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STUDENTS' PERCEPTIONS OF THE IMPORTANCE OF CHEMISTRY AND ITS CONNECTION WITH VOCATIONAL SUBJECTS IN SECONDARY MEDICAL EDUCATION

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Abstract

Chemistry provides foundational knowledge for vocational subjects in secondary medical education, yet the extent to which students recognize its relevance to vocational learning requires further examination. This study examined students' perceptions of the importance and applicability of chemistry, its relationship with vocational subjects, and the contexts in which students recognize its relevance. A cross-sectional survey was conducted with a convenience sample of 245 third- and fourth-year students from nine healthcare-related educational profiles in Serbia. Data were collected using an anonymous, author-developed questionnaire comprising Likert-scale, multiple-response, and open-ended items. Internal consistency and exploratory factor analysis were used to examine the perception scale, while nonparametric tests assessed differences by grade and educational profile. The five-item Perception of the Importance and Applicability of Chemistry scale demonstrated good internal consistency (Cronbach's α = .867). Students perceived chemistry as moderately important and applicable to vocational learning, particularly in Medical Biochemistry and Pharmacology. Acids, Bases, and pH and Biochemical Processes and Biomolecules were most frequently identified as important chemistry areas. Perception scores differed significantly by grade and educational profile. Open-ended responses indicated interest in stronger connections between chemistry and vocational subjects and more professionally relevant and practice-oriented examples. The findings suggest that making connections between chemical concepts and vocational contexts more explicit may strengthen the professional relevance of chemistry teaching. By providing evidence from students' perspectives, the study complements existing research and supports consideration of more contextually and vocationally connected approaches to chemistry teaching.

Keywords: *chemistry education, students' perceptions, vocational education, questionnaire survey, exploratory factor analysis*

Introduction

The Role of Chemistry in Developing the Competencies of Healthcare Students

The development of modern healthcare, driven by advances in medical sciences, pharmacy, biotechnology, and laboratory diagnostics, places new demands on the education of future healthcare professionals. Contemporary models of healthcare education emphasize the interdisciplinary integration of knowledge, critical thinking, and the application of scientific principles in professional contexts (Frenk et al., 2010).

Within the fundamental natural sciences, chemistry plays a particularly important role in the education of students preparing for careers in healthcare, as it enables an understanding of the molecular foundations of biological, physiological, and pathophysiological processes. Chemical

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knowledge provides a foundation for understanding the structure and function of biomolecules, mechanisms of drug action, metabolic processes, and interactions among substances in the human body. It therefore supports the acquisition of scientific knowledge relevant to healthcare-related vocational subjects and future professional practice (Pienta, 2017). Therefore, chemistry education for students in healthcare-related educational profiles represents not merely a general education subject, but also a foundation for understanding professional disciplines and applying their knowledge in future professional practice.

The importance of chemistry is particularly evident in the education of students attending secondary medical schools, as their future professional work requires an understanding of complex biochemical and chemical processes. Knowledge of solutions, acid–base equilibria, oxidation–reduction processes, and molecular interactions is essential for understanding the content of professional subjects such as pharmacology, biochemistry, physiology, pathophysiology, and laboratory medicine (Durning et al., 2012).

Chemical Literacy and Contextualized Learning

In contemporary education, particular importance is placed on the development of chemical literacy, which extends beyond the traditional understanding of chemistry as a collection of facts, formulas, and rules. Chemical literacy encompasses the ability to understand fundamental chemical concepts, interpret scientific information, and apply chemical knowledge in various everyday and professional contexts (Shwartz et al., 2006). It represents an important aspect of scientific literacy, which involves not only the acquisition of scientific facts but also their application to understanding problems, making decisions, and actively participating in society (Bybee, 1997; Holbrook & Rannikmäe, 2009). In vocational education, students' recognition of the relevance of chemical knowledge to their field of study represents an important aspect of understanding how chemistry is perceived within their broader educational experience.

The mere presence of chemical content in curricula is not sufficient to ensure its functional value in the education of future healthcare professionals. One of the key challenges of contemporary education is connecting fundamental scientific disciplines with vocational subjects, as students in traditional instructional models often acquire scientific concepts as isolated pieces of information, without a clear understanding of their application in professional contexts. Such an approach may limit the transfer of knowledge and the application of scientific concepts in different professional situations (Ambrose et al., 2010).

Contextualized learning, which connects fundamental scientific concepts with authentic professional situations, represents one of the contemporary approaches to teaching that contributes to a better understanding of the relevance of scientific knowledge and its application in practice (Gilbert, 2006). Research suggests that context-based approaches can support students' interest in chemistry and help them recognize the relevance of scientific knowledge beyond the classroom, although their effects on learning outcomes may vary across instructional settings (Bennett et al., 2007; King, 2012). For students in healthcare-related educational profiles, it enables a direct connection between chemical knowledge, vocational subjects, and future professional practice.

Integration of Chemistry with Vocational Subjects

The integration of chemistry with vocational subjects represents an important prerequisite for the development of professional competencies among students in healthcare-related educational profiles. Research on healthcare education has emphasized the importance of integrating foundational scientific knowledge with professional learning rather than teaching these areas as isolated components (Bandiera et al., 2013; Durning et al., 2012). Although

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these studies have primarily been conducted in higher education for healthcare professionals, their findings are also relevant to secondary medical schools, as this is the stage at which the foundations of professional thinking and the application of scientific knowledge are established.

Within this perspective, secondary medical education provides a relevant setting for examining the perceived professional relevance of chemistry, as students encounter chemistry both as a general scientific discipline and as a knowledge base underlying vocational subjects. The present study therefore examined not only whether students consider chemistry important, but also where they recognized its application within their vocational education and which chemistry content areas they perceived as most relevant to vocational learning. By focusing on the perspectives of secondary medical school students in Serbia, the study provided evidence that complements existing research on the role of chemistry in vocational education and could inform efforts to strengthen connections between chemistry teaching and vocational subjects.

Research Problem

Students' perceptions of the relevance of chemistry represent an important consideration in vocational education, where chemical knowledge is expected to support learning in profession-related subjects. Previous research has examined students' attitudes towards chemistry in secondary vocational schools (Rusek, 2011), while studies of context-based science education have highlighted the value of connecting scientific concepts with meaningful learning contexts (Bennett et al., 2007; Gilbert, 2006). In secondary medical education, these connections are particularly relevant because students encounter chemical concepts both in general chemistry and in vocational subjects, including medical biochemistry, pharmacology, and laboratory-related subjects.

However, the existence of conceptual connections between chemistry and vocational content does not necessarily mean that students recognize them or perceive chemistry as relevant to their education. Students are expected to relate chemical knowledge acquired in a general education subject to vocational learning, but their perceptions of where and how this knowledge is applicable require further examination. Understanding these perceptions can provide insight into the vocational subjects and chemistry content areas in which students recognize such connections, as well as their views on how chemistry teaching could be more closely related to vocational learning.

In the Serbian context, previous research has addressed the significance of chemistry curricula for secondary medical education from the perspective of vocational subject teachers (Rašić et al., 2026). The present study complements this perspective by examining students' perceptions of the importance and applicability of chemistry, differences in these perceptions across grade levels and educational profiles, and students' examples and suggestions concerning the relationship between chemistry and vocational education.

Research Aim and Research Questions

The aim of this study was to examine secondary medical school students' perceptions of the importance and applicability of chemistry in vocational education and its relationship with vocational subjects. The study also sought to identify the vocational contexts and chemistry content areas in which students recognize the relevance of chemical knowledge, examine differences in perceptions according to grade level and educational profile, and explore students' examples and suggestions concerning the connection between chemistry and vocational learning.

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The following research questions were formulated:

RQ1. How do secondary medical school students perceive the importance and applicability of chemistry and its relationship with vocational learning?

RQ2. Do students' perceptions of the importance and applicability of chemistry differ according to grade level and educational profile?

RQ3. In which vocational subjects and areas of chemistry do students most frequently recognize the relevance and application of chemistry knowledge?

RQ4. How do students describe the application of chemistry knowledge in vocational subjects and practical training, and what suggestions do they provide regarding the relationship between chemistry and vocational education?

Research Methodology

Design

The study was designed as a cross-sectional survey to examine secondary medical school students' perceptions of the importance, applicability, and vocational relevance of chemistry. A cross-sectional design was considered appropriate because the study aimed to examine students' perceptions at a single point in time and to compare these perceptions across grade levels and educational profiles, without manipulating the educational setting or introducing an intervention. Data were collected in May 2026 from third- and fourth-year students enrolled in secondary medical schools in the Republic of Serbia. The study focused on students' perceptions of the relationship between chemistry and vocational education, including the applicability of chemical knowledge to vocational subjects and future professional practice, as well as students' views on the connection between chemistry and vocational content.

Sample

The invitation to participate in the study, together with a link to the electronic questionnaire, was distributed to all secondary medical schools in Serbia. School principals were asked to forward the questionnaire to relevant subject teachers, who subsequently shared the link with eligible third- and fourth-year students. Participation was voluntary and anonymous. Information about the school attended was not collected. Consequently, although the invitation was distributed nationally, the number of schools represented among the respondents could not be determined. Furthermore, the researchers did not have information on the total number of eligible students who received the questionnaire link. Therefore, an exact response rate could not be calculated. Before completing the questionnaire, the participants were informed about the aim of the study and the way in which the data would be used. The data were processed exclusively for scientific purposes, and only information that did not allow the identification of individual participants was collected.

The sample size was not determined a priori. Participation was voluntary, and the final sample consisted of all 245 eligible students who completed the questionnaire in full during the data-collection period. According to official data from the Statistical Office of the Republic of Serbia, 11738 students were enrolled in the third and fourth grades within the field of Health and Social Welfare at the beginning of the 2025/2026 school year (Statistical Office of the Republic of Serbia, 2026). Thus, the achieved sample represented approximately 2.1% of the third- and fourth-year student population enrolled in this field of education. However, because non-probability convenience sampling was used, this proportion should not be interpreted as evidence of national representativeness, and generalization of the findings to the entire population should be made with caution. Of the participants, 143 (58.4%) were third-year students and 102

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(41.6%) were fourth-year students. The sample comprised 203 female students (82.9%) and 42 male students (17.1%).

Participants represented nine healthcare-related educational profiles. The largest groups were Nurse–Technician students (n = 103, 42.0%) and Pharmacy Technicians (n = 64, 26.1%). The remaining participants were Gynecological–Obstetric Nurse Technicians (n = 28), Physiotherapy Technicians (n = 17), Laboratory Technicians (n = 12), Nurse–Educators (n = 8), Dental Technicians (n = 7), Sanitary–Ecological Technicians (n = 5), and Cosmetic Technician (n = 1).

Instrument and Procedures

The questionnaire used in this study was developed by the authors specifically for the purposes of the present research based on the study objectives and the literature on chemistry education, chemical literacy, and vocational education. Before the main data collection, the initial version of the questionnaire was reviewed by three experts in chemistry education methodology. The experts evaluated the relevance, clarity, and appropriateness of the questionnaire items for students enrolled in secondary medical education programmes. Based on their comments and suggestions, several items were revised to improve wording and comprehensibility before the questionnaire was distributed. The final questionnaire was administered electronically using Google Forms. An English translation of the complete questionnaire is provided in Appendix A. The questionnaire included Likert-scale and multiple-response items for the collection of quantitative data, as well as open-ended items designed to provide supplementary qualitative insights into students' perceptions and suggestions.

The final questionnaire consisted of 15 items organized into three sections. The first section (Items 1–3) collected demographic and educational information, including grade level, gender, and educational profile. The second section (Items 4–11) contained eight statements addressing students' perceptions of chemistry in vocational education. Responses were provided on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Items 12 and 13 were multiple-response questions. Item 12 asked students to identify the vocational subjects in which they recognized the application of chemistry knowledge, whereas Item 13 asked them to identify the areas of chemistry they considered most important for understanding vocational subjects. Items 14 and 15 were open-ended questions. Item 14 invited students to provide a concrete example from a vocational subject or practical training in which chemistry knowledge had been required. Item 15 provided an opportunity to express additional opinions or suggestions concerning the relationship between chemistry and vocational subjects.

A separate pilot study with students was not conducted prior to the main data collection. The psychometric properties of the eight Likert-type items were examined using the full study sample (N = 245). The initial eight-item set demonstrated relatively low internal consistency (Cronbach's α = .585; Tavakol & Dennick, 2011; Taber, 2018) . Exploratory factor analysis indicated that Items 4–8 formed a coherent factor reflecting students' perceptions of the importance and applicability of chemistry in vocational education. The resulting five-item scale demonstrated good internal consistency (Cronbach's α = .867; Tavakol & Dennick, 2011; Taber, 2018). Based on the psychometric analyses, items 4–8 were retained as a five-item composite scale representing students' perceptions of the importance and applicability of chemistry. The composite score was calculated as the mean of these five items. Items 9–11 were not included in the composite score and were analysed separately.

Exploratory factor analysis (Principal Axis Factoring) with Varimax rotation and Kaiser normalization was conducted to examine the latent structure of the instrument. The suitability of the data for factor analysis was assessed using the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity (Bartlett, 1954; Kaiser, 1974). The obtained

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KMO value of 0.789 indicated good sampling adequacy for factor analysis. Bartlett's test of sphericity was statistically significant ($\chi^2 = 701.644$; $p < .001$), confirming the appropriateness of conducting factor analysis (Kaiser, 1974).

According to Kaiser's criterion (eigenvalue > 1), two factors were extracted. The first factor explained 37.338% of the variance, while the second accounted for an additional 12.591%, resulting in the two extracted factors cumulatively explaining 49.929% of the total variance. In studies conducted in the social sciences, particularly those involving newly developed attitude scales, an explained variance of approximately 50% is generally considered acceptable (Field, 2018; Hair et al., 2019).

The rotated factor loading matrix showed a clear separation of the items into two latent dimensions. The factors were interpreted and named according to the conceptual meaning of the items with the highest loadings on two factors:

- Factor 1 – Perception of the Importance and Applicability of Chemistry (Items 4–8). This factor comprises items addressing the importance of chemistry, its application in students' future professions, and its connection with vocational knowledge.
- Factor 2 – Attitudes Toward Improving Chemistry Teaching and Strengthening Its Connection with Vocational Subjects (Items 9 and 11). This factor comprises items addressing the need for stronger connections between chemistry teaching and vocational content, as well as the use of practical examples in teaching. Item P10 did not demonstrate a satisfactory factor loading on either of the extracted factors and was therefore treated as a separate variable in subsequent analyses.

Data Analysis

Descriptive statistics, including frequencies, percentages, means, standard deviations, medians, and interquartile ranges, were used as appropriate to summarize the sample characteristics and students' responses. Given the non-normal distribution of the data and the ordinal nature of the Likert-scale responses, non-parametric statistical methods were considered the most appropriate for subsequent analyses (Field, 2018). The normality of the distribution of the composite scale *Perception of the Importance and Applicability of Chemistry* was assessed using the Shapiro–Wilk test (Pallant, 2020). It indicated a statistically significant deviation from normality ($p < .001$); therefore, non-parametric statistical tests were applied in the subsequent analysis.

As the distribution of the data did not meet the assumption of normality, non-parametric statistical tests were used to examine differences. Differences between third- and fourth-year students were examined using the Mann–Whitney U test, whereas differences among students from different educational profiles were analysed using the Kruskal–Wallis test. For comparisons according to educational profile, the Cosmetic Technician profile was excluded from the Kruskal–Wallis analysis because a single observation could not provide a meaningful representation of within-profile variability. The participant was retained in the overall descriptive analyses. The remaining profile groups were included in the omnibus analysis; however, given the substantial imbalance in group sizes and the very small number of participants in several educational profiles, no post hoc pairwise comparisons were performed. The Kruskal–Wallis results were therefore interpreted as overall differences among educational profiles, without attributing statistical significance to specific pairs of groups.

In addition to statistical significance, effect size measures (r and ε^2) were reported to assess the practical significance of the observed differences. Responses to closed-ended questions were analysed using frequencies and percentages.

Items 12 and 13 allowed multiple responses. Therefore, each response option was summarized using frequencies and percentages of participants selecting that option. Because

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participants could select more than one response, the percentages across response categories were not expected to sum to 100%. Responses to the open-ended Items 14 and 15 were analysed using an inductive qualitative content approach. Two researchers independently reviewed and coded the responses by grouping conceptually similar statements into categories based on recurring content. Responses that did not provide codable content (e.g., "I do not know" or "I do not wish to answer") were excluded from the inter-coder agreement analysis. For Item 14, 175 responses containing codable content were included, and the coders agreed on 89.1% of the classifications, with Cohen's $\kappa = .857$. For Item 15, 21 responses containing codable content were included, and the coders agreed on 90.5% of the classifications, with Cohen's $\kappa = .875$. Following the independent coding, disagreements were jointly reviewed and discussed by the two researchers until consensus was reached on the final category assignment. The resulting categories were used to summarize students' examples of applying chemistry knowledge and their suggestions and views concerning the relationship between chemistry and vocational education. Representative responses were selected to illustrate the categories and contextualize the quantitative findings. Data saturation was not used as a criterion for determining the sample size or terminating data collection because the open-ended items formed part of a cross-sectional questionnaire administered to a predetermined sample rather than a standalone qualitative study based on iterative recruitment. All available responses to the open-ended items were reviewed, and the qualitative analysis was used to complement and contextualize the quantitative findings.

Research Results

I. Students' Perceptions of the Importance and Applicability of Chemistry

Descriptive analysis of the composite perception score indicated a mean of 3.44 (SD = 1.09), with a median of 3.60 (IQR = 1.80). Scores ranged from 1 to 5, and the 95% confidence interval for the mean was [3.31, 3.58]. These findings indicate that students' perceptions were, on average, slightly above the midpoint of the response scale, although substantial variability was observed across participants.

Differences in the Perception of the Importance and Applicability of Chemistry According to Grade Level

The Mann–Whitney U test revealed a statistically significant difference in the perception of the importance and applicability of chemistry between third- and fourth-year students (U = 5656.00, $Z = -2.999$, $p = .003$). Higher mean ranks were observed for third-year students (MR = 134.45) than for fourth-year students (MR = 106.95). The effect size was small ($r = .192$) (Cohen, 1988).

Differences in the Perception of the Importance and Applicability of Chemistry According to Educational Profile

Prior to the between-profile analysis, the educational profile represented by only one participant (Cosmetic Technician) was excluded from the Kruskal–Wallis test because a single observation could not provide a meaningful basis for group-level comparison. The participant was retained in all overall descriptive analyses. The Kruskal–Wallis test conducted across the remaining eight educational profiles revealed statistically significant differences in the perception of the importance and applicability of chemistry, $H(7) = 53.601$, $p < .001$, $\varepsilon^2 = .20$ (Tomczak & Tomczak, 2014). The highest mean ranks were observed among students enrolled in the Laboratory Technician (MR = 181.96) and Pharmacy Technician (MR = 167.97) programmes.

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Although the overall Kruskal–Wallis test was statistically significant, post hoc pairwise comparisons were not performed because three educational profiles had very small sample sizes (n = 5–8) and the group sizes were substantially imbalanced. Consequently, the result was interpreted as an overall difference among educational profiles, without identifying statistically significant differences between specific pairs of groups. Such unequal and very small group sizes may reduce the reliability and statistical power of pairwise comparisons and increase the risk of misleading conclusions (Field, 2018).

Perceptions of Chemistry Teaching Improvement

For Items 9–11, which were analysed as individual variables, descriptive statistics were calculated (Table 1). Mean scores ranged from 2.96 to 3.11, indicating generally neutral responses, while standard deviations (SD = 1.44–1.56) suggested moderate variability among students' responses.

Table 1
Descriptive Statistics for Items 9–11

Item	*M*	*SD*	Range
P9	3.053	1.466	4.000
P10	2.963	1.558	4.000
P11	3.110	1.440	4.000

Differences between third- and fourth-year students were examined using the Mann–Whitney U test. A statistically significant difference was found only for Item 9 (U = 6182.00, Z = −2.078, p = .038). Third-year students had higher mean ranks (MR = 130.77) than fourth-year students (MR = 112.11), with a small effect size (r = .13) (Cohen, 1988). No statistically significant differences were observed for Items 10 and 11 (p > .05).

Differences among educational profiles were examined using the Kruskal–Wallis test. No statistically significant differences were found for any of the three items (all p > .05).

II. Perception of the Application and Importance of Chemical Knowledge in Vocational Education

Application of Chemistry Knowledge in Vocational Subjects

Item 12 asked students to identify the vocational subjects in which they recognized the application of chemistry knowledge. Medical Biochemistry was the most frequently selected subject (n = 168, 68.6%), followed by Pharmacology (n = 97, 39.6%). Practical Training (n = 31, 12.7%) and Hygiene (n = 24, 9.8%) were selected less frequently. Additionally, 21 students (8.6%) indicated that they had not applied chemistry knowledge in vocational subjects. The complete distribution of responses is presented in Table 2. As participants could select more than one response, percentages were calculated separately for each option using the total sample (N = 245) as the denominator and were not expected to sum to 100%.

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Table 2
Vocational Subjects in Which Students Recognize the Application of Chemistry Knowledge (N = 245)

Vocational subject	*n*	%
Medical Biochemistry	168	68.6
Pharmacology	97	39.6
Practical Training	31	12.7
Hygiene	24	9.8
I have not applied chemistry knowledge	21	8.6
Health Care	18	7.3
Anatomy and Physiology	9	3.7
Introduction to Laboratory Work	5	2.0
Pharmaceutical Chemistry	3	1.2
Laboratory Techniques	1	0.4

Areas of Chemistry Considered Most Important by Students

Item 13 asked students to identify the areas of chemistry they considered most important for understanding vocational subjects. Acids, Bases, and pH was the most frequently selected area (n = 154, 62.9%), followed by Biochemical Processes and Biomolecules (n = 147, 60.0%). Other frequently selected areas included Chemical Bonds and Structure of Substances (n = 80, 32.7%), Fundamentals of Organic Chemistry (n = 78, 31.8%), and Dispersed Systems (n = 67, 27.3%). The complete distribution of responses is presented in Table 3.

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Table 3
Chemistry Content Areas Considered Important for Understanding Vocational Subjects

Chemistry area	*n*	% of students
Acids, Bases, and pH	154	62.9
Biochemical Processes and Biomolecules	147	60.0
Chemical Bonds and Structure of Substances	80	32.7
Fundamentals of Organic Chemistry	78	31.8
Dispersed Systems	67	27.3
Structure of Atoms and Molecules	59	24.1
Fundamentals of Inorganic Chemistry	55	22.4
Stoichiometry and Chemical Calculations	37	15.1
Oxidation–Reduction Reactions	36	14.7
Chemical Equilibrium	26	10.6
None of the Listed Areas	23	9.4
Chemical Kinetics	19	7.8
Other	5	2.0

Students' Examples of Applying Chemistry Knowledge

Responses to the open-ended Item 14 were grouped into seven content categories, presented in Table 4. Students provided examples related to biochemistry and biological processes, acid–base properties, preparation of solutions and concentration calculations, laboratory methods, pharmaceutical applications, disinfection, and the chemical structure and properties of substances. The examples included metabolic processes and biomolecules, pH measurements of body fluids, preparation and dilution of solutions, biochemical analyses, and the use of disinfectants. These responses illustrate the range of vocational contexts in which students recognized the application of chemistry knowledge.

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Table 4
Categories and Representative Examples of Students' Responses on the Application of Chemistry Knowledge

Category	Examples of students' responses
Biochemistry and Understanding of Biological Processes	"Biochemistry," "biochemistry reactions," "metabolism," "proteins," "amino acids," "ATP," "structure of fats"
pH, Acids, and Bases	"pH values of blood and body fluids," "measuring urine pH," "acids and bases"
Preparation of Solutions and Concentration Calculations	"preparation of solutions," "mass fraction," "drug dilution," "preparation of an infusion solution," "hypotonic solution"
Laboratory Techniques and Analytical Methods	"introduction to laboratory work," "analytical chemistry," "glucose oxidase method," "biochemical analyses"
Drugs and Pharmaceutical Applications of Chemistry	"dissolution of drugs," "pharmaceutical chemistry," "pharmacology," "penicillins"
Disinfection and Application of Chemical Agents	"disinfectants," "ethanol," "preparation of disinfectant solutions"
Chemical Structure and Properties of Substances	"chemical bonds," "functional groups," "chemical formulas," "properties of substances"

The largest number of students associated the application of chemistry knowledge with biochemistry and medical biochemistry. Students particularly emphasized the importance of understanding metabolic processes, the structure of biomolecules, proteins, and other substances essential for the functioning of the human body.

A considerable number of responses referred to the application of knowledge about solutions, concentrations, and acid–base properties. Students provided examples such as solution preparation, drug dilution, preparation of infusion solutions, determination of the pH of body fluids, and the use of disinfectants. Students also recognized the importance of chemistry in laboratory analyses, pharmaceutical chemistry, and pharmacology, indicating that they perceived connections between basic chemical knowledge and vocationally relevant healthcare content.

Students' Views and Suggestions for Chemistry Teaching

Responses to the open-ended Item 15 were organized into six content categories (Table 5). Some students suggested increasing the representation of chemistry in secondary medical education and strengthening its connections with vocational subjects. Other suggestions concerned a greater emphasis on professionally relevant chemistry content, more practical and laboratory-based activities, and simpler explanations of abstract concepts and calculation-based tasks. Not all responses indicated a desire for more chemistry instruction. Some students expressed limited perceived relevance of chemistry to their future profession. These differing views provide additional context for interpreting the quantitative findings on students' perceptions of chemistry.

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Table 5
Categories and Representative Examples of Students' Suggestions and Views on Chemistry Teaching

Category	Examples of students' responses
Greater Representation of Chemistry in Medical Education	"Introduce chemistry every year from the first to the fourth year"; "One year of chemistry is not enough."
Stronger Integration of Chemistry with Vocational Subjects	"Chemistry should be more connected with professional subjects"; "Biochemistry explains processes in the human body."
Greater Emphasis on Professionally Relevant Chemical Content	"More biochemistry"; "Solutions"; "Acids and bases"; "pH"; "Less stoichiometry."
More Practical and Laboratory-Based Teaching	"More laboratory work"; "More practical examples"; "Video demonstrations."
Simplification of Abstract and Calculation-Based Content	"Less stoichiometry"; "Fewer calculations"; "Explain concepts more simply."
Limited Perceived Relevance of Chemistry	"There is no connection"; "We do not need chemistry."

Discussion

The present study examined students' perceptions of the importance and applicability of chemistry in secondary medical education, differences in these perceptions according to grade level and educational profile, the vocational subjects and chemistry content areas in which students recognized the relevance of chemistry, and students' examples and suggestions concerning the relationship between chemistry and vocational education. Overall, students' perceptions of the importance and applicability of chemistry were moderately positive, although considerable variability was observed. Differences were identified according to grade level and educational profile, while students most frequently recognized the relevance of chemistry in Medical Biochemistry and Pharmacology and emphasized chemistry content related to acids, bases and pH, and biochemical processes and biomolecules. Their open-ended responses provided additional insight into the professional contexts in which they recognized the application of chemistry and their views on how chemistry teaching could be more closely connected with vocational education.

Overall, students perceived chemistry as moderately important and applicable to their vocational education, with the mean composite score slightly above the midpoint of the response scale. At the same time, the variability in scores indicates that students did not perceive the vocational relevance of chemistry uniformly. Students may recognize the importance of chemistry for their future profession while holding different views regarding its applicability to their particular educational and professional contexts.

These findings are consistent with research showing that students evaluate educational content more positively when they recognize its practical application and connection with real-life and professional contexts (Bennett et al., 2007; Reid, 2008). Similarly, Wood (2003) emphasizes that fundamental knowledge of chemistry provides a basis for understanding more complex medical disciplines, including biochemistry, pharmacology, and laboratory diagnostics. From this perspective, the perceived relevance of chemistry in secondary medical

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education may depend not only on the content itself but also on how clearly students recognize its relationship with vocational learning.

The psychometric analysis supported the use of Items 4–8 as a composite measure of students' perceptions of the importance and applicability of chemistry. The analysis also indicated that the original set of items did not represent a single underlying construct. This is consistent with research suggesting that students' attitudes toward science may involve multiple related dimensions, including perceptions of usefulness, interest, and motivation (Bauer, 2008). In the present study, items concerning possible improvements in chemistry teaching were therefore considered separately from the composite perception scale. Students' responses to Items 9–11 were generally close to the midpoint of the response scale, suggesting neither strong agreement nor strong disagreement with the proposed changes to chemistry teaching. This finding is noteworthy because students' moderately positive perceptions of the importance and applicability of chemistry were not accompanied by equally strong support for specific changes in chemistry teaching. Thus, recognizing the vocational relevance of chemistry does not necessarily imply that students uniformly favour particular approaches to its organization or improvement.

A statistically significant difference was observed between third- and fourth-year students, with third-year students showing a more positive perception of the importance and applicability of chemistry. The higher perception scores observed among third-year students are not necessarily an expected pattern, as greater exposure to vocational education might suggest that students at a later stage of schooling would recognize the professional relevance of chemistry more clearly. The present findings did not follow this assumption. However, because the study was cross-sectional and did not measure differences in curricular exposure, the timing of chemistry instruction, or the specific vocational content encountered by students in each grade, the reasons for this pattern remain unclear. This finding therefore warrants further investigation rather than a causal interpretation.

Statistically significant overall differences were also observed among educational profiles. The highest mean ranks were found among Laboratory Technician and Pharmacy Technician students. However, because post hoc pairwise comparisons were not performed, the present findings do not establish which specific educational profiles differed significantly from one another. Nevertheless, the observed pattern is compatible with the possibility that students attach greater value to knowledge when they perceive it as relevant to their educational and professional roles, as proposed within expectancy–value theory (Wigfield & Eccles, 2000).

Differences observed across educational profiles should not be attributed solely to students' professional orientation. The profiles may also differ in the amount and sequencing of chemistry-related content within their curricula, the extent to which chemistry is explicitly integrated into vocational subjects, and students' exposure to laboratory and other practical activities. In addition, instructional practices and teachers' emphasis on connections between chemistry and vocational content may contribute to students' perceptions. Because these contextual factors were not measured in the present study, their potential contribution to the observed between-profile differences cannot be separated from the differences associated with educational profile itself. Accordingly, the profile-related findings should be interpreted as exploratory differences within the present sample rather than as evidence that educational profile independently determines students' perceptions of chemistry.

Students most frequently recognized the application of chemistry knowledge in Medical Biochemistry and Pharmacology. At the level of chemistry content, acids, bases and pH and biochemical processes and biomolecules were the areas most frequently identified as important for vocational learning. Chemical bonds and the structure of substances and fundamentals of organic chemistry were also selected by a substantial proportion of students.

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This pattern suggests that students most readily recognize the relevance of chemistry when chemical concepts can be related to biological processes, medicines, substances, and other professionally recognizable contexts. Such findings are consistent with contextualized approaches to science education, which emphasize the importance of connecting scientific concepts with meaningful situations and contexts (Bennett et al., 2007; Gilbert, 2006). In secondary medical education, making these connections explicit may be particularly relevant because chemistry provides conceptual foundations for several areas encountered in vocational subjects.

The open-ended responses provided additional context for these quantitative findings. Students associated the application of chemistry with biochemistry and medical biochemistry, pharmaceutical content, laboratory techniques and analyses, solution preparation and concentration calculations, pH and acid–base properties, disinfectants, and the chemical structure and properties of substances. These examples indicate that students recognized chemistry across a range of professional contexts, particularly when its application could be linked to concrete procedures, substances, or biological processes.

Students' open-ended responses also revealed different views regarding how chemistry teaching could be more closely related to vocational education. Some students suggested greater representation of chemistry in medical education and stronger integration with vocational subjects, while others emphasized professionally relevant chemistry content, practical and laboratory-based teaching, and simpler explanations of abstract and calculation-based content. At the same time, some responses indicated limited perceived relevance of chemistry to students' future professions. This variation is consistent with the variability observed in the quantitative perception scores and indicates that students do not constitute a homogeneous group in terms of how they perceive the role of chemistry in their vocational education.

These findings have practical implications for the planning of chemistry teaching in secondary medical schools. Greater use of professionally relevant contexts could be considered as one way of making the relationship between chemistry and vocational learning more explicit. Connecting chemical concepts with examples from pharmacology, biochemistry, laboratory diagnostics, and other areas of healthcare practice may provide students with opportunities to recognize how chemical knowledge relates to their vocational education. This interpretation is consistent with the concept of contextualized learning (Gilbert, 2006; King, 2012) and with approaches to scientific literacy that emphasize the functional application of scientific knowledge (Holbrook & Rannikmäe, 2009).

More broadly, the findings are compatible with approaches in health professions education that emphasize connections between foundational scientific knowledge and professional learning (Frenk et al., 2010). However, the present study examined students' perceptions rather than the effects of a particular instructional intervention. Therefore, the findings should not be interpreted as evidence that greater integration of chemistry with vocational subjects would necessarily improve achievement, motivation, or professional competencies. Rather, they indicate that many students recognize chemistry most readily when they can relate it to vocational content and concrete professional contexts.

Conclusions, Limitations and Implications

The primary aim of this study was to examine secondary medical school students' perceptions of the importance and applicability of chemistry in vocational education, including differences according to grade level and educational profile and the vocational contexts in which students recognized the relevance of chemistry. Overall, students perceived chemistry as moderately important and applicable to their vocational learning, although considerable variability in perceptions was observed. Students particularly recognized the relevance

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of chemistry in Medical Biochemistry and Pharmacology and identified acids, bases and pH and biochemical processes and biomolecules as important chemistry content areas for vocational learning. Their open-ended responses further illustrated applications of chemistry in professionally relevant contexts, including laboratory procedures, solution preparation, pharmaceutical applications, and the use of disinfectants.

Differences in perceptions were observed according to grade level and educational profile. Third-year students showed more positive perceptions than fourth-year students, while the overall comparison among educational profiles was also statistically significant. However, because post hoc pairwise comparisons were not performed, the findings do not establish which specific educational profiles differed significantly from one another. These differences should therefore be interpreted as patterns within the present sample rather than as evidence of effects attributable independently to grade level or educational profile.

The psychometric analyses supported the use of Items 4–8 as a composite measure of students' perceptions of the importance and applicability of chemistry, with high internal consistency in the present sample. Items concerning possible improvements in chemistry teaching were considered separately. Further validation using independent student samples would be valuable before broader use of the instrument.

Students' open-ended responses also indicated interest in stronger connections between chemistry and vocational subjects, greater use of professionally relevant examples, and more practical and laboratory-based learning opportunities, although not all students expressed the same views. These findings suggest that greater attention could be given to making connections between chemical concepts and vocational contexts more explicit in secondary medical education. Contextualized examples from biochemistry, pharmacology, laboratory practice, and other healthcare-related areas may provide one way of supporting such connections.

Several limitations should be considered when interpreting the findings. First, the study used a non-probability convenience sample. Although invitations to participate were distributed to all secondary medical schools in Serbia, school affiliation was not collected in order to preserve participant anonymity. Consequently, the geographic and institutional distribution of respondents could not be determined. In addition, because the researchers did not know how many eligible students ultimately received the questionnaire link, an exact response rate could not be calculated, and potential non-response bias cannot be excluded. The findings should therefore be interpreted as reflecting the perceptions of the students included in the study rather than as nationally representative estimates of all secondary medical school students in Serbia.

Second, the educational profiles were represented by substantially unequal numbers of participants. One profile included only one student and was excluded from the inferential comparison among educational profiles, although the participant was retained in the overall descriptive analyses. Several remaining profiles also had small sample sizes. This imbalance limited the possibility of reliable pairwise comparisons, and the observed differences among educational profiles should therefore be regarded as exploratory.

Third, a major methodological limitation of the present study is that the questionnaire was not pilot-tested with students from the target population prior to the main data collection. Although the instrument was reviewed by three specialists in chemistry education to assess the relevance, clarity, and appropriateness of the items, expert review cannot fully substitute for pilot testing with the target population. Therefore, it cannot be established with certainty whether all students interpreted the items and instructions as intended or whether the response format was equally clear and appropriate for all participants. The internal consistency and exploratory factor analyses conducted on the full study sample provide information about the consistency and internal structure of the responses; however, these analyses do not directly examine students' understanding of the questionnaire items or instructions. This limitation should therefore be considered when interpreting the findings. Future research should include

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cognitive pretesting or pilot testing with students from the target population, followed by further evaluation of the instrument in an independent sample.

Fourth, the findings were based on students' self-reported perceptions rather than direct measures of chemistry knowledge, academic achievement, or professional competencies. Responses may also have been influenced by subjective judgments or response tendencies. Furthermore, the cross-sectional design does not allow changes in students' perceptions over time to be examined or causal relationships to be established. Curricular exposure, instructional practices, the timing of chemistry instruction, and the extent to which chemistry was integrated into vocational subjects were not directly measured and may have contributed to the observed differences between groups.

Although the study was conducted in Serbia, the educational issue addressed is also relevant to vocational education systems in which students are expected to connect foundational science knowledge with profession-specific learning. The findings may therefore provide a basis for comparison with other educational contexts; however, differences in national curricula, programme structures, and the organization of vocational education should be considered when assessing their transferability.

Future research should include larger and more balanced samples across educational profiles and should document school and regional representation while preserving participant anonymity. Longitudinal studies could examine how students' perceptions develop throughout secondary medical education. Future research could also investigate whether contextualized and interdisciplinary approaches to chemistry teaching are associated with students' motivation, achievement, and ability to apply chemical knowledge in vocational learning contexts.

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Declaration of Interest

The authors declare no competing interests.

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Appendix A

Questionnaire Used in the Study

The questionnaire presented below is an English translation of the original Serbian-language instrument administered to the participants. The original Serbian version is publicly available via Google Forms.

Students' Attitudes toward the Importance of Chemistry and Its Connection with Vocational Subjects in Secondary Medical Schools

Dear students,
This questionnaire is part of a research study conducted within a doctoral dissertation at the University of Novi Sad, Faculty of Sciences, Department of Chemistry, Biochemistry and Environmental Protection. The aim of the study was to examine students' perceptions of the importance of chemistry and its connection with vocational subjects in secondary medical schools. Participation in the study is voluntary and anonymous. The collected data will be used exclusively for scientific research purposes. Please read each question carefully and select the response that best reflects your opinion. Completion of the questionnaire takes approximately 5 minutes.
Thank you for your time and contribution to this research.
Respectfully,
Danica Rašić, PhD student
Faculty of Sciences, University of Novi Sad

General Information

1. Sex
- Male
- Female

2. Grade
- Third year
- Fourth year

3. Educational profile
- Nurse–Technician
- Dental Technician
- Pharmacy Technician
- Physiotherapy Technician
- Laboratory Technician
- Nurse–Educators
- Sanitary–Ecological Technicians
- Gynecological–Obstetric Nurse Technician
- Other: _____

Attitudes toward the Importance of Chemistry

For Items 4–8, indicate the extent to which you agree with each statement using a five-point scale:
1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

4. Knowledge of chemistry is important for my future profession.
1 2 3 4 5

5. Chemistry content is adapted to my educational profile.
1 2 3 4 5

6. In chemistry classes, we learn content that I can apply in vocational subjects.
1 2 3 4 5

7. Chemistry helps me better understand vocational subjects (e.g., pharmacology, biochemistry).
1 2 3 4 5

8. I often use knowledge from chemistry in learning vocational subjects.
1 2 3 4 5

Perceived Connection between Chemistry and Vocational Subjects

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For Items 9–11, use the same five-point scale:
1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

9. I believe that the connection between chemistry and vocational subjects is adequately emphasized in school.
1 2 3 4 5

10. I sometimes find it difficult to understand vocational subjects because of insufficient knowledge of chemistry.
1 2 3 4 5

11. A greater number of practical examples from medical practice in chemistry classes would be useful.
1 2 3 4 5

12. In which vocational subjects do you most frequently use knowledge from chemistry?
Multiple responses may be selected.
- Pharmacology
- Anatomy and Physiology
- Medical Biochemistry
- Health Care
- Hygiene
- Practical Training
- I do not use/apply knowledge from chemistry
- Other: _____

Application of Chemistry Knowledge in Vocational Practice

13. Which areas of chemistry do you consider most important for understanding vocational subjects in secondary medical school?
Multiple responses may be selected.
- Structure of atoms and molecules
- Chemical bonds and structure of substances
- Dispersed systems, solutions, and concentration of solutions
- Stoichiometry and chemical calculations
- Acids, bases, and pH
- Oxidation–reduction reactions
- Chemical equilibrium
- Chemical kinetics
- Fundamentals of inorganic chemistry
- Fundamentals of organic chemistry
- Biochemistry (amino acids, proteins, lipids, enzymes, carbohydrates, etc.)
- None of the listed areas
- Other: _____

14. Give one specific example from vocational subjects or practical training in which you used knowledge from chemistry.

_____

15. If you wish, you may provide your opinion or a suggestion regarding the teaching of chemistry and its connection with vocational subjects.

_____

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