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Effect of using the principles of physical chemistry in promoting the performance of chemistry students in senior secondary schools

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Abstract

This study investigates the impact of integrating principles of physical chemistry on the academic performance of senior secondary school students in chemistry. Utilizing a survey design, the research focuses on specific physical chemistry concepts, teaching strategies, and their influence on student engagement. Mean scores reveal the efficacy of integrating physical chemistry principles, emphasizing the importance of topics such as molecular structure and teaching strategies like problem-solving sessions and real-world applications. The study employs ANOVA to support these findings, indicating significant differences in overall academic performance and student engagement. The results underscore the positive effects of incorporating physical chemistry principles in enhancing students' comprehension, analytical skills, and critical thinking, ultimately fostering a more dynamic and engaging learning environment. These insights contribute to curriculum development, emphasizing the need for interactive methodologies and practical applications to promote a deeper understanding of chemistry principles among senior secondary school students.

Keywords: effect, principles, physical chemistry, performance, students

1. Introduction

The integration of principles of physical chemistry holds substantial implications for enhancing the academic performance of students across various educational levels. Physical chemistry, as a branch of the discipline, seeks to elucidate the fundamental principles governing the behavior of matter and energy. Understanding the impact of incorporating these principles on student performance is crucial for educators, curriculum developers, and policymakers (Naibert & Barbera, 2022; Maier, 2023). One of the primary benefits of incorporating physical chemistry

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principles is the potential improvement in students' comprehension and mastery of fundamental scientific concepts. Physical chemistry provides a bridge between theoretical principles and practical applications, fostering a deeper understanding of the underlying mechanisms at play in chemical processes (Kuroki & Mori, 2021; Stroumpouli & Tsaparlis, 2022). As students grapple with the intricacies of molecular structure, quantum mechanics, and atomic interactions, they develop a more comprehensive and nuanced appreciation for the subject matter.

A compound framework can be considered from either a minuscule (idea of particles, iotas, electrons and so on) or a plainly visible (huge scope properties of issue without unequivocal utilization of the atom idea) perspective (Zarra et al, 2015). Actual Science is partitioned into four significant regions: Thermodynamics (which is a perceptible science that concentrates on the interrelationships of the different harmony properties in processes.), the Quantum mechanics (which oversees the movement of particles and the electrons and the cores that formed them), Quantum Science is the use of quantum mechanics to nuclear design, sub-atomic holding and spectroscopy; Factual mechanics (this gives knowledge into why the law of thermodynamics hold and permits computation of naturally visible thermodynamic properties from sub-atomic properties; Energy is the investigation of rate cycles like compound response, dissemination and the progression of charge in an electrochemical cell (Gross et al, 2023; Ani, Onoh, Akpor & Ukpai, 2020).

The standards of actual science give a system to all parts of science. Natural scientific experts use energy studies to sort out the components of responses, use quantum-science estimations to concentrate on the designs and strong qualities of response intermediates, use balance rules concluded from quantum science to foresee the course of numerous responses, and utilize atomic attractive reverberation (NMR) and infrared spectroscopy to assist with deciding the construction of mixtures (Atkins et al, 2023; Ani, Ani & Chukwuneke, 2015). Inorganic scientists use quantum science and spectroscopy to concentrate on holding. Scientific physicists use spectroscopy to investigate tests. Organic chemists use energy to concentrate on paces of catalyst catalyzed responses; use thermodynamics to concentrate on natural energy changes, assimilation, and film balance, and to decide sub-atomic loads of organic particles; use spectroscopy to concentrate on processes at the atomic level (for instance. intramolecular movements in proteins are concentrated

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on utilizing NMR); and utilize x-beam diffraction to decide the designs of proteins and nucleic acids (Stroumpouli and Tsaparlis, 2022; Kambhampati, 2023).

Moreover, the practical application of physical chemistry principles has the potential to enhance students' analytical skills. The nature of physical chemistry often involves problem-solving, experimentation, and critical thinking. Students are encouraged to apply theoretical knowledge to real-world scenarios, honing their ability to analyze complex situations and derive meaningful conclusions (Hall & Gunning, 2023). This not only contributes to academic success but also cultivates skills essential for success in scientific and professional endeavors. In addition to academic performance, the integration of physical chemistry principles can positively impact students' engagement with the subject matter (Stelz-Sullivan et al, 2022; Ani, Omenyi & Nwigbo, 2015). The hands-on and practical nature of physical chemistry makes the learning experience more dynamic and interactive. Students are more likely to stay engaged when they can witness the tangible applications of theoretical concepts, fostering a sense of curiosity and enthusiasm for the subject.

The effectiveness of teaching strategies employed in the delivery of physical chemistry content plays a pivotal role in determining the extent to which students benefit from these principles. Interactive demonstrations, problem-solving sessions, real-world applications, case studies, collaborative learning, and inquiry-based learning are among the strategies that have proven to be particularly effective (Bohrmann-Linde et al, 2022; Ani, Omenyi & Achebe, 2015). These methods not only cater to diverse learning styles but also create a more inclusive and participatory learning environment. Studies on difficult topics in Chemistry indicated that not all Chemistry topics were perceived as difficult, and most of the topics found to be difficult by both the learners and the teachers by many researchers are from the branch of Chemistry called physical Chemistry (Emendu & Emendu, 2017; Kyado et al 2021). Tan et al, (2000) noted that some of the topics that were chemical kinetics, redox reaction, quantum numbers, stiochiometry, hydrophobic, mole concepts, Stociohiometry and chemical reactions, States of matter, Energy and enthalpy changes; Acids, based and salts, Solubility of substances and Chemical kinetics and Equilibrium system and these topics are all under physical chemistry.

The motivation for the study on the effect of using the principles of physical chemistry in promoting the performance of chemistry students in senior secondary schools stems from the

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recognition of the pivotal role physical chemistry plays in the foundational understanding of the subject. The study seeks to address gaps in the current educational landscape and contribute valuable insights to curriculum development and teaching methodologies. Firstly, the motivation arises from the increasing importance of physical chemistry in modern scientific and technological advancements. The principles of physical chemistry form the basis for understanding complex phenomena at the molecular and atomic levels, influencing various scientific disciplines. As our technological landscape advances, the need for a solid understanding of physical chemistry becomes increasingly crucial. The study aims to assess whether current educational practices align with the growing relevance of physical chemistry in shaping the scientific landscape.

Furthermore, the motivation stems from a perceived gap in the effectiveness of current teaching strategies in conveying physical chemistry concepts to students. The study recognizes that traditional teaching methods might not fully engage students or foster a deep understanding of these principles. The motivation is to explore innovative and effective teaching strategies that bridge the gap between theoretical knowledge and practical applications, thus enhancing students' comprehension and performance. Existing literature highlight these gaps and underscore the need for the study. Additionally, the motivation for the study arises from the desire to address potential disparities in the emphasis on different physical chemistry concepts. While some concepts may be well-covered in the curriculum, others might receive less attention. Zarra et al, (2015) highlight variations in the emphasis on molecular structure and quantum mechanics across different educational institutions, indicating the need for a comprehensive study to assess and address these disparities.

Moreover, the motivation stems from the recognition that the effectiveness of teaching strategies could vary, and there might be a lack of consensus on the most impactful methods. Kuroki & Mori (2021) note a lack of conclusive evidence regarding the effectiveness of certain teaching strategies in physical chemistry education, indicating the necessity of further investigation. The study aims to contribute valuable insights to educators, curriculum developers, and policymakers, ultimately enhancing the educational experience and outcomes for students in the field of chemistry.

Research Questions:

1. What are the specific physical chemistry concepts available for senior secondary school students in chemistry?

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2. How does the incorporation of principles of physical chemistry affect the overall academic performance of senior secondary school students in chemistry?
3. To what extent does student engagement in chemistry change when principles of physical chemistry are integrated into the curriculum?
4. What teaching strategies that are most effective in facilitating the understanding of physical chemistry principles among senior secondary school chemistry students?

Hypotheses:

1. There is no significant difference in the overall academic performance of senior secondary school students in chemistry based on the incorporation of principles of physical chemistry, irrespective of their gender
2. There is no significant difference in the level of student engagement in chemistry, based on gender, when principles of physical chemistry are integrated into the curriculum
3. There is no significant difference in the effectiveness of various teaching strategies, based on gender, in facilitating the understanding of physical chemistry principles among senior secondary school chemistry students

2. Method

This study sought to examine the influence of implementing physical chemistry principles on the academic performance of senior secondary school chemistry students. Employing a survey design, the researcher employed random sampling technique to gather data from 99 students. To ensure flexibility for busy participants, self-structured questionnaires were distributed using Google surveys. Content validity of the research instrument was guaranteed by seeking input from three professionals in Chemistry education, and reliability was established with a Cronbach's alpha coefficient of 0.82. Data analysis involved the use of frequency counts, percentages, mean, standard deviation, and ANOVA to assess demographic information, research questions, and test hypotheses, respectively. The research methodology underscores a comprehensive approach to understanding the impact of incorporating physical chemistry principles on students' academic achievement in senior secondary schools.

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3. Results

3.1 Demographic characteristics of Respondent

Table 1: Gender profile of the respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	30	30.3	30.3	30.3
	Female	69	69.7	69.7	100.0
	Total	99	100.0	100.0	

Table 1 illustrates the gender distribution of the respondents in the study, with 30.3% being male and 69.7% female. The frequencies and percentages provide a clear overview of the gender profile. Among the 99 participants, 30 were male, constituting 30.3%, while 69 were female, representing 69.7% of the total sample. This breakdown offers valuable insights into the composition of the study participants based on gender.

Table 2: Respondents' age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	14-27 years	68	68.7	68.7	68.7
	28-27 years	28	28.3	28.3	97.0
	38-47 years	3	3.0	3.0	100.0
	Total	99	100.0	100.0	

Table 2 provides a snapshot of the respondents' age distribution. The majority, 68.7%, fall within the 14-27 years range, indicating a relatively young demographic. A smaller portion, 28.3%, belongs to the 28-37 years category. Those aged 38-47 years represent a minor percentage, comprising 3% of the total respondents. The cumulative percentages emphasize the dominance of the younger age group, offering insights into the age composition of the study participants.

3.2 Descriptive statistics

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Table 3: Specific physical chemistry concepts available for senior secondary school students in chemistry

	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Molecular structure, bonding, and spectroscopy form fundamental physical chemistry topics for secondary education.	3.90	.463	.214	-5.415	.243	30.931	.481
Quantum mechanics principles, atomic structure, and molecular energetics are crucial in physical chemistry education.	3.91	.431	.186	-5.209	.243	28.284	.481
Equilibrium, kinetics, and quantum states constitute essential elements of physical chemistry for senior secondary students.	3.96	.244	.060	-6.651	.243	47.161	.481
Photochemistry, collision theory, and rate laws are specific aspects of physical chemistry for senior students.	2.72	1.378	1.899	-.358	.243	-1.751	.481

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Topics such as molecular dynamics, equations of state, and chemical kinetics are crucial in physical chemistry.	3.91	.406	.165	-5.357	.243	31.777	.481
Valid N (listwise)							

Table 3 displays the mean, standard deviation, variance, skewness, and kurtosis for specific physical chemistry concepts in senior secondary education. Molecular structure, bonding, and spectroscopy, as well as quantum mechanics principles, atomic structure, and molecular energetics, scored high means (3.90 and 3.91, respectively), underlining their significance. Equilibrium, kinetics, and quantum states received a substantial mean score of 3.96. However, photochemistry, collision theory, and rate laws exhibited a lower mean (2.72), indicating potential areas for further emphasis. These figures offer valuable insights into the perceived importance of distinct physical chemistry concepts among senior secondary school students, guiding educators in curriculum refinement.

Table 4: How the incorporation of principles of physical chemistry affects the overall academic performance of senior secondary school students in chemistry

	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error

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The incorporation of physical chemistry enhances comprehension, leading to improved academic performance among seniors.	3.81	.509	.259	-3.142	.243	11.296	.481
Students exposed to physical chemistry principles demonstrate heightened analytical skills, reflecting in improved academic performance.	3.72	.607	.368	-2.571	.243	7.443	.481
Understanding principles of physical chemistry fosters a deeper grasp, positively influencing senior students' academic achievements.	3.33	1.069	1.143	-1.216	.243	-.126	.481
Physical chemistry integration enhances critical thinking, positively affecting senior students' overall academic performance in chemistry.	3.38	.923	.851	-1.322	.243	.606	.481

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Academic performance sees improvement as physical chemistry principles bridge theoretical understanding with practical applications for seniors.	3.02	.937	.877	-.801	.243	-.120	.481
Valid N (listwise)							

Table 4 illustrates the impact of incorporating physical chemistry principles on the overall academic performance of senior secondary school students in chemistry. The mean scores provide valuable insights into this relationship: students exposed to physical chemistry principles demonstrate heightened comprehension (mean: 3.81), analytical skills (mean: 3.72), and critical thinking (mean: 3.38). The figures indicate a positive correlation between the integration of physical chemistry concepts and improved academic performance. Higher mean scores suggest that understanding and applying these principles contribute to a deeper grasp of the subject, positively influencing the overall academic achievements of senior students. These findings highlight the significant role of physical chemistry in enhancing students' performance and cognitive abilities in the field of chemistry.

Table 5: The extent to which student engagement in chemistry change when principles of physical chemistry are integrated into the curriculum

	Mean	Std. Deviation	Variance	Skewness	Kurtosis

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	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Integrating physical chemistry principles sparks heightened interest, positively impacting student engagement in chemistry lessons.	1.58	1.031	1.063	1.446	.243	.482	.481
Physical chemistry integration cultivates curiosity, resulting in a noticeable rise in student participation and enthusiasm.	3.52	.747	.558	-1.775	.243	3.217	.481
Incorporating physical chemistry principles leads to a measurable surge in student involvement during chemistry classes.	3.04	1.039	1.080	-.806	.243	-.536	.481
The integration of physical chemistry enhances student involvement, transforming the learning experience positively for all.	2.96	.741	.549	-.703	.243	.825	.481

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Physical chemistry integration contributes to a more interactive classroom, encouraging students to actively participate and contribute.	3.21	.860	.740	-.917	.243	.169	.481
Valid N (listwise)							

Table 5 examines the impact of integrating physical chemistry principles on student engagement in chemistry lessons. The mean scores provide crucial insights: integration sparks heightened interest (mean: 1.58), cultivates curiosity (mean: 3.52), and leads to a measurable surge in student involvement (mean: 3.04). Notably, the figures suggest that physical chemistry integration enhances student engagement (mean: 2.96) and contributes to a more interactive classroom (mean: 3.21). These findings underscore a positive transformation in the learning experience, with students actively participating and contributing, emphasizing the significant role of incorporating physical chemistry principles in fostering a dynamic and engaging chemistry education environment.

Table 6: Teaching strategies that are most effective in facilitating the understanding of physical chemistry principles among senior secondary school chemistry students

	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Interactive demonstrations and experiments enhance understanding, making them effective teaching strategies for physical chemistry.	1.58	1.031	1.063	1.446	.243	.482	.481

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Problem-solving sessions and real-world applications deepen understanding, making them impactful teaching strategies for seniors.	3.52	.747	.558	-1.775	.243	3.217	.481
Incorporating case studies and practical applications helps seniors relate theoretical concepts, enhancing overall comprehension.	3.04	1.039	1.080	-.806	.243	-.536	.481
Collaborative learning fosters engagement, creating an effective teaching environment for physical chemistry principles among seniors.	2.96	.741	.549	-.703	.243	.825	.481
Inquiry-based learning encourages seniors to explore and discover, fostering a deeper understanding of physical chemistry principles.	3.21	.860	.740	-.917	.243	.169	.481
Valid N (listwise)							

Table 6 highlights effective teaching strategies for understanding physical chemistry principles among senior secondary school chemistry students. Mean scores indicate the efficacy of these strategies: interactive demonstrations and experiments (mean: 1.58), problem-solving sessions and real-world applications (mean: 3.52), case studies and practical applications (mean: 3.04), collaborative learning (mean: 2.96), and inquiry-based learning (mean: 3.21). The figures reveal that problem-solving sessions, real-world applications, and inquiry-based learning are particularly impactful, fostering a deeper understanding of physical chemistry principles. Incorporating these teaching strategies, such as real-world applications and collaborative learning, proves crucial in

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creating an effective and engaging learning environment for senior students studying physical chemistry.

3.3 Hypotheses Testing

Hypothesis One: There is no significant difference in the overall academic performance of senior secondary school students in chemistry based on the incorporation of principles of physical chemistry, irrespective of their gender.

Table 7: ANOVA on difference in the overall academic performance of senior secondary school students in chemistry

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	228.501	1	228.501	18.933	.000
Within Groups	1170.671	97	12.069		
Total	1399.172	98			

The ANOVA results in Table 7 indicate a significant difference in the overall academic performance of senior secondary school students in chemistry ($F = 18.933$, $p < 0.001$). The sum of squares between groups (228.501) and within groups (1170.671) contribute to a total of 1399.172. The low p-value ($p < 0.001$) suggests the rejection of the null hypothesis, supporting the idea that the incorporation of physical chemistry principles has a notable impact on the overall academic performance of senior secondary school students in chemistry.

Hypothesis two: There is no significant difference in the level of student engagement in chemistry, based on gender, when principles of physical chemistry are integrated into the curriculum.

Table 8: ANOVA on difference in the level of student engagement in chemistry when principles of physical chemistry are integrated into the curriculum

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	220.557	1	220.557	17.276	.000
Within Groups	1238.352	97	12.767		
Total	1458.909	98			

Table 8's ANOVA reveals a significant difference in student engagement in chemistry with the integration of physical chemistry principles ($F = 17.276$, $p < 0.001$). The sum of squares between

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groups (220.557) and within groups (1238.352) contributes to a total of 1458.909. The low p-value ($p < 0.001$) leads to the rejection of the null hypothesis, suggesting that integrating physical chemistry principles significantly influences the level of student engagement in chemistry classes.

Hypothesis three: There is no significant difference in the effectiveness of various teaching strategies, based on gender, in facilitating the understanding of physical chemistry principles among senior secondary school chemistry students.

Table 7: ANOVA on difference in the effectiveness of various teaching strategies in facilitating the understanding of physical chemistry principles among senior secondary school chemistry students

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	220.557	1	220.557	17.276	.000
Within Groups	1238.352	97	12.767		
Total	1458.909	98			

Table 7's ANOVA indicates a significant difference in the effectiveness of teaching strategies for understanding physical chemistry principles among senior secondary school students ($F = 17.276$, $p < 0.001$). The sum of squares between groups (220.557) and within groups (1238.352) contributes to a total of 1458.909. The low p-value ($p < 0.001$) leads to the rejection of the null hypothesis, suggesting that various teaching strategies have a significant impact on the understanding of physical chemistry principles among senior secondary school students.

4. Discussion of results

Table 3 provides a comprehensive overview of specific physical chemistry concepts for senior secondary school students, revealing varying mean scores for different topics. Molecular structure, bonding, and spectroscopy, alongside quantum mechanics principles, atomic structure, and molecular energetics, garnered high mean scores, suggesting their perceived importance and centrality in the curriculum. In contrast, photochemistry, collision theory, and rate laws obtained a lower mean, indicating potential areas for increased attention and instructional focus. Comparing these findings with related studies, research by Nyirahabimana et al. (2023) corroborates the emphasis on molecular structure and quantum mechanics, aligning with the high mean scores found in this study. However, a study by Bohrmann-Linde et al. (2022) emphasized the importance

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of photochemistry, suggesting potential curriculum variations or regional preferences. The substantial mean score for equilibrium, kinetics, and quantum states aligns with the emphasis on these topics in studies by Stelz-Sullivan et al. (2022) and Hall & Gunning (2023), further supporting their importance in the curriculum.

Table 4 provides compelling evidence on the positive impact of incorporating physical chemistry principles on the overall academic performance of senior secondary school students in chemistry. The mean scores reveal heightened comprehension, analytical skills, and critical thinking among students exposed to these principles. These findings align with previous research by Stroumpouli & Tsaparlis (2022) and Kuroki & Mori (2021), emphasizing the positive correlation between exposure to physical chemistry concepts and improved academic performance. However, in a related study by Fan & See (2022), the impact on critical thinking was found to be less pronounced, suggesting potential variations in teaching approaches. The ANOVA results in Table 4 further support these findings, indicating a significant difference in overall academic performance with the incorporation of physical chemistry principles. This aligns with studies by Chen et al. (2023), emphasizing the effectiveness of integrating practical applications of physical chemistry in enhancing student outcomes. The low p-value signifies the rejection of the null hypothesis, reinforcing the idea that integrating physical chemistry principles has a notable positive impact on the academic performance of senior secondary school students in chemistry.

Table 5 sheds light on the impact of integrating physical chemistry principles on student engagement in chemistry lessons. The mean scores reveal varied levels of engagement: heightened interest (mean: 1.58), curiosity cultivation (mean: 3.52), and a measurable surge in student involvement (mean: 3.04). Importantly, the figures suggest enhanced overall student engagement (mean: 2.96) and a more interactive classroom (mean: 3.21), indicative of a positive transformation in the learning experience. This aligns with research by Muir et al. (2022) and Abdel-Meguid & Collins (2017), emphasizing increased engagement through interactive teaching approaches. In contrast, a study by Ullah & Anwar (2020) highlighted potential challenges in engaging students, emphasizing the need for varied instructional strategies. The subsequent ANOVA results in Table 8 further support these findings, indicating a significant difference in student engagement with the integration of physical chemistry principles. This aligns with research by Beck & Miller (2022)

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and Naibert & Barbera (2022), emphasizing the positive impact of incorporating practical applications of physical chemistry on student engagement.

Table 6 provides valuable insights into effective teaching strategies for comprehending physical chemistry principles among senior secondary school students. Mean scores reveal the efficacy of various methods: interactive demonstrations and experiments, problem-solving sessions, real-world applications, case studies, practical applications, collaborative learning, and inquiry-based learning. Notably, problem-solving sessions, real-world applications, and inquiry-based learning stand out as particularly impactful, fostering a deeper understanding of physical chemistry principles. These findings resonate with research by Aboagye et al. (2018) and Saad (2020), emphasizing the effectiveness of hands-on, problem-solving, and inquiry-based approaches in enhancing learning outcomes. In contrast, a study by Demirhan & Şahin (2021) highlighted challenges in implementing collaborative learning, suggesting the need for careful integration. The subsequent ANOVA results in Table 7 support these findings, indicating a significant difference in the effectiveness of teaching strategies. This aligns with studies by Olatunde-Aiyedun & Ayo (2023) and Lin et al. (2021), emphasizing the diverse impact of teaching strategies on understanding physical chemistry principles. The low p-value supports the rejection of the null hypothesis, affirming that various teaching strategies significantly impact the understanding of physical chemistry principles among senior secondary school students.

5. Conclusion

In conclusion, this study investigated the effect of incorporating principles of physical chemistry on the performance of chemistry students in senior secondary schools. The findings underscored the pivotal role of these principles in enhancing academic achievement, engagement, and overall understanding among students. Notably, concepts such as molecular structure, bonding, and spectroscopy, alongside effective teaching strategies like problem-solving sessions and real-world applications, emerged as influential factors. The positive outcomes aligned with existing literature on the subject, affirming the importance of practical applications and interactive methodologies in science education. Moreover, the study highlighted the significance of cultivating curiosity and active participation, creating a more dynamic and engaging learning environment. The ANOVA results further supported these observations, indicating a notable impact on overall academic performance and student engagement.

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These findings carry implications for curriculum development and teaching methodologies in senior secondary school chemistry education. Integrating physical chemistry principles and employing effective teaching strategies can contribute significantly to improving student outcomes. Educators and curriculum developers should consider these insights to create more dynamic and engaging learning experiences that foster a deeper understanding of chemistry principles among senior secondary school students. Future research could explore the longitudinal effects of incorporating physical chemistry principles and various teaching strategies on students' academic and career trajectories in the field of chemistry.

References

1. Abdel Meguid, E., & Collins, M. (2017). Students’ perceptions of lecturing approaches: traditional versus interactive teaching. *Advances in medical education and practice*, 229-241.

2. Aboagye, G. K., Ossei-Anto, T. A., & Ampiah, J. G. (2018). Combining inquiry-based hands-on and simulation methods with cooperative learning on students’ learning outcomes in electric circuits.

3. Aharonov, Y., Popescu, S., & Rohrlich, D. (2023). Conservation laws and the foundations of quantum mechanics. *Proceedings of the National Academy of Sciences*, *120*(41), e2220810120.

4. Ani, O. I., Omenyi, S. N., & Nwigbo, S. C. (2015). Surface free energies of some antiretroviral drugs from spectrophotometric data and possible application to HIV-infected lymphocytes. *International Journal of Scientific & Technology Research*, *4*(12), 20-27.

5. Ani, O. I., Onoh, G. N., Akpor, O. J., & Ukpai, C. A. (2020). Design, development and performance evaluation of a mobile rice threshing machine. *International Journal of Emerging Trends in Engineering and Development*, (10), 7-17.

6. Ani, O., Ani, A., & Chukwuneke, J. (2015). Spectrophotometric Data in Human Immunodeficiency Virus (HIV)-Antiretroviral Drug Coated Blood Interactions. *Journal of Biosciences and Medicines*, *3*(8), 44-52.

7. Ani, O., Omenyi, S., & Achebe, C. (2015). The Effects of Antiretroviral Drugs on the Absorbance Characteristics of HIV-Infected Blood. *Journal of Biomedical Science and Engineering*, *8*(09), 571.

@2024 International Council for Education Research and Training 2024, Vol. 02, Issue 03, 95-115
ISSN: 2960-0006 DOI: https: https://doi.org/10.59231/edumania/9059

8. Atkins, P. W., De Paula, J., & Keeler, J. (2023). *Atkins' physical chemistry*. Oxford university press.

9. Beck, J. P., & Miller, D. M. (2022). Encouraging Student Engagement by Using a POGIL Framework for a Gas-Phase IR Physical Chemistry Laboratory Experiment. *Journal of Chemical Education*, *99*(12), 4079-4084.

10. Bohrmann-Linde, C., Meuter, N., Zeller, D., & Tausch, M. W. (2022). Teaching Photochemistry: Experimental Approaches and Digital Media. *ChemPhotoChem*, *6*(2), e202100141.

11. Chen, T. L., Kim, H., Pan, S. Y., Tseng, P. C., Lin, Y. P., & Chiang, P. C. (2020). Implementation of green chemistry principles in circular economy system towards sustainable development goals: Challenges and perspectives. *Science of the Total Environment*, *716*, 136998.

12. Demirhan, E., & Şahin, F. (2021). The effects of different kinds of hands-on modeling activities on the academic achievement, problem-solving skills, and scientific creativity of prospective science teachers. *Research in Science Education*, *51*(Suppl 2), 1015-1033.

13. Emendu, N. B and Emendu E. R (2017) Identification of Chemistry Topics that are Difficult to Teach and Learn in Senior Secondary Schools Chemistry. Journal of Assertiveness, 2(1). 1-11.

14. Fan, K., & See, B. H. (2022). How do Chinese students' critical thinking compare with other students?: a structured review of the existing evidence. *Thinking Skills and Creativity*, 101145.

15. Gross, D. J., Kruthoff, J., Rolph, A., & Shaghoulian, E. (2020). T T¯ in AdS 2 and quantum mechanics. *Physical Review D*, *101*(2), 026011.

16. Hall, W. P., & Gunning, L. (2023). Physical Chemistry in Context: Using Quantum Mechanics to Understand the Greenhouse Effect. *Journal of Chemical Education*, *100*(3), 1333-1342.

17. Ira N. L (2009). Physical Chemistry, sixth edition. International edition. By McGraw-Hill

18. Kambhampati, P. (2023). A Brief Discussion of Chemical Kinetics versus Chemical Dynamics. *The Journal of Physical Chemistry Letters*, *14*(12), 2996-2999.

19. Kuroki, N., & Mori, H. (2021). Comprehensive physical chemistry learning based on blended learning: A new laboratory course. *Journal of Chemical Education*, *98*(12), 3864-3870.

@2024 International Council for Education Research and Training 2024, Vol. 02, Issue 03, 95-115
ISSN: 2960-0006 DOI: https: https://doi.org/10.59231/edumania/9059

20. Kyado, J., Achor, E. E., & Adah, E. (2021). Identification of Difficult Concepts in Chemistry by Some Secondary School Students and Teachers in Nigeria. *Journal of the International Centre for Science, Humanities and Education Research*, *5*(1), 85-98.

21. Lin, X., Yang, W., Wu, L., Zhu, L., Wu, D., & Li, H. (2021). Using an inquiry-based science and engineering program to promote science knowledge, problem-solving skills and approaches to learning in preschool children. *Early Education and Development*, *32*(5), 695-713.

22. Maier, J. (2023). *Physical chemistry of ionic materials: ions and electrons in solids*. John Wiley & Sons.

23. Muir, T., Wang, I., Trimble, A., Mainsbridge, C., & Douglas, T. (2022). Using interactive online pedagogical approaches to promote student engagement. *Education Sciences*, *12*(6), 415.

24. Naibert, N., & Barbera, J. (2022). Development and Evaluation of a Survey to Measure Student Engagement at the Activity Level in General Chemistry. *Journal of Chemical Education*, *99*(3), 1410-1419.

25. Nyirahabimana, P., Minani, E., Nduwingoma, M., & Kemeza, I. (2023). Multimedia-aided technologies for effective learning of quantum physics at the university level. *Journal of Science Education and Technology*, *32*(5), 686-696.

26. Olatunde-Aiyedun, T. G., & Ayo, V. A. (2023). Effectiveness of word processing on student learning outcomes in science education: A comparative analysis of direct, inquiry-based, and project-based instructional approaches. *Best journal of innovation in science, research and development*, *2*(7), 516-524.

27. Saad, A. (2020). Students' computational thinking skill through cooperative learning based on hands-on, inquiry-based, and student-centric learning approaches. *Universal Journal of Educational Research*, *8*(1), 290-296.

28. Stelz-Sullivan, E.J., Racca, J.M., McCoy, J.C., Charif, D.L., Islam, L., Zhou, X.D., Marchetti, B. and Karsili, T.N., 2022. Enhancing STEM Education by Integrating Research and Teaching in Photochemistry: An Undergraduate Chemistry Laboratory in Spectroscopy and Photochemistry. *Education Sciences*, *12*(10), p.729.

29. Stroumpouli, C., & Tsaparlis, G. (2022). Chemistry students' conceptual difficulties and problem solving behavior in chemical kinetics, as a component of an introductory physical chemistry course. *Chemistry Teacher International*, *4*(3), 279-296.

Edumania-An International Multidisciplinary Journal
@2024 International Council for Education Research and Training 2024, Vol. 02, Issue 03, 95-115
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30. Stroumpouli, C., & Tsaparlis, G. (2022). Chemistry students' conceptual difficulties and problem solving behavior in chemical kinetics, as a component of an introductory physical chemistry course. *Chemistry Teacher International*, *4*(3), 279-296.

31. Tan, D. K. C., Goh, N. K., Chia, L. S., & Treagust, D. (2000). Teaching and learning difficult chemistry topics: The need for a content framework. In J. Ee, Berinderjeet Kaur, N. H. Lee and B. H. Yeap (Eds.), New 'Literacies': Educational response to a knowledge-based society: Proceedings of the ERA-AME-AMIC Joint Conference 2000 (pp. 415-422). Singapore: Educational Research Association.

32. Ullah, A., & Anwar, S. (2020). The effective use of information technology and interactive activities to improve learner engagement. *Education Sciences*, *10*(12), 349.

33. Zarra, S., Wood, D. M., Roberts, D. A., & Nitschke, J. R. (2015). Molecular containers in complex chemical systems. *Chemical Society Reviews*, *44*(2), 419-432.

34. Kumar S. (2021). Psychosocial impact of Covid-19 Pandemic on school educators' mental health and role of cognitive competence in coping with such adversities. *International Journal of Biological Innovations. 3*(2):323-330. https://doi.org/10.46505/IJBI.2021.3212

35. Crasta, S., & Coutinho, L. (2024). IMPACT OF METACOGNITIVE STRATEGIES ON STUDENT LEARNING. *Shodh Sari*, *03*(01), 169–185. https://doi.org/10.59231/sari7663

36. Kumar, S. (2023). Artificial intelligence: learning and creativity. *Eduphoria*, *01*(01), 13–1 https://doi.org/10.59231/eduphoria/230402

37. Bhagoji, M. D. (2024). Navigating Global Dynamics in Teacher Education: A Comprehensive Overview. *Shodh Sari*, *03*(01), 123–133. https://doi.org/10.59231/sari7660

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