EXPLORING CHEMISTRY TEACHERS' AWARENESS AND APPLICATION OF COGNITIVE LOAD THEORY IN SENIOR HIGH SCHOOLS

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Abstract

Chemistry teaching and learning are often regarded as difficult. Several studies have explored the causes of this difficulty and demonstrated that students struggle with chemistry because of the high cognitive demands it places on them, combined with their limited working memory capacity to process such information. These studies also suggest that chemistry can be made easier for learners when instructors consider the cognitive load theory in their instructional design. According to the cognitive load theory, humans' working memory has limited capacity; therefore, for effective learning to take place, the amount of information provided should not exceed this capacity. The theory offers opportunities for chemistry instructors to develop effective instructions that reduce learners' cognitive load, thereby improving learning outcomes. This study examined senior high school chemistry teachers' perceptions of the cognitive load theory. A descriptive cross-sectional survey method was used to gather data from 94 senior high school chemistry teachers in the Cape Coast Metropolis, selected via a census. A questionnaire was adapted as the main tool for data collection. Descriptive statistics were utilised to analyse the responses. The findings revealed that 76.3% of senior high school chemistry teachers had low familiarity with and application of the cognitive load theory. It is therefore recommended that professional development programmes related to the cognitive load theory be implemented to improve teachers' understanding and application of the concept.

Keywords: *cognitive load theory, working memory, chemistry teachers, perceptions*

Introduction

Enhancing students' science education is a key aim of science teaching and educational research (Almeida et al., 2023; Gafoor & Shilna, 2012). Researchers continuously strive to develop more effective, pedagogically sound instructional strategies based on scientific principles. Their goal is to effectively teach high school students the fundamentals of science, especially chemistry (Kibga et al., 2021), which is seen as an essential foundational subject and a significant contributor to human progress (Gafoor & Shilna, 2012). However, Musonda (2021) argues that researchers claim teaching chemistry is considered unpopular, challenging, and irrelevant by students. Students find learning chemistry difficult (Anim-Eduful & Adu-Gyamfi, 2022; Nartey & Hanson, 2021; Taber, 2018). So, what explains this difficulty?

According to Joseph (2011), the challenges of learning chemistry arise from the nature of the subject itself and the traditional teaching methods that do not consider the learner's cognitive resources. Additionally, Gafoor and Shilna (2012) found in their study that chemistry is perceived as difficult for high school students because of the significant cognitive load it imposes, the limited capacity of students' working memory, and their field dependence (Reid, 2021; Sibomana et al., 2021; Tsaparlis, 2021). This indicates that teachers' ability to incorporate considerations of the cognitive load generated by chemistry instructions and the limitations of students' working memory into their instructional design can help reduce the challenges associated with learning chemistry (Upahi & Ramnarain, 2020). Such an approach can make chemistry engaging and easy to understand while stimulating students' intellectual curiosity, which in turn boosts learning. The cognitive load theory offers valuable insights into learners' cognitive processes, enabling instructors to develop effective teaching strategies (Asma & Dallel, 2020).

The cognitive load theory (CLT) originated in the 1980s and has been developed by researchers worldwide across various disciplines since the 1990s (Asma & Dallel, 2020). It can be applied in many educational contexts, including science (Szulewski et al., 2021). Proposed by John Sweller in the late 1980s, the cognitive load theory is based on the idea that humans' working memory, the part of the mind responsible for processing current activities can handle only a limited amount of information at once. Therefore, for better understanding, the information or tasks presented should not exceed the capacity of working memory (Shibli & West, 2018). De Jong (2010), summarizing the theory, asserts that effective learning is impeded when students are presented with more information than their working memory can accommodate. As a result, they struggle to transfer that information from working memory to long-term memory.

Adaboh (2016) asserts that the core principle of CLT is that the quality of instructional design and learning significantly improves when attention is paid to the role and limitations of the working memory. Understanding this information processing system, as noted by Gafoor and Shilna (2012), is vital for chemistry instructors in developing effective instructional strategies to enhance chemistry learning (Sibomana et al., 2021; Tsaparlis, 2021). Implementing the cognitive load theory can greatly benefit chemistry education (Tsaparlis, 2021; Upahi & Ramnarain, 2020). As noted by Gafoor and Shilna (2012), students’ working memory is often overloaded due to the highly complex nature of chemistry. Most high school chemistry curricula progress rapidly through atoms, molecules, and equations. Students struggle to keep up, as their working memories can easily become overwhelmed (Uzun, 2022). This requires implementing effective teaching strategies to link new abstract chemistry concepts with students' existing concrete chemistry knowledge, thereby enhancing their working memory capacity for better learning outcomes.

Through numerous Randomised Controlled Trials (RCTs), cognitive load researchers have identified various strategies to help teachers optimise student learning. The recommended instructional strategies and procedures, when implemented, prevent learners from overloading their working memory by eliminating unnecessary cognitive load that impedes learning. These strategies include the Worked Example effect, Split-Attention effect, Redundancy effect, Expert Reversal effect, Modality effect, and Element Interactivity.

For example, Figure 1 presents a spatially non-integrated diagram of a galvanic cell. To interpret the information in Figure 1, one must mentally combine the diagram with the accompanying text, as neither is meaningful on its own.

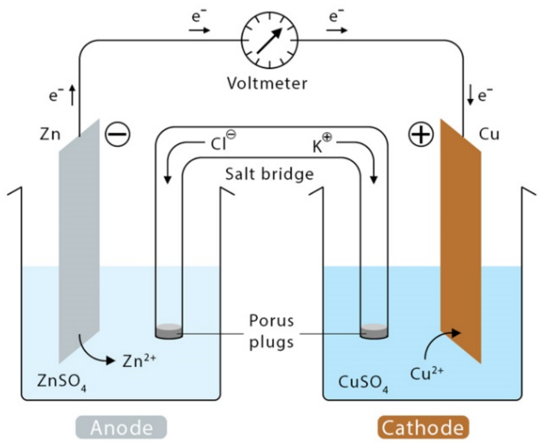

***Figure 1**: A spatially non-integrated diagram of a galvanic cell*

Accompanying text to the image in Figure 1 is found below;

1. **ANODE**: Zinc ions from the zinc electrode are oxidized to zinc atoms. This is because zinc lies higher than copper in the activities series chart and can easily be oxidised by the oxidising agent, which is the anode. The chemical reaction occurring at the anode is shown below;

   $Zn\ (s) \rightarrow Zn^{2+}\ (aq.) + 2e^{-}$

2. **CATHODE:** The electrons from the anode combine with the copper (II) ions in the solution and convert them to copper atoms. The cathode increases in mass because of the deposition of copper atoms. The concentration of electrons decreases in this half-cell. The chemical reaction is shown below;

   $Cu^{2+}\ (aq.) + 2e^{-} \rightarrow Cu\ (s)$

3. **SALT BRIDGE**: Because electrons flow from one half-cell to another, they do not complete the circuit. As a result, charge imbalance builds up. The charge build-up is avoided by connecting the two half-cell compartments by a salt bridge. A salt bridge is a U-shaped tube containing a concentrated, nonreactive electrolyte solution of some ionic compound (potassium chloride or ammonium nitrate). The ions of this neutral compound migrate to either side of the bridge to maintain the balance.

4. **A VOLTMETER** Is connected across the circuit to record the potential difference between the two half-cells. This potential difference is also known as cell potential or electromotive force (emf), represented by the symbol *E*. The cell potential is created when two dissimilar metals are coupled. It measures the energy per unit charge available from the oxidation-reduction reaction.

To understand the material in Figure 1, the learner must hold small segments of text in working memory while searching for the matching diagrammatic entity, with this ongoing process continuing until all the information is understood. Cognitive load theory research has focused over the last two decades on developing alternative instructional formats that physically locate related information and connect them to avoid extensive searching and matching, thereby reducing extraneous load.

An example of an integrated instructional design is shown in Figure 2. Fragments of text are embedded directly into the diagram near the relevant components. Arrows pointing from the text to the corresponding diagram elements help make the search process easier for learners.

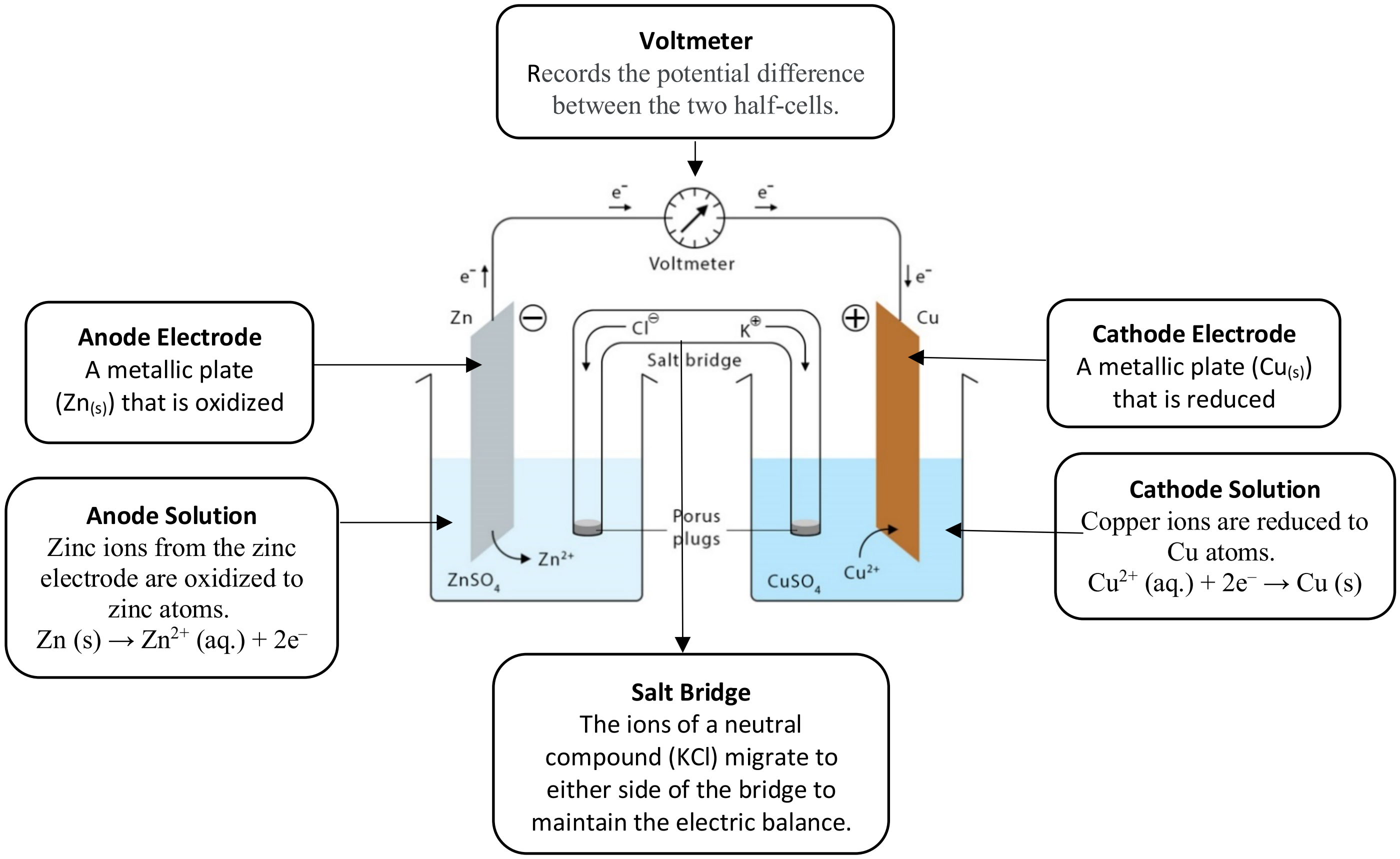

***Figure 2**: A spatially integrated diagram of the galvanic cell*

Teaching and learning chemistry within the Ghanaian context has also been recognized as challenging. The difficulties high school chemistry students face in learning the subject are evident in recent research and their performance on the West African Examination Certificate (Amoako et al., 2022; Anim-Eduful & Adu-Gyamfi, 2022; Nartey & Hanson, 2021; Taber, 2018). In response, science educators advocate for implementing a well-developed and effective instructional design (Asghar et al., 2019; Adu-Gyamfi et al., 2015). The call for teachers to prioritise learners’ cognitive processes during instructional design has been a subject of much research. This is because, cognitive load theory, as an instructional framework, equips teachers with the necessary information to effectively understand learners’ cognitive structures and how best to apply this understanding in designing effective instructions (Adaboh, 2016; Sweller, 2019).

Evidence of the impact of cognitive load theory on learners’ performance has been documented by several studies. For instance, a study by Leslie et al. (2012), demonstrated that designing multimedia instructions based on CLT positively affected primary school science learners' performance. The study indicated that understanding learners’ cognitive architecture helped instructors to use auditory and visual information more effectively.

Another study by Roodenrys et al. (2012) also reported that managing split attention by restructuring the material, using highlighting, arrows and placing material close to diagrams, when applied to learning materials, results in effective learning among tertiary chemistry students.

Additionally, in their study to determine the prevalence of various features of representation in chemistry textbooks, Nyachwaya and Gillaspie (2015) also found that cognitive load theory is a valuable lens for interpreting features of representations in chemistry textbooks. They suggested that learners could experience intrinsic, extraneous and germane cognitive load while using chemistry textbooks. However, understanding CLT will assist science teachers, learners, and textbook editors in selecting effective textbooks and instructions.

Despite the potential of cognitive load theory to enhance chemistry learning and student outcomes, there is limited research on how high school chemistry teachers perceive and implement this theory in practice. This lack of research, particularly in the Ghanaian context regarding senior high school chemistry teachers' understanding and use of cognitive load principles, hampers the development of effective, evidence-based strategies for classroom application. To address this gap, a comprehensive investigation into chemistry teachers' perceptions of cognitive load theory is necessary to inform professional development and support teaching methods that align with the theory, ultimately improving students' learning experiences. Consequently, this study focuses on exploring senior high school chemistry teachers' awareness and application of cognitive load theory.

The study sought to answer the following questions;

1. To what extent are senior high school chemistry teachers aware of the cognitive load theory?
2. How often do senior high school chemistry teachers apply the strategies of cognitive load theory in instructional design?

Methodology

This study employed a descriptive cross-sectional survey design and adopted the mixed method approach in line with the study's objectives. The choice of this design allowed the subjects to be examined in their entirely natural and unaltered environment and also enabled the researcher to embark on fact-finding and articulate essential principles of knowledge and solutions to significant problems concerning the phenomenon under investigation (Amoako et al., 2022; Weis et al., 2007). Ishtiaq (2019) emphasizes three key aspects when designing a mixed-method study: priority, implementation, and integration. This study prioritized the quantitative method followed by qualitative data analysis. This approach ensures a comprehensive understanding of the research problem while allowing for detailed explanations of statistical results through participant perspectives.

The population for this study consisted of all senior high school chemistry teachers in the Cape Coast metropolis. This study also employed a census technique to sample 94 senior high school chemistry teachers.

A questionnaire developed by Asma and Dallel (2020) to assess Algerian English teachers' understanding of cognitive load theory was adapted by the researcher to collect data. It consisted of two sections, A and B, featuring multiple-choice, closed-ended, and open-ended questions. Respondents were expected to provide brief answers to the open-ended questions and to respond to the closed-ended questions by selecting the appropriate options. Section 'A' included six questions aimed at gathering demographic information about the participants. In contrast, Section B was divided into two parts and contained 12 items. Part One included seven questions that assessed chemistry teachers' knowledge of cognitive load theory. Part two comprised five questions that evaluated chemistry teachers' application of the CLT. The researcher modified the questionnaire with a specific focus on the research questions identified earlier. Ultimately, the questionnaire contained a total of 18 items.

Results and Discussion

Research question one: To what extent are senior high school chemistry teachers aware of the cognitive load theory?

This research question aims to determine the extent of senior high school chemistry teachers' familiarity with the CLT. The statistical tool used to analyse the research question were frequency and percentage. The results are represented in Table 1

Table 1: ***A Frequency Table Showing Participants' Familiarity of the CLT***

Category	Frequency	Percentage (%)
Not at all familiar	40	50.0
Somewhat familiar	21	26.3
Moderately familiar	12	15.0
Very familiar	7	8.8
Total	80	100.0

Source: Field survey (2023)

Results from Table 1 show that approximately 40 respondents, representing 50% of the total, indicated "Not at all familiar" with the cognitive load theory. 21 respondents (26.3%) claimed to be "somewhat familiar" with the cognitive load theory, 12 respondents (15%) described their familiarity as moderate, and 7 respondents, making up only 8.8% of the respondents, were very familiar with the cognitive load theory.

The findings reveal a significant knowledge gap, with most respondents (50%) indicating "Not at all familiar" with cognitive load theory. When combined with those who were only "somewhat familiar," it shows that more than three-quarters (76.3%) of the respondents had limited knowledge of CLT. This suggests a limited depth of understanding or exposure to the theory among the surveyed population, aligning with the findings of Asma and Dallel (2020). The low awareness of the theory among teachers could also result in its limited implementation in their teaching.

While most did not understand the cognitive load theory, it is interesting to examine the minority who did. Only 8.8% of respondents claimed to be "extremely familiar" with the theory. Although they are a small group, they could be important in bridging the knowledge gap among the majority by acting as educators or ambassadors of the theory. Their greater understanding could be used for workshops, peer education, or official course development.

To better understand the participants' understanding of the theory, all were asked to share their opinions and knowledge regarding it. The following are some responses from participants who claimed familiarity with the theory:

> *"The theory holds that the amount of information given to students should not exceed the capacity of the limited working memory for learning to occur successfully."*

Other participants asserted that,

> *"Cognitive load theory is an educational theory that was developed by John Sweller and his colleagues in the 1980s. It seeks to understand how the human cognitive system processes and retains information. The theory suggests that learning is influenced by the cognitive load on a learner's working memory."*

> *"Cognitive load theory suggests that our memory can only hold a minimum amount of processed data at a time and that the methods should be laid down to avoid overloading to maximise learning."*

Others also said,

> *"It implies that the amount of information given to learners should not exceed the capacity of the working memory to promote learning."*
>
> *"It talks about how teachers can effectively utilise learners' working memory."*

Teachers' knowledge or awareness of the CLT is the first step towards their effective application of the theory as opined by Asma and Dallel, (2020) and Sweller, (2019). As evidently stated, it is important for teachers to consider their students' cognitive abilities when designing instructions otherwise, the overwhelming amount of information provided will hinder students learning (Asma & Dallel, 2020). Chemistry teachers can facilitate effective learning and reduce students' difficulty in learning chemistry by managing the cognitive load imposed on students, taking into account CLT when designing their lessons (Milenković et al., 2014). The teachers' seeming lack of exposure to the cognitive load theory can severely affect chemistry students' academic performance, as reported by Elford et al. (2022); Gafoor and Shilna (2012).

Research Question Two: How often do senior high school chemistry teachers apply the strategies of cognitive load theory to instructional design?

Research question two sought to find out how often senior high school chemistry teachers apply the strategies of the cognitive load theory in their instructions. To do this, participants were asked to indicate the frequency at which they apply the strategies of the theory. Responses were categorised into five frequency levels, ranging from "Not very often" to "Very often." The responses of the participants are provided in Table 2.

Table 2: ***A Frequency Table Showing Participants' Frequency at Applying the CLT***

Category	Frequency	Percent (%)
Not very often	36	45.0
Not often	12	15.0
Neutral	14	17.5
Often	14	17.5
Very often	4	5.0
Total	**80**	**100**

From Table 2, while 45% of participants reported applying cognitive load theory "Not very often," the remaining 55% fell into the categories of "Not often," "Neutral," "Often," and "Very often." Notably, a substantial proportion of respondents (60%) fell into the categories of "Not very often" and "Not often." This suggests that, despite the effectiveness of cognitive load theory in enhancing chemistry teaching and learning, a significant portion of chemistry teachers do not regularly incorporate it into their instructional designs, which aligns with the findings from the study conducted by Milenković et al. (2014) . This could be caused by several factors, such as a lack of knowledge about CLT, confidence in applying its principles, or the belief that CLT may not be suitable for their educational environment (Sweller, 2023; Sweller, 2020).

The "Neutral" and "Often" categories accounted for 17.5% of respondents. This indicates a moderate level of engagement with the theory. Teachers in these groups might have limited knowledge of the theory, but they do not always apply its principles in their lessons. In other words, they see the benefits of the cognitive load theory but find it difficult to implement in practice.

Only a small percentage of educators (5%) reported applying the cognitive load theory "Very often." These teachers have probably successfully integrated the principles of the theory into their lessons and are well-versed in its core ideas. By sharing their knowledge and best practices, they can serve as mentors and role models for their peers, promoting wider adoption of the theory.

Overall, the results in Table 2 reveal that 60% of senior high school chemistry teachers in the Cape Coast Metropolis rarely apply the cognitive load theory in their teaching. These findings suggest there is potential for training programmes and professional development initiatives to enhance chemistry educators' awareness of and confidence in using the CLT, as noted by Elford et al. (2022); Asma and Dallel (2020). Institutions can assist in bridging the knowledge gap between educators and practitioners by offering them valuable tools and guidance, as Owusu-Agyeman and Amoakohene, (2020) proposed (Sripradith, 2023). The findings also suggest that, although cognitive load theory is not yet widely adopted, it is gradually becoming part of instructional strategies. Over time, there may be an increase in the theory's overall adoption as educators become more familiar with it and its application.

According to Sweller (2023) and Sweller (2020), the effective implementation of Cognitive Load Theory (CLT) in instructions is influenced by various factors. Understanding these factors is crucial for policy makers and teachers aiming to optimise instructional strategies and enhance student learning outcomes (Sweller, 2024; Asma & Dallel, 2020). These factors include; Inadequate education and training (Asma and Dallel, 2020; Fallatah, 2021), Lack of resources, such as instructional time and materials (Skulmowski and Xu, 2021; Fallatah, 2021) and the lack of interest among teachers in applying the cognitive load theory, which according to Mayer, (2024) and Sweller (2024), can stem from various reasons, including insufficient knowledge, perceived complexity, and a disconnect between theory and practice.

Interventions such as Professional Development Programmes and the provision of necessary resources are essential to enhance teachers' understanding of CLT and its practical applications in instructional design. Resources should also include high-quality, CLT-aligned instructional materials and sufficient instructional time for teachers to implement the theory. Professional development programmes and training opportunities are vital in developing teachers' ability to implement CLT effectively (Bertoglio, 2024; Sweller, 2024; Sweller, 2020). There is a need for structured training programmes that equip teachers with the essential skills to apply CLT in their classrooms (Bokosmaty et al., 2015). Such programmes can offer teachers practical strategies for managing cognitive load, thereby improving their instructional effectiveness (Sweller, 2024; Sweller, 2023).

Also, CLT principles should be integrated into teacher training programs at the various teacher training institutions. This will equip teachers with the understanding and ability to effectively apply the theory before deployment unto the field (Khurshid et al., 2023). Other interventions for enhancing teachers' understanding and implementation of CLT include, Workshops or webinars on the cognitive load theory and how it applies to teaching chemistry, Coaching or mentoring from experts in the field to help teachers use the theory to teach chemistry, Collaborative lesson planning with other teachers to incorporate CLT principles into lesson design, Professional learning communities where teachers can discuss and share best practices related to the CLT and other instructional strategies (Bertoglio, 2024; Sweller, 2020).

Conclusion

The significance of considering learners' cognitive abilities when designing chemistry instructions is crucial for improving their understanding. As clearly outlined, cognitive load theory offers chemistry teachers the chance to develop effective instructions. The study results indicate a relatively low awareness and application of cognitive load theory among senior high school chemistry teachers in the Cape Coast Metropolis. It is, therefore, recommended that education and training be provided to help chemistry teachers effectively utilize cognitive load theory in their teaching. Professional development activities such as workshops, expert coaching, collaborative lesson planning, and resource provision are also necessary to strengthen chemistry teachers' use of the theory. Additionally, stakeholders involved in creating instructional or educational materials for chemistry teachers should focus on introducing or reinforcing the basics of cognitive load theory to foster better understanding.

References

Adaboh, S. (2016). Using the cognitive load theory to assist in the design of instruction for the university lecture room: Some key lessons. *Asian Journal of Educational Research, 4*(4), 53–59. https://www.researchgate.net/publication/314096362

Adu-Gyamfi, K., Ampiah, G. J., & Agyei, D. D. (2015). High school chemistry students' alternative conceptions of H2O, OH-, and H+ in balancing redox reactions. *International Journal of Development and Sustainability*, *4*(6), 744–758. https://doi.org/10.5281/zenodo.1471731

Almeida, B., Santos, M., & Justi, R. (2023). Aspects and abilities of science literacy in the context of nature of science teaching. *Science & Education, 32*(3), 567-587. https://doi.org/10.1007/s11191-022-00324-4

Amoako, S. K., Oppong, K., Tabi, J. A., & Ossei-Anto, T. A. (2022). Factors affecting trainees' performance in organic chemistry in colleges of education in Ghana. *European Journal of Education and Pedagogy*, *3*(6), 97–102. https://doi.org/10.24018/ejedu.2022.3.6.403

Anim-Eduful, B., & Adu-Gyamfi, K. (2022). Factors influencing high school chemistry teachers' and students' teaching and learning of organic qualitative analysis: A qualitative study. *European Journal of Education Studies*, *9*(7), 194–219. https://doi.org/10.46827/ejes.v9i7.4378

Asghar, A., Huang, Y.S., Elliot, K., & Skelling, Y. (2019). Exploring secondary students' alternative conceptions about engineering design technology. *Journal of Education Science, 9*(45), 1-18. https://doi.org/10.3390/educsci9010045

Asma, H., & Dallel, S. (2020). Cognitive load theory and its relation to instructional design: Perspectives of some Algerian university teachers of English. *Arab World English Journal (AWEJ)*, *11*(4), 111–127. https://dx.doi.org/10.24093/awej/vol11no4.8

Bertoglio, K. (2024). Load reduction leadership: A Novel school improvement framework based on cognitive load theory, early findings (Poster 18). AERA 2024. https://doi.org/10.3102/ip.24.2108341

Bokosmaty, S., Sweller, J., & Kalyuga, S. (2015). Learning geometry problem solving by studying worked examples. *American Educational Research Journal, 52*(2), 307-333. https://doi.org/10.3102/0002831214549450

De Jong T (2010) Cognitive load theory, educational research, and instructional design: Some food for thought. *Instructional Science 38*(2): 105–134. https://doi.org/10.1007/s11251-009-9110-0

Elford, D., Lancaster, S. J., & Jones, G. A. (2022). Exploring the effect of augmented reality on cognitive load, attitude, spatial ability, and stereo-chemical perception. *Journal of Science Education and Technology*, *31*(3), 322–339. https://doi.org/10.1007/s10956-022-09957-0

Fallatah, R. (2021). *Curriculum Development in Saudi Arabia: Saudi Primary EFL Teachers' Perspectives of the Challenges of Implementing CLT into the English Curriculum in State Schools* [Doctoral thesis, University of Exeter].

Gafoor, K. A., & Shilna, V. (2012). Creating better classroom practices for reducing cognitive load in school chemistry learning: Initial thoughts. 1–10.

Ishtiaq, M. (2019). Book Review Creswell, J. W. (2014). Research Design: Qualitative, Quantitative and Mixed Methods Approaches (4th ed.). Thousand Oaks, CA: Sage. English Language Teaching, 12(5), 40. https://doi.org/10.5539/elt.v12n5p40

Joseph, A. (2011). *Grade 12 learners' conceptual understanding of chemical representations*. [Master's thesis, University of Johannesburg (South Africa)].

Khurshid, F., O'Connor, E., Thompson, R., & Hegazi, I. (2023). Pedagogical interventions and their influences on university-level students learning pharmacology-a realist review. *Frontiers in Education*, 8. https://doi.org/10.3389/feduc.2023.1190672

Kibga, E. S., Gakuba, E., & Sentongo, J. (2021). Developing students' curiosity through chemistry hands-on activities: a case of selected community secondary schools in Dar es Salaam, Tanzania. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(5), em1962. https://doi.org/10.29333/ejmste/10856

Leahy, W., & Sweller, J. (2011). Cognitive load theory, modality of presentation and the transient information effect. *Applied Cognitive Psychology*, *25*, 943–951. https://doi.org/10.1002/acp.1787

Leslie, K. C., Low, R., Jin, P., & Sweller, J. (2012). Redundancy and expertise reversal effects when using educational technology to learn primary school science. *Educational Technology Research and Development*, *60*(1), 1–13. https://doi.org/10.1007/sl 1423-01 1-9199-0

Mayer, R. E. (2024). The past, present, and future of the cognitive theory of multimedia learning. *Educational Psychology Review, 36*(1), 8. https://doi.org/10.1007/s10648-023-09842-1

Milenković, D. D., Segedinac, M. D., & Hrin, T. N. (2014). Increasing high school students' chemistry performance and reducing cognitive load through an instructional strategy based on the interaction of multiple levels of knowledge representation. *Journal of Chemical Education*, *9*(91), 1409–1416. https://doi.org/10.1021/ed400805p

Musonda, M. (2021). Chemistry topics perceived as difficult to learn by secondary school pupils of Kasama, Luwingu, Mbala and Mungwi districts of Northern Province of Zambia. *Multidisciplinary Journal of Language and Social Sciences Education,* 4(2), 25-29.

Nartey, E., & Hanson, R. (2021). The perceptions of senior high school students and teachers about organic chemistry: A Ghanaian perspective. *Science Education International*, *32*(4), 331–342. https://doi.org/10.33828/sei.v32.i4.8

Nyachwaya, J. M., & Gillaspie, M. (2015). Features of representations in general chemistry textbooks: A peek through the lens of the cognitive load theory. *The Royal Society of Chemistry*, *17*, 58–71. https://doi.org/10.1039/c5rp00140d

Owusu-Agyeman, Y., & Amoakohene, G. (2020). Transnational education delivery in Ghana: examining the benefits, challenges and future prospects. *Policy Reviews in Higher Education, 4*(2), 135–163. https://doi.org/10.1080/23322969.2020.1774408

Reid, N. (2021). The Johnstone triangle: The key to understanding chemistry. *Royal Society of Chemistry. https://doi.org/10.1039/9781839163661*

Roodenrys, K., Agostinho, S., Roodenrys, S., & Chandler, P. (2012). *Managing one's own cognitive load when evidence of split attention is present*. *26*, 878–886. https://doi.org/10.1002/acp.2889

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education, 48*(6), 1273–1296. https://doi.org/10.1007/s11165-016-9602-2

Tsaparlis, G. (2021). Introduction− The Many Types and Kinds of Chemistry Problems. In *Problems and Problem Solving in Chemistry Education: Analysing Data, looking for Patterns and Making Deductions* (pp. 1-14). The Royal Society of Chemistry. https://doi.org/10.1039/9781839163586-00001

Shibli, D., & West, R. (2018). Cognitive load theory and its application in the classroom. *Journal of the Chartered College of Teaching, 2*(1), 1-12.

Sibomana, A., Karegeya, C., & Sentongo, J. (2021). Factors affecting secondary school students' academic achievements in chemistry. *International Journal of Learning, Teaching and Educational Research*, *20*(12), 114-126. https://doi.org/10.26803/ijlter.20.12.7

Skulmowski, A. and Xu, K. M. (2021). Understanding cognitive load in digital and online learning: a new perspective on extraneous cognitive load. *Educational Psychology Review, 34*(1), 171-196. https://doi.org/10.1007/s10648-021-09624-7

Sripradith, R. (2023). Getting to the (power) point: unleashing the impact of assertion-evidence design in powerpoint for enhancing students' English grammatical competence and retention. *Shanlax International Journal of Education, 11*(4), 45-57. https://doi.org/10.34293/education.v11i4.6375

Sweller, J. (2019). Cognitive load theory and educational technology. *Educational Communications and Technology*, *68*, 1–16. https://doi.org/10.1007/s11423-019-09701-3

Sweller, J. (2023). The development of cognitive load theory: replication crises and incorporation of other theories can lead to theory expansion. *Educational Psychology Review*, *35*(4), 95. https://doi.org/10.1007/s10648-023-09817-2

Sweller, J. (2024). Cognitive load theory and the curriculum. Research Handbook on Curriculum and Education, 155–166. https://doi.org/10.4337/9781802208542.00017

Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, *68*(1), 1-16. https://doi.org/10.1007/s11423-019-09701-3

Szulewski, A., Howes, D., van Merriënboer, J. J., & Sweller, J. (2021). From theory to practice: the application of cognitive load theory to the practice of medicine. *Academic Medicine*, *96*(1), 24-30. https://doi.org/10.1097/acm.0000000000003524

Upahi, J. E., & Ramnarain, U. (2020). Examining the Connection between Students' Working Memory and Their Abilities to Solve Open-Ended Chemistry Problems. *Journal of Baltic Science Education, 19*(1), 142-156. https://doi.org/10.33225/jbse/20.19.142

Uzun, K. (2022). Cognitive load theory and its educational implications. In K. Thamizhmaran, M. S. Bhatti & B. A. Yilmaz (Eds.), *6th international congress on life, social, and health sciences in a changing world* (pp. 1–8). BZT Academy Publishing House.

Weis, S. E., Firker, A., & Hennig, J. (2007). Associations between the second to fourth digit ratio and career interests. Personality and Individual Differences, 43(3), 485–493. https://doi.org/10.1016/j.paid.2006.12.017