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PhET Interactive Simulations As An Effective Tool For Teaching Chemistry: A Review

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ABSTRACT
Chemistry is the pivotal for preparing students in STEM fields. Traditional methods of teaching often finds it difficult to deeply engage students. Educators have found that PhET Interactive Simulsations, offers solution by allowing students to visualize and interact with scientific concepts in a risk-free environment. This review explores the impact of PhET simulations in chemistry on students learning, highlighting their effectiveness in enhancing student conceptual understanding across various topics such as chemical bonding, gas laws, chemical equilibrium, and electrochemistry. These simulations promote active learning through engagement, motivation, and collaborative experiences, aligning with best practices in education. While integrating PhET simulations into chemistry curricula presents challenges, such as technical and pedagogical considerations, their future in education involves embracing emerging technologies like virtual reality and artificial intelligence to further enhance student engagement and understanding.
Keywords: PhET interactive simulation, active learning, chemistry education, students engagement, conceptual understanding.

INTRODUCTION

Chemistry education plays a pivotal role in preparing students for careers in science, technology, engineering, and mathematics (STEM) fields, as well as fostering scientific literacy among the broader population. Traditionally, the teaching of chemistry has relied on a combination of lectures, textbooks, and laboratory experiments to convey complex concepts and theories. While these methods have their merits, they often fall short in fully engaging students and fostering deep conceptual understanding.

In recent years, there has been a growing recognition of the need for innovative approaches to chemistry education that leverage advancements in technology and pedagogy. One such approach that has gained widespread attention is the use of PhET Interactive Simulations.

Interactive simulation is considered a helpful tool for improving student understanding.The interactive simulation that can be employed in science education is PhET (Physics Education Technology). The PhET project sourced from (http://phet.colorado.edu) was developed by the University of Colorado at Boulder (Perkins *et al*., 2012). This site provides free learning simulations in physical science, mathematics, chemistry, biology, and earth sciences that can be downloaded for the benefit of classroom instruction or that can be used for individual learning (Rahmawati, *et al*., 2022).

PhET simulations offer students the opportunity to engage in virtual laboratory experiences where they can manipulate variables, observe outcomes, and conduct experiments in a risk-free environment. These simulations cover a wide range of topics in chemistry, from atomic structure and chemical bonding to thermodynamics and electrochemistry. By providing dynamic, interactive visualizations of abstract

concepts, PhET simulations help to bridge the gap between theoretical knowledge and real-world applications, making chemistry more accessible and engaging for students (Salame & Makki, 2021).

The use of PhET simulations in chemistry education has been met with enthusiasm by educators and researchers alike. Numerous studies have demonstrated the effectiveness of PhET simulations in enhancing student learning outcomes, promoting active engagement, and facilitating inquiry-based instruction. As technology continues to evolve and education paradigms shift towards more student-centered approaches, PhET simulations are poised to play an increasingly important role in shaping the future of chemistry education.

It is against this background, this review paper seeks to examine the impact of PhET Interactive Simulations on chemistry education, drawing upon existing literature to provide insights into their effectiveness, applications, and implications for teaching and learning. By analysing the findings of previous studies and identifying areas for future research, this review aims to contribute to the ongoing research for the integration of technology in chemistry education and the quest for innovative pedagogical approaches that enhance student understanding and engagement.

The Impact PhET on Student Understanding in Some Selected Topics

Several studies have demonstrated the positive impact of PhET simulations on student understanding of chemistry concepts. For example, research carried out by ; Podolefsky and Perkins (2012) found that students who used PhET simulations as part of their instruction showed significant improvement in their conceptual understanding as compared to those who relied solely on traditional instruction methods. Similarly, a study by (Salame & Makki, 2021) reported that students who were engaged with PhET simulations demonstrated improved problem-solving skills and a deeper grasp of chemical principles.

PhET Interactive Simulations have proven to be particularly effective in enhancing student understanding across a wide range of chemistry concepts. Here are some specific examples worthy of consideration, where PhET simulations have demonstrated robost efficacy:

Chemical Bonding: PhET simulations allow students to visualize and manipulate atomic interactions, helping them understand the nature of chemical bonds (Podolefsky & Perkins, 2012). Simulations such as "Bonding Basics" and "Molecule Shapes" enable students to explore different types of bonds (ionic, covalent, metallic) and how they contribute to the properties of molecules. By adjusting parameters such as electronegativity and bond length, students can observe the effects on bond strength and molecular geometry, deepening their comprehension of bonding principles.

Gas Laws: Understanding the behavior of gases can be challenging for students due to the abstract nature of gas molecules and their interactions. PhET simulations such as "Gas Properties" and "Ideal Gas Law" provide virtual laboratories where students can investigate Boyle's Law, Charles's Law, and Avogadro's Law (Podolefsky & Perkins, 2012). By changing variables such as volume, pressure, and temperature, students can observe the effects on gas behavior and visualize the relationships described by the gas laws, facilitating conceptual understanding.

Chemical Equilibrium: PhET simulations offer dynamic representations of chemical equilibrium processes, allowing students to explore how concentrations, temperature, and pressure affect the equilibrium position and the rates of forward and reverse reactions (Perkins *et al*., 2012). Simulations such as "Reactants, Products, and Leftovers" and "Equilibrium Constant" enable students to manipulate reaction conditions and observe changes in reaction kinetics and equilibrium concentrations. Through interactive experimentation, students gain insight into Le Chatelier's Principle and the factors that influence chemical equilibrium (Rahmawati, Hartanto, *et al*., 2022).

Electrochemistry: Electrochemical concepts, such as redox reactions and electrochemical cells, can be challenging to grasp without visual aids. PhET simulations like "Electrolyte Solutions" and "Galvanic Cells" provide interactive models where students can explore the flow of electrons, the movement of ions, and the principles underlying electrochemical processes (Perkins *et al*., 2012). By building and manipulating virtual cells, students can investigate factors affecting cell potential, electrolysis, and the production of electrical energy from chemical reactions.

How to Promoting Active Learning

PhET simulations are designed to actively engage students by allowing them to manipulate variables, observe dynamic phenomena, and explore cause-and-effect relationships in real-time. These interactive experiences captivate students' interest and curiosity, drawing them into the learning process. Research has shown that active engagement leads to deeper conceptual understanding and long-term retention of knowledge (Chi, 2009). PhET simulation serve as a platform for active exploration, it encourage makes leaning by students to become concrete.

In addition to promoting studentds' individual engagement and motivation, PhET simulations facilitate collaborative learning experiences among students. Collaborative learning encourages active participation, peer interaction, and the exchange of ideas, leading to enhanced learning outcomes as reported by (Jr & Zimmaro, 2002). PhET simulations provide a shared platform where students can collaborate on experiments, discuss findings, and problem solving (Richard M. Felder & Brent, 2005).

Integration into Chemistry Curricula

There are many advantages that PhET interactive simulations offer that attract teachers to integrate them into chemistry learning in general and especially during the teaching chemistry concepts (Lahlali *et al*., 2023). In recent years, there has been growing interest in integrating PhET simulations into chemistry curricula at different educational levels to enhance students' understanding of chemical phenomena (Rayan *et al*., 2023).

Several studies have examined the effectiveness of integrating PhET simulations into high school chemistry courses. Research showed that using PhET simulations as part of inquiry-based activities improved high school students' understanding of chemical equilibrium concepts and also found that incorporating PhET simulations into high school chemistry instruction enhanced students' conceptual understanding and problem-solving skills in topics such as gas laws and atomic structure (Lahlali *et al*., 2023; Mallari, 2020; Moore *et al*., 2014; Salame & Makki, 2021).

Limitations and Future Research

The integration of PhET simulations in chemistry teaching and learning may present some technical challenges such as hardware compatibility, access issues, and maintenance requirements. Pedagogical considerations involve aligning simulations with learning objectives, promoting inquiry-based learning, and designing effective assessment methods. By addressing these challenges and incorporating pedagogical strategies, educators can enhance student engagement and deepen understanding of chemistry concepts.

The future of PhET simulations in chemistry teaching may involve embracing emerging technologies such as virtual reality and artificial intelligence, as well as advancing research in instructional design and learning analytics. These developments aim to enhance student engagement, facilitate conceptual understanding, and promote active learning.

CONCLUSION

In conclusion, PhET interactive simulations represent a powerful tool used for enhancing chemistry education. It aligns with best practices in educaton by promoting active and collaborative learning, improving conceptual understanding, and making abstract concepts more accessible. As technology evolves , these simulations are poised to play an increasingly significant role in the future of chemistry education, offreing innovative approaches to teaching and learning that prepares students for succes in STEM fileds.

REFERENCES

Chi, M. T. H. (2009). Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science*, *1*(1), 73–105. https://doi.org/10.1111/j.1756-8765.2008.01005.x

Jr, I. A. S., & Zimmaro, D. M. (2002). *The Influence of Collaborative Learning on Student Attitudes and Performance in an Introductory Chemistry Laboratory*. *79*(6), 745–748.

Lahlali, A., Chafiq, N., Radid, M., Moundy, K., & Srour, C. (2023). The Effect of Integrating Interactive Simulations on the Development of Students' Motivation, Engagement, Interaction and School Results. *International Journal of Emerging Technologies in Learning*, *18*(12), 193–207. https://doi.org/10.3991/ijet.v18i12.39755

Mallari, R. L. (2020). The Effectiveness of Integrating PhET Interactive Simulation-based Activities in Improving the Student's Academic Performance in Science. *International Journal for Research in Applied Science and Engineering Technology*, *8*(9), 1150–1153. https://doi.org/10.22214/ijraset.2020.31708

Moore, E. B., Chamberlain, J. M., Parson, R., & Perkins, K. K. (2014). PhET interactive simulations: Transformative tools for teaching chemistry. *Journal of Chemical Education*, *91*(8), 1191–1197. https://doi.org/10.1021/ed4005084

Perkins, K., Moore, E., Podolefsky, N., Lancaster, K., & Denison, C. (2012). Towards research-based strategies for using PhET simulations in middle school physical science classes. *AIP Conference Proceedings*, *1413*, 295–298. https://doi.org/10.1063/1.3680053

Rahmawati, Y., Hartanto, O., Falani, I., & Iriyadi, D. (2022). *Journal of Technology and Science Education STUDENTS ' CONCEPTUAL UNDERSTANDING IN CHEMISTRY*. *12*(2), 303–326.

Rahmawati, Y., Zulhipri, Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' Conceptual Understanding in Chemistry Learning Using Phet Interactive Simulations. *Journal of Technology and Science Education*, *12*(2), 303–326. https://doi.org/10.3926/jotse.1597

Rayan, B., Daher, W., Diab, H., & Issa, N. (2023). *education sciences Integrating PhET Simulations into Elementary Science Education : A Qualitative Analysis*.

Richard M. Felder, & Brent, R. (2005). Effective_Strategies_for_Cooperative_Lea.pdf. In *Journal of Enginering Education* (Vol. 10, Issue 2, pp. 69–75).

Salame, I. I., & Makki, J. (2021). Examining the Use of PhET Simulations on Students' Attitudes and Learning in General Chemistry II. *Interdisciplinary Journal of Environmental and Science Education*, *17*(4), e2247. https://doi.org/10.21601/ijese/10966