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THE RELATIONSHIP BETWEEN LEARNING STYLES AND STUDENTS` CHEMISTRY ACHIEVEMENT

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This research aimed to determine the chemical content which is the most challenging for students, and also to study the differences in chemistry achievement among students who prefer different learning styles. The study was carried out on the sample of 265 second grade students (aged 15–16 years) from seven grammar schools in Vojvodina (Serbia). Two instruments were applied in the study to determine the learning styles: chemistry knowledge test and Learning Style Inventory (LSI version 3.1). According to the findings, students have difficulty learning the contents of the topics Chemical Equilibrium, Salt Hydrolysis and Oxidation-Reduction Reactions. The findings show that there is a significant relationship between achievements in chemistry and students' learning styles. The findings obtained in this research represent a step towards improving chemistry education since they identified the topics that students find it the most difficult to learn.

Keywords: chemistry achievement; learning difficulties; students; learning style

ЗАВИСНОСТ ПОМЕЃУ СТИЛОВИТЕ НА УЧЕЊЕ И ПОСТИГАЊАТА НА УЧЕНИЦИТЕ

Ова истражување има за цел да ги определи најтешките хемиски содржини за учениците, а исто така да ги проучи разликите во постигањата на учениците кои претпочитаат различни стилови на учење. Студијата е извршена на примерок од 265 ученици (на возраст од 15–16 години) од вторите класови на седум средни училишта во Војводина (Србија). Применети се два инструмента за да се определи стилот на учење: тест на знаење по хемија и опис на стиловите на учење (Learning Style Inventory – LSI version 3.1). Според нашите сознанија, учениците имаат тешкотии со содржините од хемиска рамнотежа, хидролиза на соли и оксидо-редукциски реакции. Овие истражувања покажуваат дека постои значајна зависност помеѓу постигнувањата по хемија и стиловите на учење. Сознанијата добиени во ова истражување се чекор напред кон подобрување на образованието по хемија поради тоа што се идентификувани темите што на учениците им се најтешки за совладување.

Клучни зборови: постигнување по хемија; тешкотии во учење; ученици; стил на учење

1. INTRODUCTION

Every chemistry teacher has probably faced students who do not like chemistry, consider the course boring, difficult and hard to understand, and cannot see the connection between the abstract terms they learn with the practical application of chemistry in their everyday lives. This phenomenon is common for different countries and different educational systems; thus, there exists a growing need among chemistry teachers and researchers in the field of chemistry education to identify the causes of problems in learning chemistry and to find adequate methods to solve them.

Although it is known that problem-based learning and learning through discovery lead to higher levels of cognitive engagement in students [1], lectures still dominate in schools in the Republic of Serbia. On the other hand, individualized teaching and student-centered learning are rarely implemented [2]. Chemistry education (general, inorganic and organic) is also dominated by frontal work of teachers [3]. Based on the results of the PISA evaluation of school achievement, it is evident that the average level of scientific competence of students in Serbia is 56 points lower than the OECD average. Bearing in mind that one year of education in OECD countries contributes to an increase of around 40 points on the PISA scale, it can be concluded that students in Serbia should be provided with one and a half years of additional education to catch up with their peers from OECD countries in terms of scientific competence [4].

Due to the growing importance of chemistry in modern life, both for individuals and for society as a whole, in recent years, the number of investigations aimed at identifying the difficulties that students and teachers face in the teaching process has increased. The fact that there are many difficulties in teaching [5] and learning chemistry [6] have been confirmed by many studies.

One of the essential problems is the fact that chemical content is studied at three levels (macroscopic, submicroscopic and symbolic levels), of which only one is directly accessible to the senses [7]. In addition, there is a shortage of time available for the implementation of a demanding curriculum. In R. Serbia, chemistry is taught for only two school years in elementary school; thus, it represents a great challenge for the teachers of chemistry to enable their students to adopt many important concepts which are the basis for their further education. The learning difficulties encountered in the learning process and student low achievement in chemistry are related to the complexity of the content. Even in the initial course of chemistry, students are expected to master chemical symbolics and terminology, and to adopt a large number of abstract concepts.

Sirhan [6] gave an overview of the chemical concepts which are difficult to grasp for many chemistry students: the molecular concept, atomic structure, kinetic theory, thermodynamics, electrochemistry, balancing redox equations and stereochemistry, chemical bonding, solution chemistry, etc. Other research suggests that understanding the acid-base concept is particularly difficult and often misinterpreted by students [8, 9]. Hydrolysis is one of the most important concepts in this field and is the source of many misconceptions. The results of the research carried out by Orwat, Bernard and Migdal-Mikuli [10] point out the difficulties in understanding the salt hydrolysis process, even in students who are exceptionally interested in chemistry. These ambiguities have roots in the lack of understanding of other basic concepts that are needed to understand the process of hydrolysis. Besides the obvious use of inaccurate analogies, a lack of laboratory practice may also be the cause of an incorrect explanation of the hydrolysis process.

Difficulties in studying chemical equilibrium were recorded in numerous studies [11–14]. Van Driel and Gräber [12] have pointed out the difficulties in studying various parts of the chemical balance concept, from understanding the nature of reversible reactions to understanding the Le Chatelier's principle.

A review of earlier research based on learning problems in teaching the topic of oxidation-reduction reactions indicates problems for both teachers [5] and students [15]. Some of the identified problems in learning appeared to be the relative strength of oxidizing and reducing agents, the concept of oxidation numbers, and the identification of redox reactions.

Based on the above, it can be concluded that it is necessary to improve the entire teaching process in order to facilitate the process of chemistry learning. Learning from the framework of the paradigm of learning styles suggests that advancement of the entire teaching process implies an understanding of individual students' differences in terms of learning [16]. Researchers and practitioners in the field of chemical education have become interested in studying the learning styles of students, and such results could be directly applicable in chemistry teaching [17]. Numerous studies have shown that understanding a student´s learning style can influence the teacher´s pedagogical approach and hence cater for the student´s preferred style. Researchers propose designing an instructional environment in accordance with students' preferences based on findings regarding the differences in the learning styles of students of high and low academic achievement [18]. Recognizing and respecting students' learning styles is a prerequisite for adapting teaching styles to individual student's needs [19, 20]. By knowing the learning styles, teachers can assess an individual student's needs more accurately and design strategies to enrich the teaching process accordingly [21].

1.1. *Learning style*

The theoretical background of this paper is Kolb's Experiential Learning Theory, which is a comprehensive model and one of the most influential theories in the field of learning styles [21–23].

Experiential learning theory defines learning as a process of grasping and transforming experience. According to ELT, the learning process is seen as a cycle based on the contextually sensitive resolution of creative tension between four modes of learning: concrete experience (CE), which emphasizes feeling, reflective observation (RO), which emphasizes reflecting, abstract conceptualization (AC), which emphasizes thinking, and active experimentation (AE), which emphasizes doing. In the learning cycle, CE (feeling) creates a need for learning, which induces reflective observation (watching). Reflective observation is accompanied by the development of new concepts (thinking) that allows new knowledge to be integrated into existing knowledge. Finally, this integration results in action (doing). Since this action changes the already acquired knowledge, new experience is obtained and the cycle is repeated. According to Kolb's experiential learning theory, it can be said that experience is the foundation of learning. Kolb states that it is very important to emphasize that not all phases of the learning cycle are equally important for students. Depending on the student's preferred phase of learning cycle, their way of learning is dominated by one of the following four learning styles: accommodating, diverging, converging and assimilating [24, 25]. Students who prefer the diverging learning style are imaginative and emotionally sensitive; thus they have broad cultural interests and like being informed. Their approach to solving problems is unsystematic, but it is more creative than that of students who prefer other styles of learning. In formal learning situations, individuals with divergent learning styles tend to attract attention and get feedback on their work. They are interested in group work and listening [25], and aspire to answer the question "Why is this important?". Teachers should operate as facilitators [26] and motivators [16, 17] in order to effectively work with these students.

Students who prefer the assimilating learning style are less focused on people and more interested in abstract ideas and concepts [24]. They want to know the facts and present them in an organized and logical form. They aspire to answer the question "What is the concept?" [17]. They are good at systemizing a wide range of information into a logical structure. Instead of making premature decisions, they ponder thoroughly and carefully. In formal learning situations, they prefer lectures and reading and require time to think [25]. Teachers should act as subject experts [16, 17, 26] in order to effectively work with these students.

Students who prefer the convergent learning style are the best at the practical use of ideas and theories [25]. They aspire to answer the question "How is the concept applied?" [17]. They prefer solving problems and making decisions based on rational solutions. Also, they prefer practical problem solving rather than dealing with social and interpersonal issues. Individuals with a convergent learning style are typically logical, pragmatic and unemotional. In formal learning situations, they prefer experimenting with ideas and participating in simulations, laboratory work and research, as well as working with practical applications [25]. In order to effectively work with these students, teachers should act as standard setters/evaluators [26].

Individuals who prefer an accommodating learning style have a strong ability to learn from direct experience and function well in ambiguous and uncertain situations. Students with an accommodating learning style enjoy achieving challenging goals and facing challenging endeavors. They tend to act on intuition rather than logic. They aspire to answer the question "What are the possibilities?". In formal learning situations, they prefer field work and working with others [25]. In order to effectively deal with these students, teachers should ask straight questions and create opportunities for problem-based learning [16], thereby acting as coaches [26].

2. EXPERIMENTAL SECTION

2.1. *Aim of the research*

This research was conducted with the aim of answering several research questions: which general chemistry content is difficult for Serbian grammar school students, what learning styles do students prefer and how does the achievement in chemistry differ between students with different learning styles? The answers to these questions could be important and helpful for teachers because they could provide them with additional information about teaching topics that require greater attention in the learning process. Teachers could also gain insight into student learning strategies and could choose appropriate teaching activities in accordance with the individual preferences of their students, and all that could make the learning process more effective.

2.2. *Participants*

The research was carried out on a sample of 265 second grade students (the age range was 15–

16) from seven grammar schools in Vojvodina (Serbia). The sample comprised 40.0% male and 58.9% female students, with three students (the remaining 1.1%) choosing not to submit gender information. Prior to the research, the school principal and teachers were asked permission to conduct the research. Respondents were volunteers who agreed to participate in the study anonymously and were informed that the results would only be used for scientific purposes. The study was conducted during regular chemistry classes. After completion of the study, students were informed about their preferred learning styles.

2.3. *Instruments*

Students' achievement was measured using a knowledge test, which was constructed for the purpose of this research. It consisted of 17 questions. Tasks in the test were formulated as multiple choice questions because these are most commonly applied in practice [27]; they enable the testing of the large amounts of content, answering a large number of questions in a relatively short time, and the possibility of guessing the correct answer is less likely than in alternative type questions [28]. The test covered the general chemistry content in accordance with grammar school curriculum and the recommended textbook [29]. It comprised the following topics: Types of substances, Atomic structure, Chemical bonding, Disperse systems, Chemical reactions, Acids, bases and salts, and Redox reactions. Every correct answer was given one point. The knowledge test is provided in the Appendix I as supplementary material.

The students' learning styles were identified using Learning Style Inventory, LSI version 3.1. [30]. The questionnaire consists of 12 items which are responded to by ranking the offered answers with the numbers 1–4 in the order which best describes the individual learning style (1 – refers least to the respondent, to 4 – refers most to the respondent). The information about students' individual learning styles was obtained in the manner described in Kolb [30]. In the first step, individual scores on four subscales: concrete experience (CE), abstract conceptualization (AC), active experimentation (AE) and reflective observation (RO) were identified based on the students' self-assessment. This was followed by calculating values (AC-CE) and (AE-RO) to determine their preferences in the dimension of grasping experience and information processing. Finally, each student's preferred style was determined as accommodating, divergent, convergent or assimilating.

2.4. *Data analysis*

The knowledge test was characterized by pre-test and post-test quality assurance characteristics according to the model described in Segedinac, Segedinac, Konjović and Savić [31]. According to this model, the pre-test quality assurance assessment involves multiple validations of tests in terms of the variety of questions, the adequacy of the terminology used, the meaning of the requests, and the length of the sentences. Pre-test quality assurance characteristics were evaluated by an expert group comprised of a university professor, a research associate and a professor of chemistry from a grammar school. Post-test quality assurance characteristics involved the calculation of descriptive and psychometric indicators of knowledge tests.

Students' learning styles were determined in the manner described in Kolb [30]. One-way analysis of variance (ANOVA) was applied to test the difference in achievement between groups of students with different learning styles. Preliminary testing confirmed the assumption of normality and homogeneity of variance. The IBM SPSS (version 21) software package was used for statistical data processing.

3. RESULTS

3.1. *Chemistry achievement*

The chemistry knowledge test was applied to identify learning topics that are the most difficult for students. This test included general chemistry content from all 7 topics covered by the curriculum in R. Serbia: Types of substances, Atomic structure, Chemical bonding, Disperse systems, Chemical reactions, Acids, bases and salts, Redox reactions. The Cronbach's alpha coefficient was 0.76 and the reliability of the test could be considered satisfactory [32]. The average score of the test was 8.32 points. The best score was the maximum 17 points, while the lowest result was 1 point. To reduce the possibility of students guessing the correct answer, the suggestion was made to have students leave the question unanswered if they did not know it. Descriptive parameters of the test are shown in Table 1. The number of questions for a topic was proportional to the number of classes planned for that topic. The test comprised questions of the three levels of difficulty, according to Bloom's taxonomy of educational goals: knowledge, understanding and application levels.

Table 1

Descriptive parameters of the knowledge test

Question	Topic	Difficulty index	Discrimination index
1	Types of substances	.91	.29
2	Atomic structure	.52	.41
3	Atomic structure	.43	.28
4	Atomic structure	.67	.31
5	Chemical bonding	.51	.40
6	Acids, bases and salts	.29	.19
7	Chemical bonding	.90	.22
8	Disperse systems	.35	.31
9	Chemical reactions	.62	.30
10	Acids, bases and salts	.45	.47
11	Atomic structure	.43	.47
12	Redox reactions	.29	.33
13	Redox reactions	.28	.15
14	Chemical bonding	.31	.50
15	Atomic structure	.52	.45
16	Chemical reactions	.84	.23
17	Chemical reactions	.28	.28

Item difficulty levels ranged from 0.28 to 0.91, with the total value of 0.51 for the whole test, which is considered optimal [33]. Indices of discriminations for the questions in the test ranged from 0.29 to 0.48. According to the criterion established by Ebel and Frisbie [34], all questions have acceptable values for discrimination indices. All of these characteristics indicate that the applied test is reliable and has acceptable characteristics, and can therefore be used for research purposes.

Students' learning styles

In order to investigate the differences in achievement in chemistry tests for students with different learning styles, it was necessary to identify the individual learning style for each participant. Preferred learning styles were determined using LSI (version 3.1) which is one of the most frequently used inventories, characterized by good internal consistency [23, 35, 36]. Values for the internal consistency coefficients obtained in this research were: 0.72 for CE, 0.63 for RO, 0.71 for AC and 0.62 for AE. These values are in accordance with the values obtained in other studies [22] and can be considered satisfactory. The representativeness of the items expressed by the normalized Kaiser-Meyer-Olkin (KMO) coefficient is high and amounts to 0.74. The values of skewedness and kurtosis range from -0.25 to 0.73. Such a distribution of results can be described as normal, which makes data suitable for further statistical analysis.

Learning styles of students

The values obtained for the four stages of the learning cycle are shown in Figure 1. As indicated by the data obtained for a learning cycle, respondents' AC is more pronounced than their CE in the dimension of grasping experience, while in the dimension of transforming experience, RO (observation) is more pronounced than AE (action).

Based on the values obtained in dimensions AC-CE and AE-RO, it is possible to identify students' preferred learning styles. The distribution of the students' learning styles identified using the LSI instrument, defined as accommodating, assimilating, divergent and convergent, is shown in Figure 2.

As indicated by the results, the majority of surveyed students prefer the assimilating learning style. This style is preferred by 140 students (52.8%), followed by divergent learning style (25.7%), and convergent learning style (13.6%), while the accommodating learning style is the least frequent (7.9%). The chi-squared matching test shows that learning styles in the sample are present in varying degrees: χ^2 (3) = 126.86, $p < 0.01$.

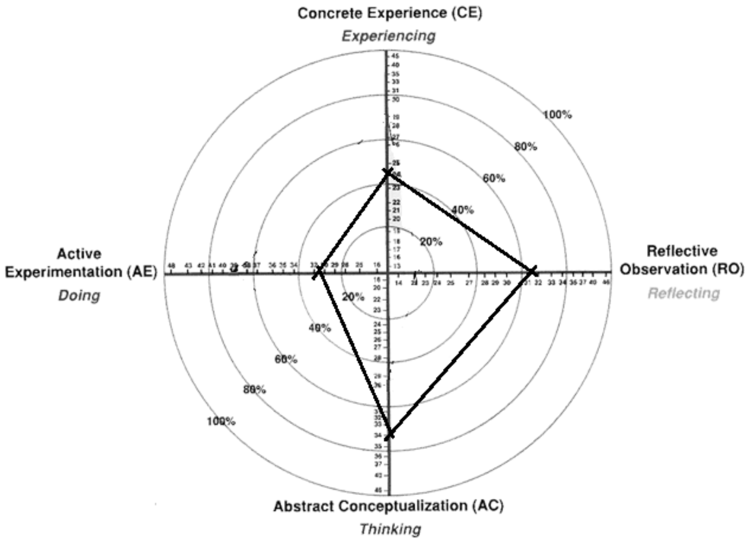

Fig. 1. Scores in the learning cycle

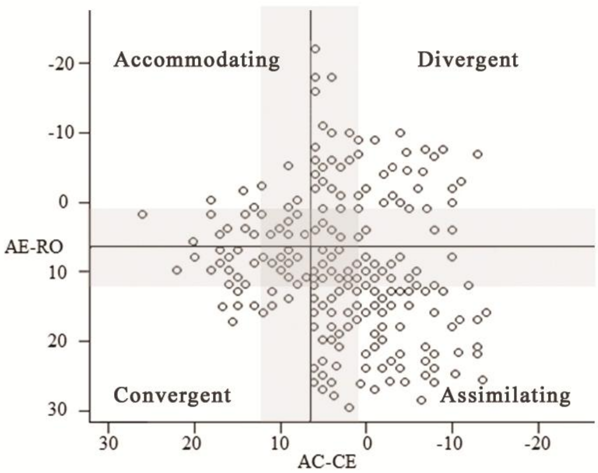

Fig. 2. Learning style distribution in the research sample

Relationship of learning style and chemistry achievement

According to the preferred style of learning, students were divided into four groups. One-way analysis of variance (ANOVA) was used to examine differences in achievement between students with different learning styles (Table 2). Descriptive characteristics of the knowledge test show that the distribution of results is normal (Skewedness = 0.44; Kurtosis = 0.07). Levene's test was applied to check the assumption on normality and homogeneity of variance. The obtained results confirmed the assumption (F = 1.704, p = 0.13).

T a b l e 2

Achievement of students on the knowledge test in relation to students' learning styles

Learning styles	N	M	SD	F	p
Accommodating	21	8.19	2.75	2.82	.04
Diverging	68	7.48	3.73		
Assimilating	140	8.44	3.42		
Converging	36	9.47	2.97		

As seen from the values shown, the highest scores were achieved by students who prefer a convergent learning style and the lowest by students with a divergent style. In other words, students who are pragmatic, and who prefer problem solving, experimentation and laboratory work have the highest achievement. A statistically significant difference at p < 0.05 was found between the results of the knowledge test for the four respondent groups. The eta squared statistic was 0.03, which indicates a small effect size.

The groups which differ from each other were identified using the *post hoc* Tukey HSD test (Table 3). Subsequent comparisons using the Tukey HSD test have shown that only the mean value of the group of students with convergent learning style is significantly different from the mean value of the group of students who prefer divergent learning style, while the differences between other groups of students were not statistically significant.

T a b l e 3

Results of the Tukey HSD test: differences between the achievements of students of the different learning styles at the general chemistry knowledge test

Learning styles		Mean difference	Std. error	*p*
Accommodating	Diverging	0.70	0.84	0.84
	Converging	1.28	0.93	0.52
	Assimilating	– 0.25	0.79	0.99
Diverging	Converging	– 1.99	0.69	0.02
	Assimilating	– 0.96	0.49	0.23
Converging	Assimilating	1.03	0.63	0.37

According to these findings, it can be confirmed that the achievement of students in chemistry depends on the preferred learning style. This indicates that there is consistency in the material that is difficult for students to learn and understand, regardless of the preferred learning style. In a previous study, it was also found that the role of learning styles on academic performance on the fundamental chemical concepts (Atomic structure, Periodic system of chemical elements and Chemical bonding) was not statistically significant [37].

4. DISCUSSION

In this study, we investigated the distribution of learning styles in grammar school students and the differences in chemistry achievement between students who prefer different learning styles. An analysis of arithmetic means of student achievements for each task revealed that the most common problems were related to the topics of Chemical reactions and Redox reactions. Students had the lowest score in questions which required them to name those factors which affect the equilibrium constant of a reaction, calculate the numerical value of the equilibrium constant, and understand the process of salt hydrolysis. Students also had difficulties identifying redox reactions and determining the oxidation states of elements in compounds. The highest scores were recorded in tasks concerning types of substances and molar mass. Students were successful in distinguishing pure substances (elements and compounds) from mixtures, and in choosing the correct unit for the molar mass.

The obtained results are in accordance with numerous previous studies. Van Driel and Gräber [12] found that students have difficulties understanding the chemical equilibrium concept, from understanding the nature of reversible reactions to understanding the Le Chatelier's principle. Summarizing several previous studies, Kind [38] pointed out difficulties faced by students in understanding that the equilibrium constant K always has a constant value for a specific reaction at a specific temperature and is calculated using Equilibrium Law, which was confirmed in the present study. The students participating in this research scored the lowest number of points in questions that addressed the factors which affect the equilibrium constant K and the calculation of the numerical value of equilibrium constants.

Students' difficulties in understanding the chemical equilibrium deserve special attention because this is a very important chemical concept. Voska and Heikkinen [39] developed a two-step diagnostic instrument to identify student conceptualizations (TISC) related to the application of Le Chatelier's principle, the equilibrium constant and the impact of the catalyst. By applying this test, the most common misconceptions were identified in the sample of students. These authors established that over 60% of students believe that it is possible to predict the effect of temperature change on chemical equilibrium without knowing whether the reaction is exothermic or endothermic. Also, the same number of students think that the addition of the common ion in the solution-precipitate equilibrium system leads to better solubility of the precipitate. In another research, Kind [38] stated that it was necessary for students to understand the mathematical relationship between the equilibrium constant K and the concentration of the reactants and reaction products in order to overcome the identified problems concerning a misunderstanding of the equilibrium constant. Only when they learn this will students be able to understand why temperature affects equilibrium. Also, we must be aware that the chemical equilibrium concept is very specific in terms of the chemical language. It has been established that a lack of understanding of the chemical language is one of the key factors for the misunderstanding of this concept [11]. Therefore, the proper use of terminology and consistency in its use is very important. Research has shown that the application of appropriate worksheets [13] and cooperative learning using the Jigsaw Technique [14] leads to the increase in student achievement in the content related to chemical equilibrium.

The concept of a chemical equilibrium in a water solution of salts is also a point of misunderstanding among students. In a previous study by Orwat et al. [10], it was found that students were able to determine the acidity of the water solution of a substance on the basis of its chemical formula, while they were unsuccessful in writing chemical equations that explain the phenomena of hydrolysis. In our research, students could not even predict the pH value of the salt solution. Understanding a complex process of hydrolysis requires knowledge of other basic concepts such as equilibrium processes, acids and bases, pH values, chemical bonds, etc. De Jong and Treagust [15] reached the same conclusions: they also pointed out the problems in understanding the oxidation-reduction concept, such as recognizing the relative strength of oxidizing and reducing agents and the concept of the oxidation state, as well as identifying redox reactions on the basis of chemical equations. The students in our research had the same difficulties.

One of the possible explanations for students having the lowest achievement in the listed tasks is that the related topics contain a lot of concepts that are abstract to them. However, this cannot be the only reason, since in the questions related to other, as well as abstract areas such as atomic structure and chemical bonding, students scored much better. The analysis of the curriculum shows that some parts of the material are completely new to students, while others represent an upgrade of the content of the Chemistry course in elementary school, as well as of other courses (for example, the term isotope is also thought in Physics course). The tasks in which the students had the lowest achievement are those that are related to the topics that were first introduced in the curriculum of chemistry for grammar schools. In addition, teachers' instructions were often oriented to the purely academic approach to chemistry rather than relating chemistry to everyday life phenomena. Teaching and learning chemistry requires a broader perspective and meaningful learning [40] which can be achieved by presenting students with problems that relate to everyday life and satisfy their curiosity while increasing their motivation for learning [41].

The present research is based on the use of Kolb's Learning Style Inventory (LSI), which many authors [22,23] consider to be one of the most widely used measures for identifying preferred learning styles. Our research shows that most students in the sample preferred the assimilating learning style, followed by the diverging and converging styles, while the accommodating style was the least present in students. A similar distribution of learning styles has been identified in previous national surveys [42]. In other research studies, the assimilating learning style has also been identified as the most preferred [43, 44]. This can be explained by the fact that, in formal learning situations, students with an assimilating learning style prefer teachers' lectures [25], which is still the dominant form of instruction in schools in R. Serbia [3]. The above indicates that, in learning chemistry, students like to know the facts, present them in an organized and logical form, and are good at systematizing a wide range of information into a logical structure. Since laboratory and independent research work is less common in Serbian schools [3], it may explain the smaller number of students with a convergent learning style. Finally, the result that the number of students who prefer accommodating learning style is the lowest can probably be explained by the assumption that confronting students with challenging requirements, open issues and opportunities for learning through problem solving is the least represented.

The results revealed that there are significant differences in chemistry achievement between the groups of students who have different learning style preferences. Additionally, it has been documented that those students with the highest achievements prefer the convergent learning style. This means that the highest achievements in chemistry are scored by students who try to answer the question of how to apply the concept. Namely, these students are characterized by logic and pragmatism, and a tendency to solve practical tasks and problems, experimenting with ideas and participating in simulations and laboratory work. According to our knowledge, no study has been carried out in which, using the LSI, the identified learning styles are related to the achievement in chemistry, and there are no relevant results with which the results obtained in this study could be directly compared.

5. CONCLUSION, LIMITATIONS AND IMPLICATIONS FOR FURTHER RESEARCH

Generally speaking, students who prefer a convergent learning style have the highest achievements in chemistry; the most successful are pragmatic students who like laboratory work and practical problem solving. However, the obtained results confirm that all students have difficulties in studying certain chemical concepts, such as chemical equilibrium, salt hydrolysis and oxidation-reduction reactions. Students do not understand the meaning of the concept of the equilibrium constant, nor are they able to calculate its numerical value. Also, students cannot predict the acidity of aqueous solutions of inorganic salts due to their hydrolysis. Students are not able to recognize oxidation-reduction reactions on the basis of the reaction equation, nor can they determine the oxidation states of the elements in the compounds. Given that these concepts create difficulties in learning and understanding among all students equally, the implication of this research is the need to devote more attention to their study, not only on the theoretical (abstract) level, but also to link these concepts to the phenomena in everyday life.

The limitation of this study could be found in the sample of respondents and the sample of chemistry content. Namely, the tested students only attended grammar schools and had a single educational profile. Also, only students' knowledge of general chemistry concepts was investigated. Therefore, in further research, secondary students of other educational profiles with curricula that include chemistry courses (with broader or narrower syllabi) should also be surveyed, and their knowledge of other chemistry disciplines (such as organic chemistry, physical chemistry, chemical technology, etc.) should be tested. Such research could provide additional information on the distribution of learning styles and the differences in chemistry achievement among students who prefer different learning styles. In addition to all of the above, it should be noted that despite considerable empirical support for Kolb's theory of experiential learning, there are criticisms of the theory and inventory that limit its use. Manolis et al. [21] pointed out that the ipsative nature of the scale limits its psychometric qualities and also stated that the length of the scale (48 questions) is the disadvantage. Finally, the degree to which an individual possesses a particular learning style cannot be determined – the scale only identifies the individual's preferred style.

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REFERENCES

[1] M. Prince, R. Felder, The Many Faces of Inductive Teaching and Learning, *J. Coll. Sci. Teach*. **36**, 14–20 (2007). DOI:2200/20080506115505992T.

[2] *Strategy of development of education in Serbia to 2020* (2012). Službeni glasnik Republike Srbije [*RS Official Gazette of the Republic of Serbia*], No. 107/2012.

[3] S. Olić, J. Adamov, Nastavne strategije i učeničko postignuće, *Nastava i vasp*., **66**, 55–66 (2017). DOI:10.5937/nasvas1701055O.

[4] D. Pavlović Babić, A. Baucal, *Podrži me, inspiriši me,* Institut za psihologiju, Beograd, 2012.

[5] O. De Jong, J. Acampo, A. H. Verdonk, Problems in teaching the topic of redox reactions, *J. Res. Sci. Teach.*, **32**, 1097–1110 (1995). DOI: 10.1002/tea.3660321008.

[6] G. Sirhan, Learning Difficulties in Chemistry: An Overview, *J. Turkish Sci. Educ.*, **4**, 2–20 (2007).

[7] A. H. Johnstone, Teaching of Chemistry – Logical or Psychological?, *Chem. Educ. Res. Pract*., **1**, 9–15 (2000). DOI:10.1039/a9rp90001b.

[8] J. D. Bradley, M. D. Mosimege, Misconceptions in acids and bases: a comparative study of student teachers with different chemistry backgrounds., *South African J. Chem*., **51**, 137–145 (1998).

[9] T. Pinarbasi, Turkish Undergraduate Students' Misconceptions on Acids and Bases, *J. Balt. Sci. Educ.*, **6**, 23–34 (2007).

[10] K. Orwat, P. Bernard, A. Migdał-mikuli, Alternative Conceptions of Common Salt Hydrolysis Among Upper-Secondary-school Students, *J. Balt. Sci. Educ.*, **16**, 64–76 (2017).

[11] L. Tyson, D. F. Treagust, R. B. Bucat, The Complexity of Teaching and Learning Chemical Equilibrium, *J. Chem. Educ*., **76**, 554–558 (1999). DOI:10.1021/ed076p554.

[12] J. H. Van Driel, W. Gräber, The teaching and learning of chemical equilibrium in: *Chemical Education: Towards Research-Based Practice*, J. K. Gilbert, O. de Jong, R. Justi, D. F. Treagust, J. H. van Driel (Eds.), Springer Science & Business Media, pp. 271–292, 2002.

[13] N. Yildirim, S. Kurt, A. Ayas, The effect of the worksheets on students' achievement in chemical equilibrium, *J. Turkish Sci. Educ*., **8**, 44–58 (2011).

[14] K. Doymus, Teaching chemical equilibrium with the jigsaw technique, *Res. Sci. Educ.*, **38**, 249–260 (2008). DOI:10.1007/s11165-007-9047-8.

[15] O. De Jong, D. F. Treagust, *The teaching and learning of electrochemistry* in: *Chemical education: Towards research-based practice*, J. K. Gilbert, O. de Jong, R.

Justi, D. F. Treagust, J. H. van Driel (Eds.), Springer Science & Business Media, 2002, pp. 317–337.

[16] R. M. Felder, R. Brent, Understanding student differences, *J. Eng. Educ.*, **94**, 57–72 (2005). DOI:10.1002/j.2168-9830.2005.tb00829.x.

[17] M. H. Towns, Kolb for chemists: David A. Kolb and experiential learning theory, *J. Chem. Educ.*, **78**, 1107-1117 (2001). DOI:10.1021/ed078p1107.7.

[18] E. Collinson, A survey of elementary students' learning style preferences and academic success, *Contemp. Educ*. **71**, 42–48 (2000).

[19] M. Abdulwahed, Z. K. Nagy, Applying Kolb's experiential learning cycle for laboratory education, *J. Eng. Educ*., **98**, 283–294 (2009). DOI:10.1002/j.2168-9830.2009.tb01025.x.

[20] S. Pfeifer, D. Borozan, Fitting Kolb's learning style theory to entrepreneurship learning aims and contents, *Int. J. Bus. Res*., **11**, 216–223 (2011).

[21] C. Manolis, D. J. Burns, R. Assudani, R. Chinta, Assessing experiential learning styles: A methodological reconstruction and validation of the Kolb Learning Style Inventory, Learn. *Individ. Differ.*, **23**, 44–52 (2013). DOI:10.1016/j.lindif.2012.10.009.

[22] O. O. Demirbas, H. Demirkan, Learning styles of design students and the relationship of academic performance and gender in design education, *Learn. Instr.*, **17**, 345–359 (2007). DOI:10.1016/j.learninstruc.2007.02.007.

[23] B. Heffler, Individual learning style and the learning Style Inventory, *Educ. Stud.*, **27**, 307–316 (2001). DOI:10.1080/03055690120076583.

[24] A. Kolb, D. Kolb, The Kolb Learning Style Inventory – Version 3.1 2005 Technical Specifications, LSI, *Tech. Man*., 1–72 (2005). DOI:10.1016/S0260-6917(95)80103-0.

[25] A. Kolb, D. Kolb, Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education, *Acad. Manag. Learn. Educ.*, **4**, 193–212 (2005).

[26] A. Y. Kolb, D. A. Kolb, A. Passarelli, G. Sharma, On becoming an experiential educator the educator role profile, *Simul. Gaming.*, **45**, 204–234 (2014). DOI:10.1177/1046878114534383.

[27] M. H. Towns, Guide to developing high-quality, reliable, and valid multiple-choice assessments, *J. Chem. Educ.* **91**, 1426–1431 (2014). DOI:10.1021/ed500076x.

[28] T. M. Haladyna, M. C. Rodriguez, *Developing and Validating Test Items*, Routledge, London, 2013.

[29] S. Đukić, R. Nikolajvić, M. Šurjanović, *Opšta hemija*, Zavod za udžbenike, Beograd, 2011.

[30] D. Kolb, *Kolb Learning Style Inventory (LSI Workbook)*, Hay Group, Boston MA, 2010.

[31] M. Segedinac, M. Segedinac, Z. Konjovic, G. Savic, A formal approach to organization of educational objectives, *Psihologija*. **44**, 307–323 (2011). DOI:10.2298/PSI1104307S.

[32] A. Field, *Discovering statistics using SPSS*, Sage, London, 2009.

[33] L. Ding, R. Chabay, B. Sherwood, R. Beichner, Evaluating an electricity and magnetism assessment tool: Brief electricity and magnetism assessment, *Phys. Rev. Spec. Top. Phys. Educ. Res.*, **2**, 1–7 (2006). DOI:10.1103/PhysRevSTPER.2.010105.

[34] R. Ebel, D. Frisbie, *Essentials of Educational Measurement*, Pretince-Hall of India, New Delhi, 1991.

[35] D. C. Kayes, Internal validity and reliability of Kolb's learning style inventory version 3 (1999), *J. Bus. Psychol.*, **20**, 249–257 (2005). DOI:10.1007/s10869-005-8262-4.

[36] C. McCabe, Preferred Learning Styles among College Students: Does Sex Matter?, *N. Am. J. Psychol.*, **16**, 89–104 (2014). DOI:http://dx.doi.org/10.1108/17506200710779521.

[37] D. A. Kidanemariam, Do Learning Styles Influence Students' Understanding of Chemistry Concepts and Academic Performance in Chemistry ?, *Mediter. J. Soc. Sci.*, **3**, 167–172 (2013). DOI:10.5901/jesr.2013.v3n5p167.

[38] V. Kind, Beyond Appearances: Students' misconceptions about basic chemical ideas, *Sch. Educ.* 1–84 (2004). DOI:10.1017/CBO9781107415324.004.

[39] K. W. Voska, H. W. Heikkinen, Identification and analysis of student conceptions used to solve chemical equilibrium problems, *J. Res. Sci. Teach.*, **37**, 160–176 (2000). DOI:10.1002/(SICI)1098-2736(200002)37:2<160::AID-TEA5>3.0.CO;2-M.

[40] D. Treagust, R. Duit, M. Nieswandt, Sources of students' difficulties in learning Chemistry, *Educ. Química.*, **6**, 228–235 (2000).

[41] M. Stuckey, I. Eilks, Increasing student motivation and the perception of chemistry's relevance in the classroom by learning about tattooing from a chemical and societal view, *Chem. Educ. Res. Pr.*, **15**, 156–167 (2014). DOI:10.1039/C3RP00146F.

[42] S. Olić, J. Adamov, Relationship between learning styles grammar students and school achievement, *Teme - Časopis za društvene nauk*., **40**, 1223–1240 (2016). DOI:10.22190/TEME1604223O.

[43] Y. Yamazaki, Learning styles and typologies of cultural differences: A theoretical and empirical comparison, *Int. J. Intercult. Relations.*, **29**, 521–548 (2005). DOI:10.1016/j.ijintrel.2005.07.006.

[44] N. E. Cagiltay, Using Learning Style Theory in Engineering Education, *Eur. J. Eng. Educ*., **33**, 415–424 (2008).