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Systematic Review on Chemistry Knowledge in High School Students

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Abstract:- Chemistry knowledge in students refers to the understanding of the fundamental concepts and principles of chemistry, including the structure and properties of matter, chemical reactions, stoichiometry, kinetics, chemical equilibrium and other related topics. Students acquire theoretical and practical knowledge to understand and apply chemical principles in experiments, data analysis and problem solving in the field of chemistry. Objective: To examine the scientific literature on chemistry knowledge in high school students through a systematic review of the last 5 years. Methodology: A systematic literature review was conducted from 2019 to 2023, in Scopus, Pubmed and Web of Science, following the PRISMA method statements. The inclusion criteria were empirical articles published in English and Spanish. Results: 15 articles were selected, indicating that knowledge of chemistry in high school students is essential to develop a deep understanding of matter and the transformations that occur in it. They provide a solid foundation for scientific and technological careers and foster critical thinking. Conclusion: chemistry knowledge in students refers to the understanding of the fundamental concepts of chemistry, including the structure and properties of matter, chemical reactions, stoichiometry and other principles. This knowledge enables students to apply chemistry in practical situations and to develop analytical and problem-solving skills in this scientific field. The depth and breadth of knowledge may vary according to the educational level and interest of the students.

Keywords:- *Knowledge. Chemistry, students.*

I. INTRODUCTION

Chemistry literacy in students refers to the understanding, skills, and competencies that students possess in the field of chemistry. It encompasses the understanding of fundamental concepts, the ability to apply scientific principles, and the mastery of chemistry-related laboratory techniques (1,2). In assessing students' chemistry knowledge, several factors can be taken into account, such as their familiarity with key concepts, problem-solving skills, critical thinking skills, and practical laboratory skills (2). Assessment of chemistry knowledge can be done through examinations, quizzes, laboratory reports, projects, and other assessment methods. Taken together, systematic reviews and research studies in this area contribute to our understanding of how students develop chemistry knowledge, the challenges they may face, and effective strategies to support their learning and achievement in chemistry education (3).

On the other hand, learning and teaching methods is to realize meaningful learning. To achieve this, it is necessary for the learner to filter the knowledge he obtains from the outside world into his own cognition. In this context, fundamental concepts must be thoroughly recognized (4). In general, incorrect prior knowledge that prevents meaningful learning can be identified as misconceptions. Since the understanding of a chemical concept requires as the understanding of a chemical concept requires identification at both the macroscopic and microscopic level, learners can develop several misconceptions by considering abstract concepts.

Research on students' understanding of chemistry aims to examine the effectiveness of different teaching methods, instructional strategies, and educational interventions in promoting and improving students' understanding of chemistry (5). It can also investigate the impact of various factors, such as curriculum design, teacher qualifications, student characteristics, and learning environments, on students' chemistry knowledge. Chemistry knowledge in high school students is of vital importance, as it provides a solid foundation for understanding the world around us from a scientific perspective (6,7). Chemistry is a discipline that studies the composition, structure, properties and transformations of matter, and its application extends to various fields of science and technology.

First, knowledge of chemistry enables students to understand the atomic structure and organization of the elements in the periodic table. This gives them a fundamental understanding of matter and its constituent elements, as well as the periodic properties and trends in the periodic table. In addition, students gain knowledge about the different types of chemical bonds, such as ionic and covalent bonds, and how they form and break. This is fundamental to understanding how atoms combine to form molecules and compounds, and how these interactions affect the chemical properties of substances (8,9).

Another relevant aspect of chemistry knowledge in high school students is the understanding of chemical reactions. They learn to interpret and balance chemical equations, understand the concepts of reactants and products, and recognize the different types of reactions, such as synthesis, decomposition, substitution, and neutralization reactions. This enables them to understand how matter is transformed and how atoms are conserved during chemical reactions (10). Students also learn about the properties of matter, both physical and chemical. This includes the ability to measure and describe properties such as density, solubility, acidity or basicity, electrical conductivity, melting point, and boiling point. This knowledge enables

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them to understand and classify different substances and evaluate how they interact with their environment.

In addition, high school students' knowledge of chemistry includes concepts about the conservation of mass and energy in chemical reactions. They learn about the law of conservation of mass and the law of conservation of energy, as well as the concept of enthalpy and energy transfers in chemical reactions (11,12). Chemistry also plays an important role in understanding everyday phenomena, such as combustion, photosynthesis, cellular respiration, and the acidity of substances. Students can apply their knowledge of chemistry to understand how these processes work and their relevance in daily life.

Therefore, the general objective was to examine the scientific literature on chemistry knowledge in high school students through a systematic review of the last 5 years using the PRISMA statements.

II. METHODOLOGY

A. Type of research

A systematic bibliographic review of the literature on students' knowledge of chemistry was carried out. For which, the recommendations of the PRISMA method were followed.

B. Search strategy

The following databases were reviewed: Scopus, Web of Science and Pubmed in the period from 2019 to 2023. We selected those related to spinal cord injury, prevalence and risk factors, the keywords related to the desired objectives, according to the terms Mesh and Decs: "Knowledge", "chemistry", "students", and connections were made with Boolean operators "AND" and "OR". After a first search, each article was reviewed according to title and abstract, those that had the description of the clinical variables and the prevalence and risk factors related to spinal cord injury. However, in cases in which the study methodology was not clear and the results were not precise, the article was excluded.

C. Research and study selection:

The research strategy (keywords and search sequence) for each database was:

• ***Scopus***(362 articulos): TITLE-ABS-KEY (chemistry AND knowledge AND students) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "CHEM")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")).

• ***Web of Science***(150 articulos): (chemistry AND knowledge AND students) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "CHEM")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")).

•***Pubmed***(417 articulos): (chemistry AND knowledge AND students) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "CHEM")) AND (LIMIT-TO (LANGUAGE , "English") OR LIMIT-TO (LANGUAGE , "Spanish")).

D. Inclusion criteria

The selection of articles was carried out as follows:

- Languages: studies in Spanish, English were included, due to the fact that the topic spinal cord injury has been widely studied, for which translators specialized in the medical area were available.
- Year of publication: between 2018 and 2022.
- Articles related to the subject of knowledge in chemistry.
- Quantitative studies.
- Quality of the articles.

E. Exclusion criteria

- Clinical Cases
- Case series
- Qualitative studies
- Narrative literature reviews.
- Systematic literature reviews.
- Meta-analysis.
- Studies with unexplained methodologies.
- Letters to the editor.
- Inability to retrieve the full text of the article.
- Repeated article from a previous search.

F. Evaluation of the quality of the study

The Consolidated Standards for Reporting Trials (CONSORT-2010) guidelines will be used to assess study quality. This checklist will be used worldwide to improve reported randomized controlled clinical trials using a list of 25 items to assess the title (including the type of design), the abstract (structured and complete), the background and explanation of rationale, the definition of objectives and hypotheses, description of the trial design (including major changes in methods after trial initiation and reasons), eligibility criteria of participants, the setting and location where the data were collected, the description of the intervention (with sufficient detail to allow for replication), fully defined outcome measures, sample size calculation (or power analysis), the method used to generate the power sample data, the method used to generate the power sample data, the method used to generate the power sequence (with sufficient detail to allow for replication), fully defined outcome measures, sample size calculation (or power

analysis), the method used to generate the power sample data, and the method used to generate the power sample data, the method used to generate the randomization sequence (including type of randomization), use of blinding methods, statistical procedures used for analyses, description of results (including comparison at baseline), discussion of results (including limitations and generalization), and other information (registry, protocol, and funding).

G. Procedure

The data obtained were summarized in tables, in which the main prevalences and risk factors related to spinal cord injury were presented.The following steps were considered: in the first stage, the topic was identified and the research questions were formulated: What is the students' knowledge of chemistry?

In the second stage, the inclusion criteria were applied, such as original articles related to spinal cord injury, prevalence and risk factors, published in Spanish, English, with full text and online, and the exclusion criteria were also considered. In the third stage, the selection was made, where after reading the abstract, the article was chosen and reviewed in depth.Then, in the fourth and fifth stages, the evaluation of the studies and the interpretation of the results obtained was carried out with more criteria, to reach the sixth stage where the form of discussion and synthesis of knowledge was given; the summary of the data was placed in a matrix prepared by the author, finally the data obtained were compared with those of other investigations in order to structure the definitive review article.

III. RESULTS

While in Table 1, it was evidenced that in the first search (n=929; 100%) most of the articles was 44.89% (n=417) in the Pubmed database, according to the inclusion criteria from 2019 to 2022 a total of 159 empirical articles were found, filtering according to the type of document 42 articles were found, according to the language 38 articles and finally according to the area of research 34 articles were selected (see in Table 1).

Table 1: Initial search and application of inclusion criteria selection

	First search		time limit (2019-2023)		types of documents ECA, EC METANALYSIS		Language: English and Spanish		Research area	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Scopus	362	38,97	83	52,2	20	47,62	19	50	18	52,94
WOS	150	16,15	32	20,13	10	23,81	7	18,42	6	17,65
Pubmed	417	44,89	44	27,67	12	28,57	12	31,58	10	29,41
Total	929	100	159	100	42	100	38	100	34	100

Note.-This table explains the application of the articles after limiting the inclusion criteria.

Subsequently, the results of the systematic review are presented following the PRISMA statements (Figure 1) and then, with the selected articles, the Matrix of the articles selected in the systematic review was presented (Table 2).

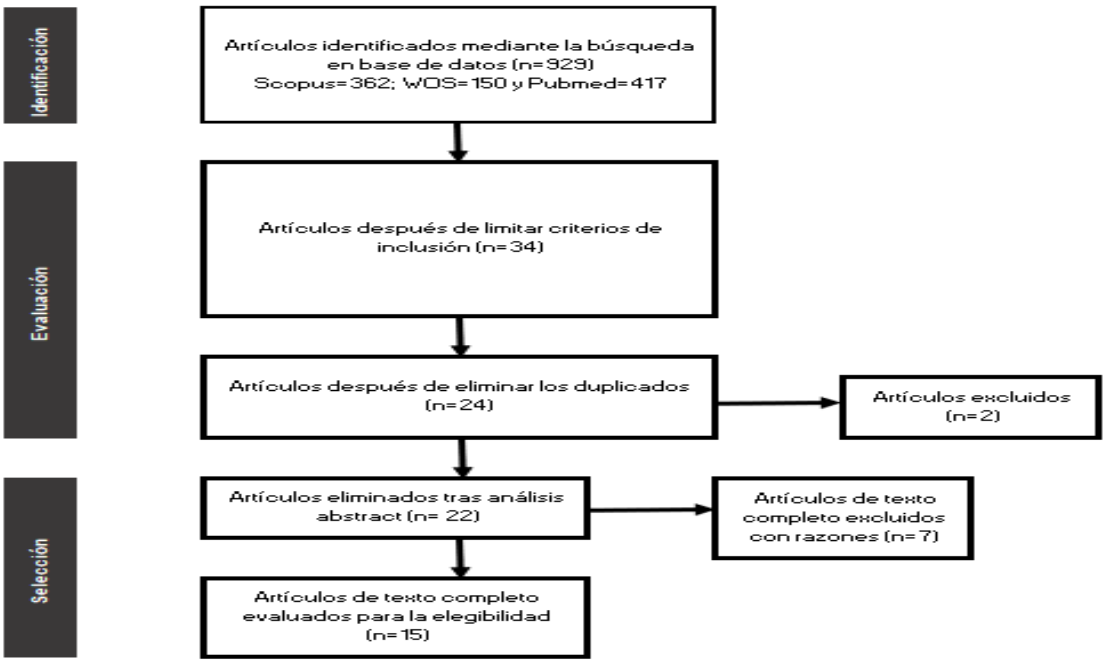

Fig. 1: PRISMA diagram.

Tabla 2: Matriz de los artículos seleccionados en la revisión sistemática

Title	First Author	Journal/Book	Publication Year	DOI
Students' use of chemistry core ideas to explain the structure and stability of DNA	Roche Allred ZD	Biochem Mol Biol Educ	2021	10.1002/bmb.21391
How Do Chemistry Faculty and Graduate Students Engage in Decision Making on Issues Related to Ethical and Responsible Conduct of Research Including Authorship?	Gao Y	Sci Eng Ethics	2022	10.1007/s11948-022-00381-6
Inquiry-based learning and students' self-efficacy in Chemistry among secondary schools in Kenya	Nzomo C	Heliyon	2023	10.1016/j.heliyon.2022.e12672
Pre-service Chemistry Teachers' Views about the Tentative and Durable Nature of Scientific Knowledge	Mueller S	Sci Educ (Dordr)	2022	10.1007/s11191-022-00374-8
"Big Ideas" of Introductory Chemistry and Biology Courses and the Connections between Them	Roche Allred ZD	CBE Life Sci Educ	2022	10.1187/cbe.21-10-0301
Team-based learning-adopted strategy in pharmacy education: pharmacology and medicinal chemistry students' perceptions	Attia RT	Futur J Pharm Sci	2023	10.1186/s43094-023-00464-6
Fundamental Chemistry of Essential Oils and Volatile Organic Compounds, Methods of Analysis and Authentication	Sadgrove NJ	Plants (Basel)	2022	10.3390/plants11060789
Remote Teaching of Chemistry Laboratory Courses during COVID-19	Díez-Pascual AM	J Chem Educ	2022	10.1021/acs.jchemed.2c00022
Exploring Differences in Student Learning and Behavior Between Real-life and Virtual Reality Chemistry Laboratories	Hu-Au E	J Sci Educ Technol	2021	10.1007/s10956-021-09925-0
The Scientific Method as a Scaffold to Enhance Communication Skills in Chemistry	Montgomery TD	J Chem Educ	2022	10.1021/acs.jchemed.2c00113
Collaborative Active Learning Activities Promote Deep Learning in a Chemistry-Biochemistry Course	Andrews DA	Med Sci Educ	2020	10.1007/s40670-020-00952-x
Beyond "study skills": a curriculum-embedded framework for metacognitive development in a college chemistry course	Gamby S	Int J STEM Educ	2022	10.1186/s40594-022-00376-6
Activating discipline specific thinking with adaptive learning: A digital tool to enhance learning in chemistry	Vincent-Ruz P	PLoS One	2022	10.1371/journal.pone.0276086
Reducing the prior-knowledge achievement gap by using technology-assisted guided learning in an undergraduate chemistry course	Lou AJ	J Res Sci Teach	2020	10.1002/tea.21596
Teaching Chemistry with Arduino Experiments in a Mixed Virtual-Physical Learning Environment	Papadimitropoulos N	J Sci Educ Technol	2021	10.1007/s10956-020-09899-5

Fifteen selected articles from PRISMA were found on knowledge in chemistry.Research indicates that chemistry is a discipline that encompasses a vast field of knowledge that is fundamental and relevant in our society. Through the study of chemistry, we gain a deep understanding of matter and its properties, as well as the transformations that occur at the molecular and subatomic levels. In this essay, we will explore some of the most relevant knowledge of chemistry and its importance in various aspects of our lives.

First, knowledge of the elements and their organization in the periodic table is fundamental in chemistry. The periodic table provides us with information about the atomic structure of the elements, their atomic mass, electronic configuration and chemical properties. This knowledge is essential to understand the relationship between elements, predict their chemical behavior and understand how they combine to form compounds.Another relevant knowledge in chemistry is that of chemical bonds. Chemical bonds are the

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forces that hold atoms together in a molecule or compound. Understanding the different types of bonds, such as ionic, covalent and metallic bonds, is essential to understanding the structure of substances and their chemical properties. For example, knowledge of covalent bonds allows us to understand why some substances are electrically conductive, while others are not.

Stoichiometry is another relevant concept in chemistry. Stoichiometry refers to the quantitative relationship between reactants and products in a chemical reaction. It makes it possible to determine the amount of substances involved in a reaction, to calculate theoretical yields and to understand the proportions in which elements combine to form compounds. This knowledge is essential in chemical synthesis, sample analysis and understanding chemical reactions in general.Knowledge of the properties of matter and chemical changes is also fundamental in chemistry. Understanding physical properties, such as density, boiling point, solubility and conductivity, helps us to classify and characterize substances. In addition, knowledge of chemical changes, such as oxidation-reduction reactions, acid-base reactions and precipitation reactions, allows us to understand how substances are transformed and how new products can be obtained from specific reactants.

Furthermore, chemical thermodynamics is another important field of knowledge in chemistry. Thermodynamics studies energy transfers and transformations in chemical systems. Understanding the concepts of enthalpy, entropy and free energy allows us to predict the direction and feasibility of chemical reactions. It is also relevant to the design and optimization of chemical processes and the understanding of phenomena such as reaction kinetics and chemical equilibrium.In conclusion, chemistry encompasses a wide range of relevant knowledge that is fundamental to our understanding of the world and to many applications.

Below, in Table 3, we determine the quality of the selected studies in which they meet most of the CONSORT checklist criteria.

Table 3: Assessment of the studies quality based on the CONSORT checklist

	First Author	Title: includes design type	Abstract: structured-	Introduction: background.	Methods: objectives-	Methods: design described	Methods: Participants	Methods: Interventions	Methods: Outcomes	Methods: Sample size calculation -	Methods: Randomization	Methods: Implementation	Methods: Statistical	Results: participants flow	Results: numbers analyzed	Results: outcomes- estimates	Discussion: limitations	Discussion: generalization	Discussion: interpretation	Other registration- protocol-funding
1	Roche Allred ZD																			
2	Gao Y																			
3	Nzomo C																			
4	Mueller S																			
5	Roche Allred ZD																			
6	Attia RT																			
7	Sadgrove NJ																			
8	Díez-Pascual AM																			
9	Hu-Au E																			
10	Montgomery TD																			
11	Andrews DA																			
12	Gamby S																			
13	Vincent-Ruz P																			
14	Lou AJ																			
15	Papadimitropoulos N																			

Note.-The quality of the selected articles was determined by systematic review, in which the green cell: presented-reported. Gray cell: presented or reported with some limitations. White cell: not presented or not reported.

IV. DISCUSSION

The main objective was to examine the scientific literature on students' knowledge of chemistry through a systematic review of the last 5 years using PRISMA statements. Fifteen scientific articles were selected for this review. The selected research studies are then compared with the subject matter of this research.

Chemistry knowledge in students refers to the set of concepts, principles, and skills that students acquire in the study of chemistry (2,13,16). This knowledge includes: Fundamental concepts, i.e., understanding the structure and properties of matter, atoms, elements and molecules, as well as chemical interactions and the forces that govern them. Also chemical reactions in order to know and understand how chemical reactions occur, including the formation and breaking of bonds, the balance of chemical equations and the conservation of mass. On the other hand, knowledge in

stoichiometry is important in order to understand how to calculate and relate the quantities of substances involved in a chemical reaction, using stoichiometric coefficients and concepts such as moles and molar mass. In addition, knowledge in kinetics and chemical equilibrium: Learn about the rate of chemical reactions, the factors that affect it and how to reach a state of chemical equilibrium, where the direct and inverse reaction rates are equal. Finally, it is organic and inorganic chemistry: Become familiar with organic compounds, which contain carbon, and inorganic compounds, which do not contain carbon, and understand their properties and reactivity.

Chemistry is a fascinating discipline that plays a crucial role in our understanding of the world around us. Learning chemistry in high school students is of utmost importance, as it provides them with a solid foundation of scientific knowledge and develops fundamental skills that prepare them for the future (4,5).

First, the study of chemistry provides students with the scientific foundation necessary to understand the structure, composition, and properties of matter. Through chemistry, students learn about atoms, elements, molecules, and chemical reactions (6,7,8). These concepts are essential to understanding other scientific fields, such as biology, physics, and geology. By having a solid understanding of chemistry, students can approach scientific problems more effectively and acquire a more complete knowledge of the natural world.

In addition to providing scientific knowledge, chemistry also develops critical thinking skills in students (11,12,17). During chemistry classes, students learn to analyze problems, formulate hypotheses, perform experiments, and evaluate the results (18-20). Through this scientific methodology, logical thinking, problem-solving skills, and evidence-based informed decision making are fostered. These skills are valuable in both academia and everyday life, as they enable students to approach challenges systematically and reach evidence-based conclusions (21-25).

Chemistry also has numerous practical applications in everyday life. From food and drug development to the development of materials and technologies, chemistry is present in almost every aspect of our modern lives. Learning chemistry in high school enables students to understand how chemical knowledge is used in industry and society at large (15,17,27,28). This empowers them to make informed decisions about their own health, environment, and career choices. In addition, chemistry also promotes environmental awareness by teaching students about pollution and environmental problems related to chemicals, which motivates them to take action to protect and preserve our environment (20,29,30).

Finally, learning chemistry in high school can open doors to future careers in science. Chemistry is a broad and diverse discipline that offers numerous career opportunities in fields such as research, medicine, engineering, pharmacy, and biotechnology, among others (22,31). By exposing students to chemistry at an early stage, they are given the opportunity to discover their passion for this discipline and cultivate their talent in it. This can lead to rewarding career paths and contributions to solving scientific and societal problems.

V. CONCLUSIONS

A systematic bibliographic review of the literature on students' knowledge of chemistry was carried out by means of a systematic review. The recommendations of the PRISMA method were followed to carry out this process. In conclusion, learning chemistry in high school students is essential for multiple reasons. It provides a solid foundation of scientific knowledge, develops critical thinking skills, offers practical applications in daily life, promotes environmental awareness, and opens doors to future scientific careers. Chemistry is not only an academic subject, but a discipline that helps us understand and improve the world we live in. On the other hand, it is recommended that more empirical and epidemiological research be conducted in Ecuador on the knowledge of chemistry in high school and university students.

- **Conflict of Interest:** The authors declare no conflict of interest.

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