ENHANCING STUDENT'S PARTICIPATION IN CHEMISTRY PRACTICAL WORK: THE ROLE OF EXPERIMENTAL SIMULATION SOFTWARE

Nnamani Onyekachi Stephen
**Department of Chemistry, Federal College of Education, Technical, Isu, Ebonyi State, Nigeria*

Abstract

At every stage of the educational process, the ever-rising tide of technological advancements has brought new possibilities for enhancing both classroom instruction and student learning. Computer simulation tools have increased students' interest, motivation, and engagement in learning scientific concepts. The current research investigated the potential for the ChemLab simulation software to impact secondary school student's interest in participating in chemistry laboratory experiments. Two hundred nine senior secondary school students enrolled in science classes participated in the research project. The result established a statistically significant effect of ChemLab simulation software on the respondent's intention to engage in chemistry lab experiments at F (1,207), 4.60 P.05 with adjusted R^2 indicating that ChemLab simulation software contributed approximately 9.11% of the variance in student's intention to engage in a chemistry lab experiment. The finding has implications for the design of laboratory exercises for secondary school chemistry classrooms.

Keywords**:** ChemLab, simulation, chemistry, secondary school, students

Introduction

At every stage of education, the government of Nigeria is working to integrate more cutting-edge technology and creative approaches into the classroom. This is pertinent to the recommendation made in the National Policy on Education (2004) for increased funding for high-quality research in the sciences and technologies. In today's world, the level of a society's development can be gauged by looking at its level of technological advancement. Technological advancement paves the way for wealth creation, improved quality of life, and genuine economic expansion and transformation in any community (Anaeto et al., 2016). Several different pieces of research have established a connection between technological innovation and Nigeria's national progress (Ajah & Chigozie-Okwum, 2019; Ajibo et al., 2019; Akpojedje & Ighodaro, 2019; Bubou, 2011; Mashi et al., 2014; Nwankwo & Njoku, 2020; Oghogho, 2013; Oladeji & Adegboye, 2019; Oloruntoyin & Adeyanju, 2013; Siyanbola et al., 2016). In the body of research that has been conducted, a general agreement has been reached to the effect that receiving a proper education in the sciences is indispensable for expanding one's access to scientific opportunities and cultivating the skills that are required for arriving at the level of technical proficiency that is desired. Promoting scientific literacy should be the primary focus of science education in every subject area (Upahi et al., 2020). The study of chemistry is an essential part of the science curriculum in Nigeria, where it significantly contributes to the country's economic growth and cultural advancement (Nnamdi, 2014).

Chemistry is a branch of physical science concerned with matter's characteristics, composition, and reactions (Otor et al., 2015). Chemistry is a crucial field of science and the foundation of the biological sciences (Mahdi, 2014; Hailemariam, 2017). In addition, Oladeji and Adegboye (2019) assert that chemistry is one of the science disciplines that play a crucial role in science because it provides the ability to understand the complexity of molecules and their properties. Eya and Ezeh (2020) emphasized that chemistry education is crucial for fostering human development and achieving sustainable economic progress. Exposure to chemistry fundamentals is essential for promoting scientific attitudes in kids that are transferrable to other areas of life (Chepkorir et al., 2014).

Consequently, chemistry in the Nigerian environment has been plagued by difficulties associated with a lack of student motivation, negative attitudes, low enrollment, limited laboratory facilities, and instructional competency (Edomwonyi-Otu & Avaa, 2011; Emendu & Okoye, 2015; Muhammad, 2017; Ojukwu, 2016). Conceivably, the subject is often seen to be a complex area of study for students (Gladys et al., 2017; Salame et al., 2019) and has been associated with low performance (Abudu & Gbadamosi, 2014; Jack, 2013; Nbina, 2012), particularly in laboratory trials. Thus, laboratory exercises are primarily designed to investigate individual patterns and establish scientific competencies. Practical experimentation with chemical laws and observing a phenomenon in a laboratory improves a student's scientific aptitude (Chang et al., 2015).

Experiments in the laboratory are crucial for secondary school science education (Sharpe & Abrahams, 2020). Numerous post-primary curricula emphasize the importance of laboratory experiments in the syllabi of science topics such as chemistry and physics (Šorgo & Špernjak, 2012). Students can conduct basic experiments on fundamental laws and principles and gain skills with various measuring equipment and other physics-related apparatus through practical laboratory experiences. Experiments improve essential learning skills (Babalola, 2017). Laboratory experiments in physics represent learning undertaken in a particular setting to increase learners' motivation and engagement with relevant learning events derived from everyday experiences and phenomena (Stanley, 2000). Laboratories play a very active and vital role in chemical education. Understanding the fundamental principles and concepts required to detect hidden ideas and describe and explain underlying laws and theories is essential to applying sophisticated reasoning abilities.

With increasing evidence of poor engagement in the practical component of the course (Lawrie et al., 2009), the present study examines the role of experimental simulation software in expanding students' participation in laboratory experiments. Within the realm of 'active learning,' there is a growing trend toward using high-quality software that allows pupils to engage in various activities within a particular setting. One of the most important developments in modern chemistry is using computer simulations of laboratory procedures, either as a preliminary step or as a means of delivering a virtual inquiry. This can be done by sending a digital query or as a preliminary action. For example, several disparate studies have employed computer simulations to improve chemistry learning in recent years (Ahmad et al., 2021; Alkan & Koçak, 2015; Haase & Matthes, 2019; Jabeen & Afzal, 2020; Kempf et al., 2002; Mihindo et al., 2017; Nkemakolam et al., 2018; Olakanmi, 2015; Peechapol, 2021; Shibata, 2021; Sui & Yao, 2016; Zendler & Greiner, 2020). However, the current emphasis is on ChemLab laboratory experimental simulation tool.

ChemLab is a simulation tool for chemistry that allows students to do experiments as if in a natural laboratory. It has a list of experiments from which users can access the preferred experiment to conduct. Each experiment consists of three sections encompassing introduction, method, and observation. This section provides an overview of the investigation that will be shown. All the reactions that will occur in an experiment are described in detail. The user is encouraged to read the entire introduction to understand what will happen in an investigation. This section features step-by-step instructions for experimenting. On the toolbar of this chemistry simulator, students can find all of the equipment and chemicals, including a beaker, funnel, HCL, Nitric Oxide, etc.

ChemLab is a low-cost, commercially available software that does not require sophisticated hardware and is exclusively suited for teaching chemistry in schools (Rossi et al., 2012). The software includes simulations for titration, decantation, pouring, and heating, among other things. Temperature, weight, volume, pH, and other data are also included. New chemicals can be added, and different reactions can be combined. The software allows the user to participate in a live lab simulation. It has a wizard that simplifies the process of creating simulations. Demonstrations are possible, and they can be used in a variety of settings.

In contemporary science education in Nigeria, growing intimation suggests a decline in laboratory experiments in secondary schools. The trend has been attributed to various factors, including inadequate laboratory equipment, poor funding, teacher factor, and students' attitudes and motivation. Indeed, the surge in technological innovations has offered varying opportunities to enhance science learning. For instance, chemistry laboratory simulation software describes a problem-solving activity with a playful attitude. Thus, it might potentiate students' engagement in a laboratory experiment in secondary school. However, numerous scholars have tested different virtual methods for enhancing chemistry practical in the Nigerian context (Aliyu & Talib, 2019; Chado et al., 2021; Gambari et al., 2018; Nathaniel A., 2016; Odewumi et al., 2019). However, the Modell ChemLab simulations tool, which seems indispensable in increasing students' motivation in learning, has not been utilized for chemistry practicals in Nigeria. Therefore, the present study investigates the software as a tool to encourage students' engagement in the chemistry laboratory.

Hypothesis: ChemLab simulation software would influence student's engagement in chemistry laboratory experiments

Method

The research population comprises secondary school students from Ebonyi State, Nigeria. Participants were male and female high school seniors from five state public and private secondary schools. Two hundred fifteen students who satisfied the inclusion requirements (such as being enrolled in a science class and having participated in a laboratory experiment) were pooled from their respective schools with the assistance of school teachers and administrators between April and July 2022. Before the commencement of the study, the students were prepped and informed of its aim. In particular, all ethical issues were considered.

Procedure

The schools were categorized into sch1 – sch5 and authorization was received from the school authorities. In particular, the respondents were assembled in a controlled laboratory setting within their school premises. They were briefly exposed to a simulation laboratory concept using the ChemLab software. The activity lasted three days in each of the schools. However, three days gap was given after they witnessed the simulation practice before they were made to respond to a self-report measure assessing their intention to participate in a real-life laboratory experiment. The 215 participants were given the questionnaire to complete on the spot. Intention to engage in laboratory practicals was rated on a 10-item Linkert form scale with 5-point ratings ranging from 1 (not likable at all) to 5 (very likable). The scale was validated following a pilot study, and a Cronbach alpha .78 reliability coefficient was obtained. A higher score indicates a high intention to participate in experimental practice**.** Upon inspection of the returned questionnaires, 209 were correctly completed, while six were incorrectly completed. Thus, the 209 correctly completed forms were used for statistical analysis.

Result

Testing the study hypothesis

The primary assumption of the study is that ChemLab simulation software would exacerbate engagement in a chemistry laboratory experiment. The data from 209 respondents, 15.8% (sch1), 16.3% (sch2), 21.4% (sch3), 19.5% (sch4), and 27% (sch5), were computed using a simple linear regression model. The result established a statistically significant effect of ChemLab simulation software on the respondent's intention to engage in chemistry lab experiments at F (1,207), 4.60 P< .05 with adjusted R^2 indicating that ChemLab simulation software contributed about 9.11% of the variance in student's intention to engage in a chemistry lab experiment.

Table 1: shows the regression analysis of the result.

	B	SEB	β	t	R^2	Sig
Constant	3.45	.013		26.49	.911	.000
ChemLab	-.35	.016	-.15	-2.15		.000

Discussion

The present study examined ChemLab simulation software as a tool that could influence students' engagement in chemistry laboratory experiments in secondary school. Two hundred and nine senior secondary school students enrolled in the science classes participated in the study. The regression analysis revealed that ChemLab simulation software statistically significantly predicted engagement in lab experiments among the respondents F (1,207), 4.60 P< .05. Thus, the finding suggests that the students exposed to ChemLab simulation software are more likely to engage more in lab experiments than others. Most importantly, the result indicated that exposure to the simulation tool explained about 9.11% of the differences in students' intention to engage in a chemistry lab experiment. Thus, the result offers support to previous findings, which applauded the use of simulation tools in chemistry learning (Dalgarno et al., 2009; Donnelly et al., 2013; Jabeen & Afzal, 2020; Kotoka & Kriek, 2014; Nathaniel A., 2016; Nkemakolam et al., 2018). They discovered that simulations boost students' chemistry achievement more than the lecture method does. The fact that computer simulation offered virtual laboratories and feedback on the chemical concept may have contributed to its superiority over the lecture technique. Users can interact with computer simulations, which minimizes the abstractness of hazardous chemistry concepts to the students. Simulation activates experimental awareness and will enable students to visualize, explore and formulate scientific explanations in chemistry that were otherwise impossible to understand and comprehend in the conventional lab experiment. This implies that computer simulation improves students' willingness more when compared with the traditional method. Similarly, the result indicates that students who experience simulation exercises in relation to chemistry experiments are more suitable to acquire a positive attitude toward chemistry practicals. Thus, ChemLab might potentiate curiosity in lab experiments and probably instigate private investigations. Accordingly, they progress in the direction expected to achieve the goal of a scientific-driven society.

Limitations, strengths, and future directions

Because the study did not adopt an experimental approach, it becomes difficult to establish the cause-effect relationship of the variables. More so, the self-reported intention to engage in experimental practices might trigger biases constraining the generalization of the finding. Despite the practical limitations, the present study contributes to the literature by identifying Model ChemLab simulation software as a positive predictor of students' engagement in a chemistry laboratory experiment in secondary schools. Thus, the result broadens our knowledge about the positive impact of technological innovation relative to science education. Moreover, indications suggest a scarcity of literature investigating the predictive variables in chemistry experiments in secondary education in Nigeria based on ChemLab software. Thus, justifying the current study. Future researchers should utilize experimental methods to identify cause-effects and adopt multiple data collection approaches.

Conclusion

The linear regression analysis conducted on the study data proved the critical effect of ChemLab simulation software in predicting students' engagement in chemistry lab experiments at the senior secondary school level. Indeed, the research hypothesis was supported by the result of the study. Therefore, it is concluded that ChemLab simulation software is a critical determinant of students' participation in lab experiments. The finding provides valuable data suggesting that ChemLab simulation software can be used to conduct digital experiments to support science education on the cloud visually and interactively. A significant part of laboratory experiences, such as observation, analysis, and discussion, can be delivered on a large scale through digital simulation. Thus, the technology can potentially broaden participation in experimental chemistry, especially for students and teachers in underserved communities who may lack the expertise, equipment, and supplies needed to conduct specific experiments. Indeed, a platform that enables anyone to store, process, and disseminate experimental data via the digital revolution is proposed. Also, the result of the study implicates ChemLab as a possible innovative teaching technique for sustaining chemistry laboratory experiments in Nigeria's secondary schools.

References

Abudu, K. A. &, & Gbadamosi, M. R. (2014). Relationship between teacher's attitude and student's academic achievement in senior secondary school chemistry. A case study of Ijebu-Ode and Odogbolu Local Government Area of Ogun state. *Wudpecker Journal of Educational Research ISSN*, *3*(3).

Ahmad, N. J., Yakob, N., Bunyamin, M. A. H., Winarno, N., & Akmal, W. H. (2021). Interactive computer animation and simulation affect students' achievement and motivation in learning electrochemistry. *Jurnal Pendidikan IPA Indonesia*, *10*(3). https://doi.org/10.15294/JPII.V10I3.26013

Ajah, I. A., & Chigozie-Okwum, C. C. (2019). Prospects of ICT for digital growth and national development in Nigeria. *African Research Review*, *13*(3).

https://doi.org/10.4314/afrrev.v13i3.17

Ajibo, C. C., Anozie, M. C., Onyeabor, E., Umahi, T. O., Odinkonigbo, J. J., & Agu, H. (2019). Technology transfer for development in Nigeria: patterns, problems, and prospects. *Commonwealth Law Bulletin*, *45*(1). https://doi.org/10.1080/03050718.2019.1689150

Akpojedje, F. O., & Ighodaro, H. F. (2019). A study on Nigeria's political economy of transforming indigenous technology through appropriate engineering and technological development. *Journal of Advances in Science and Engineering*, *2*(1). https://doi.org/10.37121/jase.v2i1.30

Aliyu, F., & Talib, C. A. (2019). Virtual chemistry laboratory: A panacea to problems of conducting chemistry practical at science secondary schools in Nigeria. *International Journal of Engineering and Advanced Technology*, *8*(5). https://doi.org/10.35940/ijeat.E1079.0585C19

Alkan, F., & Koçak, C. (2015). Chemistry laboratory applications supported with simulation. *Procedia - Social and Behavioral Sciences*, *176*. https://doi.org/10.1016/j.sbspro.2015.01.566

Anaeto, F., Asiabaka, C., Ani, A., Nnadi, F., Ugwoke, F., Asiabaka, I., Anaeto, C. A., & Ihekeronye, N. (2016). The roles of science and technology in national development. *Direct Research Journal of Social Science and Educational Studies*, *3*(3).

Babalola, F. (2017). Advancing practical physics in Africa's schools. In *PQDT - UK & Ireland*.

Bubou, G. M. (2011). Platform technologies and socio-economic development: The case of information and communications technologies (ICTs) in Nigeria. *Australian Journal of Emerging Technologies and Society*, *9*(1).

Chado, A., Dalhatu, B., & Mohammed, S. (2021). Effects of virtual laboratory instructional strategy on students' achievement in chemistry practical among senior secondary schools in Minna Metropolis, Niger State. *International Journal of Instructional Technology and Educational Studies*, *2*(3). https://doi.org/10.21608/ihites.2021.90629.1048

Chang, M., Lachance, D., Lin, F., Al-Shamali, F., & Chen, N. S. (2015). Enhancing orbital physics learning performance through a hands-on Kinect game. *Egitim ve Bilim*, *40*(180). https://doi.org/10.15390/EB.2015.3145

Chepkorir, S., Cheptonui, E. M., & Chemutai, A. (2014). The relationship between teacher-related factors and students' attitudes towards secondary school chemistry subject in Bureti district, Kenya. *Journal of Technology and Science Education*, *4*(4). https://doi.org/10.3926/jotse.118

Dalgarno, B., Bishop, A. G., Adlong, W., & Bedgood, D. R. (2009). Effectiveness of a virtual laboratory as a preparatory resource for distance education chemistry students. *Computers and Education*, *53*(3). https://doi.org/10.1016/j.compedu.2009.05.005

Donnelly, D., O'Reilly, J., & McGarr, O. (2013). Enhancing the student experiment experience: visible scientific inquiry through a virtual chemistry laboratory. In *Research in Science Education* (Vol. 43, Issue 4). https://doi.org/10.1007/s11165-012-9322-1

Edomwonyi-Otu, L., & Avaa, A. (2011). The challenge of effective teaching of chemistry: A case study. *Leonardo Electronic Journal of Practices and Technologies*, *10*(18).

Emendu, N.B., & Okoye, C. . (2015). Identifying problems associated with studying chemistry in Anambra State, Nigeria. *International Journal of Scientific and Research Publications*, *5*(6).

Emendu, Nnamdi B. (2014). The role of chemistry education in national development. *The International Journal Of Engineering And Science*.

Eya, N. ., & Ezeh, D. N. (2020). Meta-analysis of the influence of gender on students' academic achievement in chemistry in Nigeria. *Journal of Chemical Society of Nigeria*, *45*(4). https://doi.org/10.46602/jcsn.v45i4.488

G. Mahdi, J. (2014). Student attitudes towards chemistry: an examination of choices and preferences. *American Journal of Educational Research*, *2*(6). https://doi.org/10.12691/education-2-6-3

Gambari, A. I., Kawu, H., & Falode, O. C. (2018). Impact of a virtual laboratory on the achievement of secondary school chemistry students in homogeneous and heterogeneous collaborative environments. *Contemporary Educational Technology*, *9*(3). https://doi.org/10.30935/cet.444108

Gebre Silassie Hailemariam, A. (2017). Assessment of female students' achievement in chemistry subject at Merti Secondary School. *Education Journal*, *6*(6). https://doi.org/10.11648/j.edu.20170606.16

Gladys Uzezi, J., Ezekiel, D., & Musa Auwal, A.-K. (2017). Assessment of conceptual difficulties in chemistry syllabus of the Nigerian science curriculum as perceived by high school college students. *American Journal of Educational Research*, *5*(7). https://doi.org/10.12691/education-5-7-3

Haase, S., & Matthes, K. (2019). The importance of interactive chemistry for stratosphere-troposphere coupling. *Atmospheric Chemistry and Physics*, *19*(5). https://doi.org/10.5194/acp-19-3417-2019

Jabeen, F., & Afzal, M. T. (2020). Effect of simulated chemistry practicals on students' performance at secondary school level. *Journal of Education and Educational Development*, *7*(1). https://doi.org/10.22555/joeed.v7i1.2600

Jack, G. U. (2013). Concept mapping and guided inquiry as effective techniques for teaching difficult concepts in chemistry : effect on students' academic achievement. *Journal of Education and Practice*, *4*(5).

Kempf, A., Sadiki, A., & Janicka, J. (2002). Prediction of finite chemistry effects using large eddy simulation. *Proceedings of the Combustion Institute*, *29*(2). https://doi.org/10.1016/S1540-7489(02)80241-3

Kotoka, J., & Kriek, J. (2014). The impact of computer simulations as interactive demonstration tools on the performance of grade 11 learners in electromagnetism. *African Journal of Research in Mathematics, Science and Technology Education*, *18*(1). https://doi.org/10.1080/10288457.2014.884263

Lawrie, G., Adams, D., Blanchfield, J., Gahan, L., & Weaver, G. C. (2009). The CASPiE Experience: Undergraduate research in the 1st year chemistry laboratory. *UniServe Science Proceedings*.

Mashi, S. A., Inkani, A. I., & Yaro, A. (2014). An appraisal of the role of science and technology in promoting national development efforts in Nigeria. *The International Journal Of Engineering And Science*, *3*(2).

Mihindo, W. J., Wachanga, S. W., & Anditi, Z. O. (2017). Effects of computer-based simulations teaching approach on students' achievement in chemistry learning among secondary school students in Nakuru Sub County, Kenya. *Journal of Education and Practice*, *8*(5).

Muhammad Shamsuddin, I. (2017). Solving the problems of chemistry education in Nigeria: a panacea for national development. *American Journal of Heterocyclic Chemistry*, *3*(4). https://doi.org/10.11648/j.ajhc.20170304.12

Nathaniel A., O. (2016). The Effect of Combined Virtual and Real Laboratories on Students' Achievement in Practical Chemistry. *International Journal of Secondary Education*, *4*(3). https://doi.org/10.11648/j.ijsedu.20160403.11

Nbina, J. (2012). Analysis of the poor performance of senior secondary students in chemistry in Nigeria. *African Research Review*, *6*(4). https://doi.org/10.4314/afrrev.v6i4.22

Nkemakolam, O. E., Chinelo, O. F., & Jane, M. C. (2018). Effect of computer simulations on secondary school student academic achievement in chemistry in Anambra State. *Asian Journal of Education and Training*, *4*(4). https://doi.org/10.20448/journal.522.2018.44.284.289

Nwankwo, W., & Njoku, C. C. (2020). Sustainable development in developing societies is the place of ICT-driven computer education. *International Journal of Emerging Technologies in Learning*, *15*(12). https://doi.org/10.3991/ijet.v15.i12.14007

Odewumi, M. O., Falade, A. A., Adeniran, A. O., Akintola, D. A., Oputa, G. O., & Ogunlowo, S. A. (2019). Acquiring basic chemistry concepts through virtual learning in Nigerian senior secondary schools. *Indonesian Journal on Learning and Advanced Education (IJOLAE)*, *2*(1). https://doi.org/10.23917/ijolae.v2i1.7832

Oghogho, I. (2013). ICT for national development in Nigeria: creating an enabling environment. *International Journal of Engineering and Applied Sciences*, *3*(2).

Ojukwu, M. O. (2016). Perception of students on causes of poor performance in chemistry in external examinations in Umuahia North Local Government of Abia State. *International Journal of Education & Literacy Studies*, *4*(1). https://doi.org/10.7575/aiac.ijels.v.4n.1p.67

Oladeji, S. I., & Adegboye, A. A. (2019). Science and technology policy for Nigeria's development planning. *Journal of Education, Society, and Behavioural Science*. https://doi.org/10.9734/jesbs/2019/v32i430182

Olakanmi, E. E. (2015). The effects of a web-based computer simulation on students' conceptual understanding of the rate of reaction and attitude towards chemistry. *Journal of Baltic Science Education*, *14*(5). https://doi.org/10.33225/jbse/15.14.627

Oloruntoyin, S. T., & Adeyanju, I. A. (2013). The role and prospect of information and communication technology in national development. *International Journal of Computing Academic Research (IJCAR)*, *2*(3).

Otor, E. E., Ogbeba, J., & Ityo, C. N. (2015). Influence of improvised teaching instructional materials on chemistry students' performance in senior secondary schools in Vandeikya Local Government Area of Benue State, Nigeria. *International Research in Education*, *3*(1). https://doi.org/10.5296/ire.v3i1.7181

Peechapol, C. (2021). Investigating the effect of virtual laboratory simulation in chemistry on learning achievement, self-efficacy, and learning experience. *International Journal of Emerging Technologies in Learning*, *16*(20). https://doi.org/10.3991/ijet.v16i20.23561

Rossi, A., Rossi, A. V., & Toretti, G. A. (2012). Good results are possible in difficult conditions: chemistry classes, computers, and public schools. *Brazilian Journal of Computers in Education*, *11*(1).

Salame, I. I., Patel, S., & Suleman, S. (2019). Examining some of the students' challenges in learning organic chemistry. *International Journal of Chemistry Education Research*, *3*(1). https://doi.org/10.20885/ijcer.vol3.iss1.art2

Sharpe, R., & Abrahams, I. (2020). Secondary school students' attitudes to practical work in biology, chemistry, and physics in England. *Research in Science and Technological Education*, *38*(1). https://doi.org/10.1080/02635143.2019.1597696

Shibata, K. (2021). Simulations of ozone feedback effects on the equatorial quasi-biennial oscillation with a chemistry climate model. *Climate*, *9*(8). https://doi.org/10.3390/cli9080123

Siyanbola, W., Adeyeye, A., Olaopa, O., & Hassan, O. (2016). Science, technology and innovation indicators in policy-making: The Nigerian experience. *Palgrave Communications*, *2*. https://doi.org/10.1057/palcomms.2016.15

Šorgo, A., & Špernjak, A. (2012). Practical work in biology, chemistry, and physics at lower secondary and general upper secondary schools in Slovenia. *Eurasia Journal of Mathematics, Science and Technology Education*, *8*(1). https://doi.org/10.12973/eurasia.2012.813a

Stanley, H. E. (2000). Exotic statistical physics: applications to biology, medicine, and economics. *Physica A: Statistical Mechanics and Its Applications*, *285*(1). https://doi.org/10.1016/S0378-4371(00)00341-1

Sui, H., & Yao, J. (2016). Effect of surface chemistry for CH4/CO2 adsorption in kerogen: A molecular simulation study. *Journal of Natural Gas Science and Engineering*, *31*. https://doi.org/10.1016/j.jngse.2016.03.097

Upahi, J. E., Ramnarain, U., & Ishola, I. S. (2020). The Nature of Science as Represented in Chemistry Textbooks Used in Nigeria. *Research in Science Education*, *50*(4). https://doi.org/10.1007/s11165-018-9734-7

Zendler, A., & Greiner, H. (2020). The effect of two instructional methods on learning outcome in chemistry education: The experiment method and computer simulation. *Education for Chemical Engineers*, *30*. https://doi.org/10.1016/j.ece.2019.09.001