbol of fluorine, the formulas of certain compounds and the equations of chemical reactions in Mita Petrović's textbook, and the controversial allotropic modification of nitrogen in Sima Lozanić's textbook. Neither textbook mentions Arrhenius's theory of electrolytic dissociation or Mendeleev's periodical system

of the elements. Arrhenius's theory of electrolytic dissociation was posited in 1884, and the textbooks analysed were published in 1892 and 1895, respectively. The omittance of this theory may be explained by the fact that, for a number of years, Arrhenius's theory was under dispute among the scientific public. Neither of the analysed textbooks mentions the periodical system of the elements that Mendeleev published in 1869. This was not the case with the second edition of Sima Lozanić's textbook, dating from 1897. It is surprising that Sima Lozanić did not include the periodical system of the elements in his secondary-school textbook, considering it was included in his previously published inorganic chemistry textbook for High Schools.

CONCLUSIONS

Towards the end of the 19th century, general, inorganic and organic chemistry in secondary schools in Serbia were studied based on the textbooks *Chemistry for Secondary Scho ols* by Sima Lozanić and *Chemistry for Secondary Schools, based on Prokop Prohaszka and Others* by Mita Petrović. In these two textbooks, a difference in the organisation of the contents of the textbooks is apparent. The discussion was ongoing for years: should general chemistry be presented under inorganic chemistry or as a special section of textbooks. In the former, general chemistry, with the basic chemical concepts, principles, theories and laws, is presented in the opening section, thus forming a basis for inorganic and organic chemistry in the remainder of the textbook. In the latter textbook, the two largest sections are taken up by inorganic and organic chemistry and contents related to general chemistry are presented within the inorganic chemistry section, in those places that the author considered to be the most convenient for the students' understanding of the said contents. Based on the authors' introductory statements, the impression is given that both approaches are the result of their thinking and assessment of the type of organisation of the textbook contents would contribute to the students' better understanding chemistry. The latter author's approach followed more closely the organisation of the then chemistry curriculum, but the former author's approach has been retained in today's chemistry curricula. It may be assumed that the said approach was developed during the course of Sima Lozanić's studies under Wislicenus and Hofmann. However, the approach applied by Sima Lozanić was criticised by Marko Leko, the reviewer of the *Chemistry for Secondary Scho ols* textbook. The only justification for criticising Sima Lozanić's textbook, based on the present analysis, lies in the fact that he mentioned a controversial allotropic modification of nitrogen. It may be assumed that this arose out of a wish to make the textbook's contents as up-to-date as possible, but in this case, the said scientific information was insufficiently verified. In the second edition of the textbook, Sima Lozanić had already left out the controversial allotropic modification of nitrogen.

The analysed textbooks differ in terms of the scope of their contents, Sima Lozanić's textbook being the more voluminous of the two. As regards the accuracy of the textbooks' contents, several segments of Mita Petrović's textbook were assessed to be inaccurate.

Both textbooks link theoretical contents with corresponding experiments, with the experiments presented in Sima Lozanić's textbook being better suited to the lesson at hand, thus providing a better grounding for understanding the theoretical contents. Both textbooks contain examples that stress the practical significance of chemistry and its connection with everyday life. Also, in both textbooks the authors point out the toxicity of certain substances. Sima Lozanić's textbook, compared to that of Mita Petrović, to a greater extent includes contents related to the history of chemistry which, at the time, could acquaint young people with the nature of science and scientific/research work, the essential turning points in science and the contribution of science to the development of society.

Concerning the structural components, both textbooks contain: the main text, with in-built descriptions of experiments and their results, illustrations and questions. Apart from these components, Mita Petrović's textbook also contains instructions and references to other parts of the text. With regards to the organisational components, both textbooks contain: a table of contents, an introductory explanation of the structure of the textbook within the framework of the preface, an alphabetically arranged index of terms and tables of the elements.

In the final analysis, it could be concluded that Sima Lozanić's textbook is of a better quality compared to that of Mita Petrović, not so much in terms of the choice of contents but in the way the contents are presented and the presentation order.

SUPPLEMENTARY MATERIAL

Structural and organisational components and quantitative data of the textbooks analysed, as well as experiments described and questions and instructions found in them, are available electronically from http://www.shd.org.rs/JSCS/, or from the corresponding author on request.

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ИЗВОД

УЏБЕНИЦИ ХЕМИЈЕ ЗА СРЕДЊУ ШКОЛУ У 19. ВЕКУ

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Настава хемије, као самостални предмет у Србији, датира од 1874. године. Први уџбеници хемије за средњу школу појавили су се у другој половини 19. века. Циљ овог рада јесте да се кроз анализу два средњошколска уџбеника из хемије, аутора Симе Лозанића (1895) и Мите Петровића (1892), сагледа шта се од научних знања из хемије презентовало ученицима у средњим школама у другој половини 19. века и према којим принципима су тада писани уџбеници. У оквиру истраживања дефинисани су критеријуми за праћење квалитета средњошколских уџбеника хемије у контексту времена у коме су настали. Најбитнија нађена разлика између два анализирана уџбеника односи се на организацију садржаја. Уџбеник Симе Лозанића карактерише већа систематичност у излагању садржаја и доследност у приступу кроз цео уџбеник. У оба уџбеника видљива су настојања да се садржаји хемије повежу са свакодневним животим, као и да се поред практичног значаја супстанци укаже на њихову токсичност.

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