

Periodic Table Comprehension And Academic Rigor In Chemistry Education: A Comparative Study Of UAE And Indian High School Students

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Abstract

The study titled 'Comparative Analysis of Periodic Table Comprehension and Academic Rigor in Chemistry Education: A Study of UAE and Indian High School Students' focuses on evaluating the chemistry education of high school students in the UAE and India, particularly examining their understanding of the periodic table and their academic rigor. The research sample consisted of 14 students from both urban and rural settings in India and the UAE, all enrolled in grades 11 and 12 under the same curriculum. Participants were aged between 15 to 18 years old. Key findings reveal that while students from both countries generally held similar views on topics related to chemistry education and the periodic table, there was a notable disparity in the perceived difficulty of the subject. Specifically, students in the UAE tended to find chemistry more challenging compared to their counterparts in India. The study suggests that this variation in perception may stem from differences in educational practices, particularly the prevalent reliance on school coaching in the UAE. This reliance potentially influences students' experiences and attitudes towards the subject. In conclusion, despite a shared curriculum, distinct cultural and educational contexts play a significant role in shaping students' perspectives and experiences in chemistry education. This underscores the importance of considering local educational dynamics when interpreting comparative studies of academic subjects across different countries.

Keywords: Periodic table, Education System, UAE, India, CBSE, Chemistry Education

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I. Introduction

History and Classification of the Periodic Table

The periodic table is an exceptional demonstration of the structured nature of the chemical elements, it establishes the fact that the chemical elements are not random units of entities but there exists a richness of intricate relationships which makes an in-depth look at the chemical elements a rewarding experience and enriches our understanding of chemistry. It captures the essence of chemistry in an engrossing manner and provides a framework for understanding the elemental similarities. The classification of elements into groups and the development of the Periodic table are the consequences of organizing the knowledge gained by a series of scientists (NCERT, 2023), four individuals, in particular, have contributed greatly to the abstract philosophies of the periodic table, periodic law, and of the elements therein through their observations and experiments: Dimitri Mendeleev, Henry Moseley, John Alexander Newlands, and Johann Dobereiner. The periodic table enables the rationalization of extensive data and also facilitates accurate predictions. As we trace the evolution of the Periodic table from its inception by Mendeleev, in 1905, the original pioneer periodic table consisted of eight vertical columns and twelve horizontal rows arranged on the basis of their similarities in the empirical formulas and properties of the compounds formed by the elements. These short-form tables thrived until well into the beginning of the twentieth century when chemistry witnessed profound developments in theories about sub-atomic particles. Modification was spurred, In 1913 by the groundbreaking work of Henry Moseley who showed, through the x-ray spectra of the elements, that the atomic number is a more fundamental property of an element than its atomic mass, leading to a paradigm shift in the classification of elements. Mendeleev's periodic table and periodic law were therefore modified and classified on the basis of atomic numbers in stark contrast to the initial classification based on atomic mass. (SCERRI, 2011)

Overview of Chemistry Education in India and UAE

The higher education system in India is characterized by a plethora of institutions and a diverse range of programs. India has one of the largest higher education systems in the world, with over 276,840 secondary schools, out of these, 148,447 schools (53.6 percent) have integrated science lab facilities, as per UDISE on 30th September 2021. In stark contrast, the educational network of the UAE is quite new. In 1952, there were few

formal schools in the country. In the 1960s and 1970s, significant expansion efforts were made. In the 2017-2018 academic year, approximately 1,080,000 students were enrolled at 1,219 public and private schools as per the embassy of the UAE. Notably, 54% of students studying in the UAE choose the business rather than science fields, with KHDA (2015) enrollment reports indicating that only 35% of students are enrolled in STEM majors. One of the studies that discussed the shortage of UAE STEM states that only 21% of students are enrolled in STEM majors where the majority of students are males. In 2013, only 3% graduated in medicine and health science, while 46.9% graduated in business, social sciences, and humanities studies. Chemistry education involves imparting knowledge, teaching, and learning skills and concepts of chemistry in academic institutions, ranging from high schools and colleges to universities. Over the years, extensive efforts and undivided attention have been devoted to understanding the learning process and learning efficiency of chemistry students. The CBSE (Central Board of Secondary Education) curriculum is the national board for secondary education encompassing both public and private schools in India, run by the Government of India. The total number of CBSE schools in India was 28,486 as of March 2023. Additionally, as per KHDA 2024, the CBSE curriculum is adopted by 34 schools in the UAE. The curriculum follows a multitude of learning outcomes relative to the subject of chemistry for the senior secondary stage as outlined by the National Council for Educational Research and Training (NCERT). These outcomes include, taking appropriate precautionary measures while handling apparatus, relating processes and phenomena with causes, explains scientific terms/ factors/ laws/ theories governing processes and phenomena are a few of the initiatives that the curriculum wishes to achieve in chemistry students of grade 12 by the end of the academic year.

Importance of Understanding the Periodic Table in Chemistry

A seldom mentioned attribute of the periodic table is that it concerns a rather holistic and all-inclusive aspect of chemistry since it embodies all the elements and in addition highlights layer upon layer of relationships among the elements. (Scerri, 2010, p.70). The periodic table of elements is arguably one of the most powerful and universally accepted icons of science, both in principle and in practice: serving as a comprehensive blueprint that captures the essence of the whole of chemistry. The periodic table organizes elements in accordance to the similarities in their chemical properties so one can identify the characteristics of an element just by glimpsing at its location on the table. Each of the eighteen groups of elemental entities presents similar or even identical qualities. The periodic table is useful to predict the properties of elements, including those that have not yet been discovered. A classic example is in 1869 when Mendeleev published his framework of the periodic table both germanium (1886) and gallium (1875) were unknown. He had left placeholders after aluminum and silicon and had called these elements Eka-Aluminum and Eka-Silicon. Mendeleev had not only successfully and accurately predicted the existence of germanium and gallium but had also described some of their physical properties (atomic weight, density, melting point). (Cao et al., 2021)

The Central Board for Secondary Education (CBSE)

It is a standardized school curriculum designed to provide rigorous and in-depth learning while ensuring the syllabus is manageable and comparable to international standards. It's offered in 24 countries across the world. While the course is widely considered to be tougher than the Indian State Boards, it is also seen as more student-friendly, ensuring pupils don't face too much pressure and opting for more interesting, engaging learning methods. Higher Secondary is the most crucial stage of school education because at this juncture specialized discipline-based, career-oriented courses are introduced. Students after 10 years of general education, at the senior secondary stage, have the flexibility to choose subjects according to individual preferences from a wide plethora of Science and Technology subjects, Visual and Performing Arts subjects, and Commerce subjects, namely Biology, Physics, Chemistry, Drama, Business Studies and Economics. Students who opt for Chemistry often have a purpose of pursuing their career in basic sciences or professional courses like medicine, engineering, or technology and study courses in applied areas of science and technology at a higher level. The curriculum of Chemistry at the Senior Secondary Stage in CBSE aims to promote an understanding of fundamental facts and application of concepts in chemistry to industry/ technology while retaining the excitement of chemistry and competent to meet the challenges of studying chemistry in academic and professional courses (such as medicine, engineering, and technology). (CBSE, 2024)

Academic Rigor and Its Impact on Teaching

Academic rigor encompasses the stringent devotion to fostering high levels of performance among all individuals in a classroom. It pertains to the rigorously structured courses, programs, or assessments that demand intellectual challenges and meticulous standards from students. Rigorous academic environments notoriously emphasize precision, and an increased level of intellectual engagement among students and teachers. This concept encompasses the difficulty of materials, strenuousness of materials, thought-provoking inquiries necessitating higher-order thinking skills, and the expected standards of reasoning.

While the term "academic rigor" has been entrenched in educational discourse for a significant period, its definition can vary. It is widely acknowledged in educational circles but is not always understood among educators universally, particularly regarding its implementation within classrooms.

A classroom characterized by academic rigor provides students with statistical measures of their performance, encourages them to apply learned knowledge to real-life situations, and designs assignments aimed at specific learning outcomes. This rigorous environment promotes precision in academic pursuits and fosters heightened intellectual engagement among both students and educators. (Wyse, Soneral, 2018)

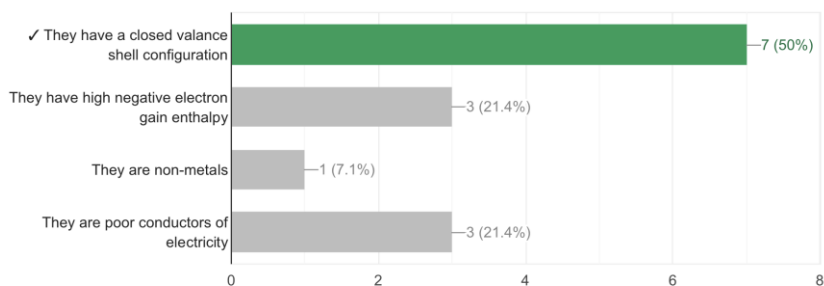
II. Methodology

The primary objective of the study was to conduct a Comparative Analysis of Periodic Table Comprehension and Academic Rigor in Chemistry Education: A Study of UAE and Indian High School Students. This approach aimed to provide insights into how educational practices influence students' understanding of the Periodic Table and their academic engagement in chemistry education within two distinct cultural settings. This study employs a structured questionnaire as its primary tool to examine variations in teaching and learning methodologies across different cultural contexts. Data collection involved administering the questionnaire to a representative sample comprising Grade 11 and Grade 12 students from both rural and urban regions of the UAE and India, in such a way as to ensure proportional representation of government and private schools and schools representing different levels of socio-economic status. The questionnaire encompassed a combination of quantitative and qualitative items to assess the overall understanding of chemistry concepts among the respondents. Specifically, it included 5 questions which were formatted like a quiz based on previous educational learning designed to gauge factual and theory-based understanding. Additionally, 10 questions were structured to capture subjective opinions and perspectives, allowing respondents to express their views on various aspects related to chemistry education and the teaching styles involved. The aim of the questionnaire and the study was clearly communicated to participants to enhance engagement. This dual approach facilitated a thorough examination of both factual knowledge acquisition and individual perceptions regarding chemistry education among the surveyed high school students. Participants emphasized the importance of honest and thoughtful responses. Demographic information was collected from the participants while ensuring anonymity to encourage candid responses.

III. Results

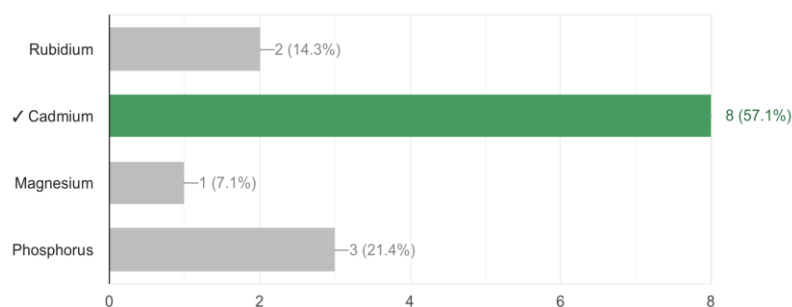
Which statement is most likely false for an element present in group 17 of the periodic table?

7 / 14 correct responses



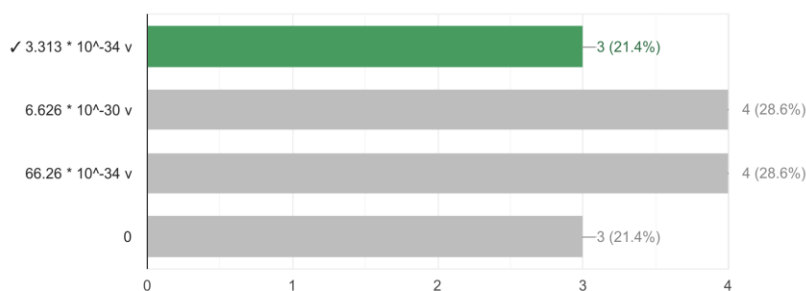
Which of these elements is not part of the representative elements?

8 / 14 correct responses



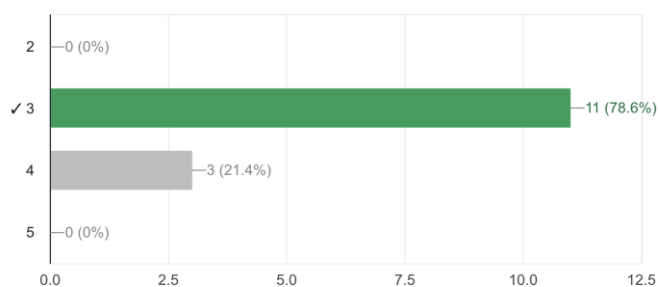
Which of the following quantities of energy cannot be emitted or absorbed in the form of electromagnetic radiation? (ν here represents frequency)

3 / 14 correct responses



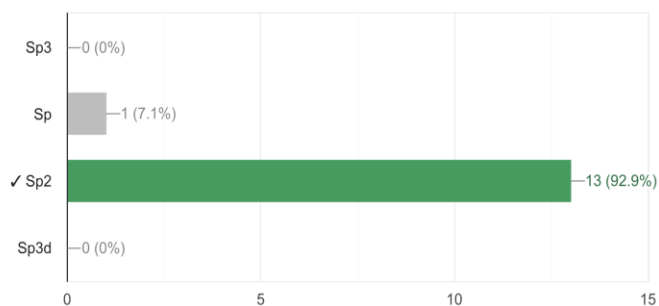
The number of significant digits in 0.0350

11 / 14 correct responses



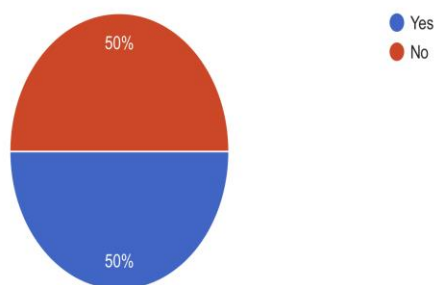
The hybridization of a benzyl carbonium ion is?

13 / 14 correct responses



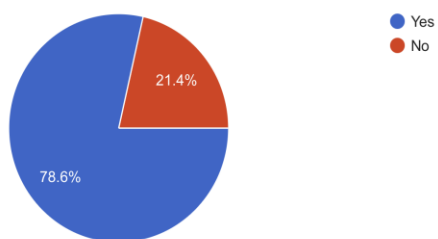
Do you think chemistry is a difficult subject to learn?

14 responses



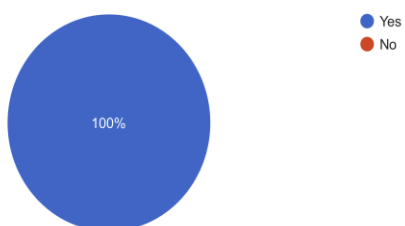
Are you able to understand the chemistry concepts taught in class?

14 responses



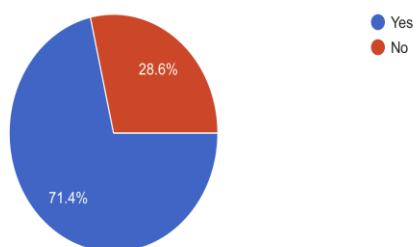
Are you allowed to use labs for chemistry experiment?

14 responses



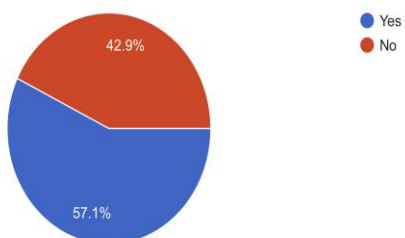
Do you think the current curriculum prepares you for higher education?

14 responses



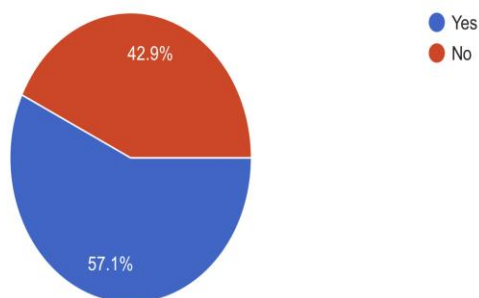
Do you find the teaching methods used in chemistry classes engaging?

14 responses



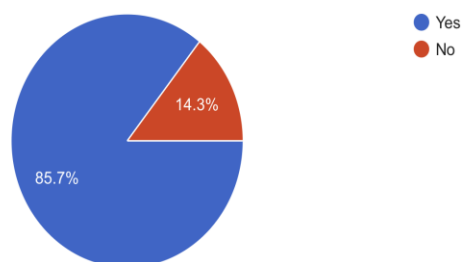
Do you think a strong foundation in mathematics is necessary to understand chemistry?

14 responses



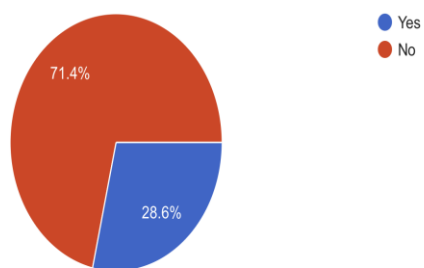
Are you able to apply your knowledge of chemistry in exams?

14 responses



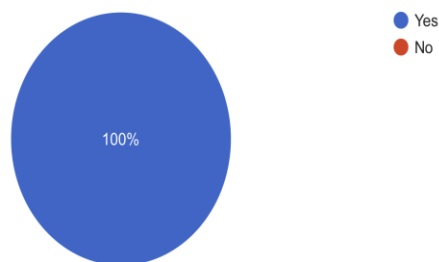
Do you think chemistry education can help solve real world problems?

14 responses



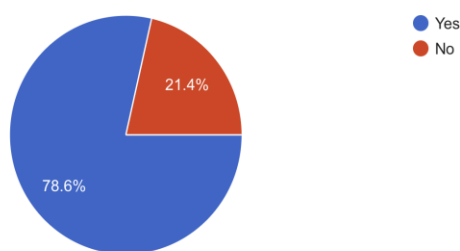
Do you think an understanding of the periodic table is essential for mastering chemistry?

14 responses



Are you able to relate the physical properties of an element with the periodic table?

14 responses



IV. Discussion

The study aimed to compare how UAE and Indian high school students comprehend the Periodic Table and engage academically in chemistry education. It utilized a structured questionnaire administered to Grade 11 and Grade 12 students from diverse socio-economic backgrounds and school types in both countries. The questionnaire included factual quizzes and subjective questions to assess knowledge acquisition and perceptions, ensuring participant understanding and anonymity for candid responses.

The questionnaire commenced with a quiz comprising five questions designed to assess prior educational learnings. The overall success rate among students was 75%. Amongst the five questions, two questions pertained to concepts from the periodic table, while the remaining three explored diverse aspects of chemistry.

The first question explored the understanding of students about the properties exhibited by elements placed in the same group in the periodic table. This question yielded a 50% accuracy rate, with 7 students providing correct responses. Additionally, 21.4% of students (3 students) selected either option B or option D.

The second question evaluated students' comprehension of the organization of elements based on their outermost shell. Representative elements are defined as those elements whose last electron resides in the S or P orbital. In simpler words, the representative elements consist of the p-block elements together with the s-block elements.

Students demonstrated a higher accuracy rate on this question compared to the previous one, with 57.1% (8 students) answering correctly.

The third question focused on the quantization of energy as elucidated by Max Planck. According to Planck's quantum theory, atoms and molecules can emit or absorb energy only in discrete quantities. The smallest unit of energy that can be emitted or absorbed in the form of electromagnetic radiation is known as a quantum, symbolized by Planck's constant 'h'.

The accuracy rate for this question was notably lower compared to the others, with only 21.4% of students providing the correct answer. Additionally, 28.6% (4 students) selected options B or C, both of which were incorrect choices.

Question 4 delved into the fundamental concepts of chemistry. Students exhibited an exceptionally high accuracy rate on this question, with 78.6% (11 students) selecting the correct option. It is noteworthy that only 21.4% (3 students) answered incorrectly, all of whom mistakenly assumed the answer to be 4 (option C) as the answer.

The final question in the quiz pertained to organic chemistry concepts and boasted the highest accuracy rate among students. Remarkably, only 7.1% (1 student) answered incorrectly.

The next ten questions that were part of the questionnaire were opinion-based and did not have a right or wrong answer.

The first question from the set of opinion-based questions produced mixed results, with 50% of the students finding chemistry to be a relatively easy subject to learn, while the other 50% disagreed. 40% of the Indian students who participated in the quiz found chemistry difficult to learn comparatively a larger percentage (75%) of the UAE students, that took part in the quiz, also found chemistry difficult to learn. Chemistry is often categorized as challenging due to its abstract concepts and the need to visualize molecular structures and reactions, which can be less concrete as compared to the more formulaic nature of physics and mathematics. This abstract nature can make chemistry seem unpredictable and harder to grasp for some students compared to subjects that follow more straightforward proofs or calculations. Each student's experience with chemistry can vary widely based on their learning style, background knowledge, and interest in the subject matter. (Cardellini, 2012)

Chemistry is perceived as a more challenging subject among UAE students, a perception potentially influenced by the comparative lack of external support in science education. In contrast, Indian students find chemistry easier to learn due to the additional coaching and support available outside of regular school hours.

The majority of students, 78.6%, found it easy to grasp the concepts taught in class, while a minority (21.4%) faced difficulties in understanding the same concepts. This question yielded similar results from both UAE and Indian students. Specifically, 80% of students studying chemistry in India were able to grasp concepts taught in class, while 75% of students studying chemistry in the UAE reported the same. The concern about the teachings of chemistry in school arises from the lack of understanding of the chemical disciplines and how they supply this knowledge to students. effective teaching of chemistry requires more than just covering content from textbooks. Teachers should aim to connect theoretical concepts with real-world applications and contexts that are relevant and meaningful to students. This approach helps students understand the practical implications of chemistry and fosters a deeper comprehension of the subject. (Subramainan., Mahmoud., 2020)

Both Indian and UAE students find it easy to understand concepts taught in class, which can be attributed to the presence of good teachers in both regions.

Lab work is an integral part of the chemistry experience as it allows students to explore chemical concepts, observe changes in matter, and develop scientific skills in a professional scientific setting. students can benefit from both positive and negative experiences in laboratories. Undesirable events, though rare, provide valuable opportunities to learn and enhance safety competencies by understanding what went wrong and how to prevent similar incidents in the future. Learning from such examples contributes to a more robust understanding of safety protocols and practices. It was remarkable to note that all 14 students, regardless of UAE and India, surveyed for the quiz were able to utilize laboratory facilities available in their respective schools. (Ferjencik, Jalovy. 2010)

All students in both UAE and India were allowed to use chemistry labs in school, this is essential because Lab work is an integral part of the chemistry experience as it allows students to explore chemical concepts, observe changes in matter, and develop scientific skills in a professional scientific setting. students can benefit from both positive and negative experiences in laboratories. Undesirable events, though rare, provide valuable opportunities to learn and enhance safety competencies by understanding what went wrong and how to prevent similar incidents in the future. Learning from such examples contributes to a more robust understanding of safety protocols and practices.

The majority of students, 71.4%, agreed that chemistry taught in schools lays a solid foundation for higher education in the field of chemistry. This question highlighted a significant difference between the two cultures: 80% of Indian chemistry students believed that school teachings prepared them for higher education, whereas only 50% of UAE chemistry students shared the same belief. All students were part of the CBSE curriculum and held a common view that the curriculum prepared them for higher education.

The fifth question yielded divided results among students: 57.1% believed that the teaching methods employed by teachers in chemistry were engaging, while 42.9% felt that chemistry classes were not engaging. 70% of the Indian students felt chemistry classes were engaging but only 25% of the UAE students shared the same notion.

The sixth question followed a similar yet surprising response pattern as question 5. A large percentage of students, 42.9%, believed that a strong foundation in mathematics is not an essential quality to understanding chemistry despite math being deeply rooted in parts of physical chemistry. The views on the sixth question revealed conflicting opinions among Indian students, with 50% believing that mathematics was crucial for building a stronger foundation in chemistry, comparatively a higher proportion, 75%, of UAE students shared this belief. Chemistry students perceived that possession of sufficient mathematical knowledge applicable to chemistry, acknowledged a strong correlation between mathematics and chemistry, and recognized that proficiency in mathematics significantly impacts a student's academic performance. (Akinoso et Al.,2016)

The seventh question received an overwhelmingly positive response, with 85.7% of students demonstrating efficient application of their chemistry knowledge during exams. The response had an overall positive outcome from both Indian and UAE students. Specifically, 90% of Indian students and 75% of UAE students can correctly apply their knowledge in exams.

Students overall believed that chemistry education cannot help solve real-world problems. This perspective is surprising because concepts from chemistry and their applications are utilized globally to explain various phenomena and actively contribute to solving real-world challenges. Only 30% of Indian students believed that chemistry was useful in solving real-world problems, and an even lower percentage, 25%, of UAE students agreed with this viewpoint. All 14 (100% from both UAE and India individually) students unanimously agreed that a thorough understanding of the periodic table is crucial for mastering chemistry. Notably, 78.6% of students were able to correlate the physical properties of an element with its respective position in the periodic table. This eludes that 11 out of the 14 students who participated in the quiz demonstrated a solid understanding

of the periodic table. More precisely 80% of the Indian students and 75% of the UAE students were able to relate the physical properties of elements.

It is important to note that a lower percentage of UAE students perceive chemistry classes in school as engaging as compared to 70% of Indian students. This significant disparity in viewpoints can be attributed to several factors, including inadequate teacher support a prevailing apprehension towards the subject, and the general fear lingering around the subject, as it was noted that 75% of UAE students find chemistry challenging to learn, contrasting with only 50% of Indian students who share this sentiment. It is imperative to enhance educational approaches that not only foster engagement but also cultivate students' interest in chemistry.

The author acknowledges certain limitations inherent in the present study. Firstly, the sample size, consisting of 15 students (8 from India and 7 from UAE), is deemed insufficient to generalize the findings beyond the specific study groups. Secondly, the research scope is confined solely to the countries of UAE and India, thereby potentially limiting the generalizability of the results. To address these constraints, future works are planned to aim for a larger and more diverse participant pool. This expansion aims to gather additional empirical evidence and enhance the representativeness of the study's findings.

V. Conclusion

The study aimed to compare UAE and Indian high school students' comprehension of the Periodic Table and their academic engagement in chemistry education. The study employed a questionnaire structure that included factual quizzes and subjective questions to assess knowledge acquisition and perceptions administered to Grade 11 and Grade 12 students from diverse socio-economic backgrounds and various school types in both countries. It ensured anonymity for candid responses. Based on the findings of the study comparing UAE and Indian high school students' perceptions and performance in chemistry education, several insights emerge.

Firstly, there is a noticeable difference in how students from these two countries comprehend and engage with chemistry concepts, particularly regarding the periodic table and fundamental principles like quantum theory. UAE students, as indicated by the study, perceive chemistry as more challenging compared to their Indian counterparts, possibly influenced by varying levels of external support and teaching methodologies. Moreover, while both groups generally find chemistry classes engaging to some extent, there's a clear disparity in the intensity of this engagement, with a higher proportion of Indian students expressing satisfaction with their chemistry learning experiences. This difference underscores the importance of effective teaching strategies and support systems in shaping students' attitudes and academic performance in chemistry. In conclusion, while there are shared perceptions and challenges in learning chemistry among UAE and Indian students, the study emphasizes the need for tailored educational approaches that enhance engagement, support, and practical application opportunities. Addressing these aspects can potentially bridge educational disparities and improve overall learning outcomes in chemistry across diverse socioeconomic backgrounds and educational systems.

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