ENHANCING SELF-LEARNING IN CHEMISTRY: A LITERATURE REVIEW AND THE ROLE OF CHEMISTORY EXPLORER

H. Rahmalan[1], S. Mohtar[1], and N. A. Arbain[1]

[1]Fakulti Teknologi Maklumat dan Komunikasi,
Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

Corresponding Author's Email: hidayah@utem.edu.my

Article History: Received 15 March 2024; Revised 15 April 2024; Accepted 15 May 2024

ABSTRACT: This paper presents a comprehensive literature review of the factors contributing to effective self-learning in chemistry. The literature highlights the importance of interactive and engaging learning tools, personalized feedback, historical contextualization, and gamified elements in enhancing self-learning outcomes. "Chemistory Explorer" integrates these key elements through its interactive timeline, virtual laboratories, multimedia content, photo booth, and game puzzle modules. By providing an immersive and personalized learning experience, the platform fosters deeper understanding, critical thinking, and motivation among learners. The study demonstrates best practices of self-learning in chemistry and advances them by leveraging cutting-edge technology to make chemistry education more accessible and effective. This research underscores the platform's potential to revolutionize self-learning in chemistry and contribute to the broader educational landscape.

KEYWORDS: *Chemistry; Self-learning; Interactive Learning; Game; Artificial Intelligence Features*

1.0 INTRODUCTION

Chemistry is a complex subject that many students find daunting due to its intricate concepts and vast information. Mastery of atomic and molecular concepts, such as nuclear structure, molecular bonding, and reaction mechanisms, is critical but often challenging. To address these difficulties, active learning strategies like interactive simulations, group discussions, and hands-on experiments can make the subject more engaging and accessible.

Self-directed learning plays a crucial role in empowering students to take control of their educational journey, enhancing understanding and retention of chemistry's complex concepts. With the rise of digital and interactive tools, students can address individual learning needs at their own pace. This literature review examines the factors influencing effective self-learning in chemistry, highlights innovative strategies, and explores how technology can revolutionize chemistry education, making it more accessible and effective for all learners.

2.0 THE IMPORTANCE OF SELF-LEARNING IN CHEMISTRY

Self-learning in chemistry enables students to take charge of their education, enhancing understanding and critical thinking. Advanced technologies like interactive simulations and AI-driven platforms have revolutionized learning, offering personalized content and adaptive feedback to address individual needs. Tools such as virtual labs and multimedia resources make complex concepts more accessible and engaging while fostering curiosity. By utilizing these innovations, educators can create flexible and dynamic learning environments, improving students' grasp of chemistry and inspiring lifelong interest in the subject.

3.0 KEY FACTORS FOR EFFECTIVE SELF-LEARNING IN CHEMISTRY

A review of recent literature highlights several key factors for effective self-learning in Chemistry, which covers motivation and engagement, feedback and assessment, and the use of cognitive and metacognitive strategies.

3.1 Motivation and Engagement

Successful self-learning in chemistry requires a synergistic approach that combines various elements to foster a deeper understanding of the subject [1]. Recent research has highlighted the importance of creating personalized and creative learning experiences to complement the conventional methods of teaching chemistry [2]. One key factor is the integration of inquiry-based learning, where students are encouraged to actively engage in the learning process by exploring and investigating chemical phenomena [3]. This approach could provide innovative strategies that will enhance chemistry learning by improving understanding, engagement, critical thinking, and problem-solving skills.

Motivation and engagement are crucial for self-learning [2], [4]. Chemistry can be perceived as a challenging subject, calling for innovative approaches to spark curiosity and motivation, helping students tackle chemistry’s challenges and explore complex topics independently. Tools and resources that increase engagement, such as interactive learning environments, have been found to sustain motivation over time [5].

3.2 Feedback and Assessment

The provision of personalized feedback and formative assessment is a key factor in fostering effective self-learning in chemistry. Creative story writing enhances students' understanding of chemical elements in online learning, as suggested by [2]. Consistent teacher-student communication improves outcomes, but challenges include shallow research and limited teacher consultation. Meanwhile, assessment results showed satisfactory scores in conveying element properties through stories. Feedback, collaboration, and creativity were emphasized, despite challenges. Improvements include more consultations, flexible timelines, and model stories. Organized communication and adaptable guidelines are crucial for meaningful learning experiences.

3.3 Self-directed learning & e-Learning

Interactive and engaging tools promote the development of cognitive and metacognitive skills essential for self-directed learning in chemistry [6]. Research highlights that online platforms enhance students' self-regulation by enabling them to set learning goals and actively participate in their education [7]. Studies also show that web-based learning moderately increases self-regulated learning among high school students, proving the effectiveness of integrating technology into chemistry education [8]. Virtual laboratories and instructional videos cater to diverse learning styles, fostering engagement and personalized learning experiences [9]. Furthermore, innovative pedagogies, such as critical thinking tools and project-based learning, support self-development in chemistry studies [10]. AI-based chatbots like "Edubot" provide interactive tutorials and self-assessment, addressing resource gaps and improving student performance [5]. Together, these technological advancements create a dynamic framework that enhances self-learning in chemistry.

E-learning platforms promote self-directed learning, inclusivity in chemistry education, and personalized learning experiences [11][12][13]. Their effectiveness depends on teachers' guidance and support [11][13]. Effective chemistry eLearning platforms enhance learning through personalized experiences, using AI and analytics such as I3Learn platform [14], and well-designed resources and activities such as Quimieduca [15].

4.0 THE ROLE OF TECHNOLOGY IN ENHANCING SELF-LEARNING IN CHEMISTRY

Technology enhances self-learning in chemistry by supporting Self-Regulated Learning (SRL) with interactive resources [16]. Online platforms improve students' self-regulation and engagement, integrating tools like virtual labs and videos for personalized learning [17][18]. Innovative pedagogical technologies and AI-based chatbots offer critical thinking tools, project-based learning, and self-assessment, boosting performance and addressing resource gaps [19][20].

4.1 E-Learning Platforms for Chemistry Education

E-learning platforms in chemistry education offer transformative methods, such as virtual laboratories and simulations, that enhance traditional approaches [21]. Adaptive learning technologies provide personalized learning paths [22], and multimedia resources support various learning styles, aiding comprehension [23]. Online assessments and real-time feedback improve performance and retention [24]. Collaborative e-learning tools promote peer interaction and problem-solving [25]. Accessibility and usability ensure inclusivity, especially for students with disabilities [26]. Integrating e-learning with existing curricula enhances traditional education [27]. This ensures that their implementation enhances rather than disrupts established teaching practices.

4.2 Gamification and Interactive Learning

Gamification and interactive learning tools, including virtual and augmented reality, significantly enhance engagement and understanding in chemistry education. They improve student motivation, performance, and conceptual knowledge by incorporating game-like elements and immersive technologies [28][29][30]. Effective design ensures these tools align with educational objectives and complement traditional teaching methods [31][32].

Gamification and interactive learning tools offer significant potential to enhance chemistry education by increasing student engagement, improving conceptual understanding, and providing hands-on experience in a safe, virtual environment. As technology continues to evolve, further research is needed to optimize these approaches and integrate them effectively into chemistry curricula.

4.3 Gap and challenges in current self-Learning Tools

Recent studies highlight challenges in Malaysian chemistry self-learning tools, such as underdeveloped self-directed skills and difficulties with online learning methods post-COVID-19 [33][34]. Reluctance to embrace digital tools and limited rural laboratory facilities also impede progress [35][36][37][38]. Improving self-learning requires engaging resources, better integration of traditional and modern methods, and addressing rural needs to ensure equitable access to quality education.

5.0 CONCLUSION AND FUTURE WORK

E-learning platforms like Chemistory Explorer revolutionize chemistry education with tools that enhance traditional methods and support self-directed learning. By integrating historical context, interactive elements, and multimedia-rich content, it engages diverse learning styles and fosters critical thinking and problem-solving skills essential for STEM success. This innovative approach can also serve as a model for advancing interactive education across other STEM disciplines.

However, Chemistory Explorer faces challenges, including development costs, scalability, and resistance from educators accustomed to traditional methods. Resource-limited environments pose additional barriers, such as inadequate infrastructure and gaps in digital literacy. To overcome these, the platform should focus on accessibility and inclusivity, offer offline functionality, and partner with organizations for support. Conducting pilot studies and expanding to other subjects will enhance its global relevance, ensuring a lasting impact on education.

ACKNOWLEDGMENTS

The authors would like to express their gratitude to Universiti Teknikal Malaysia Melaka (UTeM) for providing invaluable support and resources throughout this research. Although this study received no specific financial funding, the encouragement and access to state-of-the-art facilities, academic guidance, and collaborative opportunities provided by UTeM were instrumental in the successful completion of this work.

REFERENCES

[1] A. H. Sandtorv, "How to be a Successful Organic Chemist," 2017.

[2] R. Lansangan *et al.*, "CHEMISTORY: Integration of Creative Story Writing in Understanding Chemical Elements in Online Learning," *KIMIKA,* vol. 32, no. 1, pp. 110-128, 2021.

[3] Lauri Kõlamets, Heili Kasuk, Jack Holbrook, and R. Mamlok-Naaman, "The Relevance of Learning Outcomes Included in Estonian Grade 7-9 Science Subject Curricula Associated with the Concept of Energy," *Journal of Baltic Science Education,* vol. 22, no. 4, pp. 653-667, 2023.

[4] Ö. T. Kırık and Y. Boz, "Cooperative learning instruction for conceptual change in the concepts of chemical kinetics," *Chemistry Education Research and Practice,* vol. 13, no. 3, pp. 221-236, 2012.

[5] F. Ni'mah, S. Ibnu, and S. Rahayu, "How guided inquiry and coupled inquiry influence students attitude toward chemistry in buffer solution and solubility topics," in *AIP Conference Proceedings*, 2018, vol. 2049, no. 1: AIP Publishing.

[6] Y. Rahmawati, A. Ridwan, T. Hadinugrahaningsih, and Soeprijanto, "Developing critical and creative thinking skills through STEAM integration

in chemistry learning," in *Journal of Physics: Conference Series*, 2019, vol. 1156: IOP Publishing, p. 012033.

[7] Muhab S, Irwanto IR, ALLANAS E, YODELA E. Improving students' self-regulation using online self-regulated learning in chemistry. Journal of Sustainability Science and Management. 2022 Oct;17(10):1-2.

[8] Indriani NC, Mustaji M, Mariono A. The Influence of Web-Based Learning on Students' Self-Regulated Learning in High School Chemistry Learning. International Journal of Educational Research Review. 2023 Feb 19;8(2):257-67.

[9] Schweiker S, Levonis S. Enhancing chemistry education through technology-enhanced learning: Impact on student outcomes. ASCILITE Publications. 2023 Nov 28.

[10] Mahroof A, Gamage V, Rajendran K, Rajkumar S, Rajapaksha S, Wijendra D. An AI based chatbot to self-learn and self-assess performance in ordinary level chemistry. In2020 2nd International Conference on Advancements in Computing (ICAC) 2020 Dec 10 (Vol. 1, pp. 216-221). IEEE.

[11] Buchholz J, Jesgarz M, Schneeweiß N, Sieve B. Supporting self-directed learning in chemistry education with digital learning environments. CHEMKON. 2022 Jun 15;29:319-24.

[12] Dori YJ, Ngai C, Szteinberg G, editors. Digital Learning and Teaching in Chemistry. Royal Society of Chemistry; 2023 Jul 12.

[13] Blonder R. Digital Learning Platforms: Digital Platforms for Increasing Inclusion in Chemistry Education.2023.

[14] Roski M, Ewerth R, Hoppe A, Nehring A. Exploring Data Mining in Chemistry Education: Building a Web-Based Learning Platform for Learning Analytics. Journal of Chemical Education. 2024 Feb 13;101(3):930-40.

[15] Quesada-Soto LD, Villalobos-González W, Hernández-Chaverri RA, Rios-Badilla E. Development, implementation, and evaluation of the virtual platform Quimieduca as a didactic strategy for the teaching of Chemistry in high school. Educación Química.;35(2):18-32.

[16] Indriani, N. C. L., Mustaji, & Mariono, A. (2023). The Influence of Web-Based Learning on Students' Self-Regulated Learning in High School Chemistry Learning. International Journal of Educational Research Review, 8(2), 257–267. https://doi.org/10.24331/ijere.1249689.

[17] Mahroof, A., Gamage, V., Rajendran, K., Rajkumar, S., Rajapaksha, S., & Wijendra, D. (2020). An AI Based Chatbot to Self-Learn and Self-Assess Performance in Ordinary Level Chemistry. ICAC 2020 - 2nd International Conference on Advancements in Computing, Proceedings, 216–221. https://doi.org/10.1109/ICAC51239.2020.9357131.

[18] Muhab, S., Irwanto, I., Allanas, E., & Yodela, E. (2022). Improving Students' Self-Regulation Using Online Selfregulated Learning In Chemistry. Journal of Sustainability Science and Management, 17(10), 1–12. https://doi.org/10.46754/jssm.2022.10.001

[19] Ni'Mah, F., Ibnu, S., & Rahayu, S. (2018). How guided inquiry and coupled inquiry influence students attitude toward chemistry in buffer solution and solubility topics. AIP Conference Proceedings, 2049, 1–9. https://doi.org/10.1063/1.5082442.

[20] S. Schweiker, S., & M. Levonis, S. (2023). Enhancing chemistry education through technology-enhanced learning: Impact on student outcomes. 2023: ASCILITE 2023 Conference Companion Materials, 54(2), 1–2. https://doi.org/10.1111/ejed.12330

[21] Hernández-Ramos J, Rodríguez-Becerra J, Cáceres-Jensen L, Aksela M. Constructing a novel e-learning course, educational computational chemistry through instructional design approach in the TPASK framework. Education Sciences. 2023 Jun 26;13(7):648.

[22] Al-Dahhan WH, Zainulabdeen K, Yousif E, Al-Amiery AA, Bufaroosha M. A Study on The Reality of e-Learning for Chemistry Students During The COVID-19 Pandemic. Journal of Educational Chemistry (JEC). 2023 Jun 28;5(1):1-8.

[23] Winkelmann, K., Keeney-Kennicutt, W., Fowler, D., & Macik, M. (2020). Development, implementation, and assessment of general chemistry lab experiments performed in the virtual world of Second Life. Journal of Chemical Education, 97(7), 1884-1890.

[24] Zhai, X., Yin, Y., Pellegrino, J. W., Haudek, K. C., & Shi, L. (2021). Applying machine learning in science assessment: a systematic review. Studies in Science Education, 57(1), 1-47.

[25] Pekdağ, B. (2020). Video-based instruction on safety rules in the chemistry laboratory: its effect on student achievement. Chemistry Education Research and Practice, 21(3), 953-968.

[26] Demopoulos, C., Karampelas, K., & Kouloumbaritsi, A. (2022). Evaluating students' understanding of atomic structure: Development of a two-tier diagnostic test. Chemistry Education Research and Practice, 23(1), 169-188.

[27] Gal, E., & Weiss, P. L. (2019). Virtual reality social skills training for individuals with autism spectrum disorder. In Virtual Reality in Health and Rehabilitation (pp. 235-252). CRC Press.

[28] Setiawan, A. R., Utari, S., & Nugraha, M. G. (2023). Augmented Reality in Chemistry Learning: A Systematic Literature Review. International Journal of Interactive Mobile Technologies, 17(3), 4-20.

[29] Rodríguez-Rodríguez, J., Vicente-Sáez, R., & Martínez-Fresneda, H. (2022). Perspectives on the future of education: Educational ecosystem approaches. Sustainability, 14(3), 1180.

[30] Chong, M. C., Francis, K., Cooper, S., Abdullah, K. L., Hmwe, N. T. T., & Sohod, S. (2020). Access to, interest in and attitude toward e-learning for continuous education among Malaysian nurses. Nurse Education Today, 84, 104247.

[31] Misbah, N. H., Hamzah, M. I., & Izham, M. (2022). Embracing Technology in Education: Teachers' Readiness towards the Implementation of Digital Learning in Malaysian Schools. International Journal of Instruction, 15(1), 855-872.

[32] Rahman, N. A., Mohd Zain, M. F., & Mohamad Yatim, M. H. (2023). The Implementation of Flexible Chemistry Laboratory Kit in Rural Secondary Schools: Teachers' Perspectives. Journal of Turkish Science Education, 20(1), 56-71.

[33] Rahim, A. F. A., & Chandran, S. K. K. (2021). Inevitable Changes in Assessment Practices in Malaysian Schools During the COVID-19 Pandemic: Challenges and Solutions. International Journal of Academic Research in Progressive Education and Development, 10(2), 263-274.

[34] Almeida, F., Simoes, J., & Martins, R. (2022). Gamification in chemistry education: A systematic literature review and future perspectives. Education Sciences, 12(1), 4.

[35] Dávila-Acedo, M. A., Borrachero, A. B., Cañada-Cañada, F., & Martínez-Borreguero, G. (2022). Gamification in chemistry education: Analysis of its use at different educational levels. Chemistry Education Research and Practice,

23(2), 273-291.

[36] Hsu, Y. S., Lin, Y. H., & Yang, B. (2023). The impact of interactive molecular dynamics simulations on students' understanding of thermodynamics in chemistry education. Journal of Science Education and Technology, 32(1), 26-40.

[37] Jagodzinski, P., & Wolski, R. (2020). Augmented reality in teaching and learning chemistry: A review of the literature with topic modeling. Journal of Science Education and Technology, 29(6), 796-819.

[38] Sung, H. Y., Hwang, G. J., & Chen, S. F. (2021). Effects of embedding a problem-posing-based gaming approach within a flipped learning model on students' learning performance in a chemistry course. Computers & Education, 173, 104296.