




# Knowledge construction in chemistry through web-based learning strategy: a synthesis of literature

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## Abstract

Smartphones and computer-based technology have revolutionized different development sectors including education. The current review describes the existing literature on Web-Based Learning (WBL) as a novel methodology applied in teaching and learning, and its potential effectiveness in teaching and learning chemistry. Further, the study intends to reflect on how the WBL could be applied in the Rwandan context of teaching and learning chemistry as the country adopted the competency-based curriculum (CBC) in 2015. This review is a narrative overview in which much of the existing literature such as books, articles, and other online literatures related to the study were reviewed. The literature was obtained from different electronic databases including Scopus, ERIC, ISI web of knowledge, academia, web of science, digital library, and google scholar.

**Keywords** Synthesis of literature · Teaching and learning · Chemistry · Constructivism · Web-based learning

## 1 Introduction

The world is becoming more internationally connected and there is an increase in education internationalization (Boholano, 2017). The qualitative education system should encourage learners to be citizens of the world, instead of being only in their own countries (Boholano, 2017). Current learners are prepared to become future scientists, researchers, leaders, and thinkers of the world, and consequently, they need qualitative and applicable education that prepares them with the skills required for success (Barkatsas & Bertram, 2016). The learners of the 21st century are good at using computer-based technology during their learning activities, and educators have to ensure that they are equipped with all the necessary skills and competencies that

allow them to succeed in the current world (UNESCO, 2014). The use of Web-Based Learning (WBL) creates an instructional mode that enables learners to develop creativity and innovation (Chatwattana & Nilsook, 2017). Learners do not only rely on knowledge but also need skills to apply their knowledge to solve real-world problems (Hysa, 2014).

Now days, there is a fast development of the internet and digital tools, and the web has become a dominant, interactive, universal medium for the teaching and learning process (Epignosis, 2014). The internet offers chances for learners in terms of responding to their questions and provides learner-centered instruction (Epignosis, 2014). Furthermore, the internet is considered one of the worldwide broadcasting ways of sharing information and collaboration between individuals regardless of their geographic location (Leiner et al., 1997). Active learning is essential for both internal and external processes due to its capacity to shape thinking and effective educational experience prompt deep and meaningful understanding (Tran, 2011). Web-Based Learning (WBL) encourages learners to learn at their own pace (Yamini & Malarvizhi, 2017). The latter adds value to the teaching and learning processes as it supports a paradigm shift from a teacher-centered to a learner-centered education system (Hicks & Graber, 2014). Web-Based collaborative learning has been developed to help the students achieve more at their level of understanding of sciences including chemistry (Bin, 2014). Students might not have efficient resources to get the information needed in their learning, but web-based learning encourages students to acquire up-to-date information (Bin, 2014). Since the active learning methods were found to be effectively used in the implementation of the competence-based curriculum (CBC) in Rwanda, a WBL would play an important role in helping learners develop competencies.

According to Czujko-moszyk (2014), Web-Based Learning (WBL) is built on the community of inquiry model which is grounded in the work of John Dewey. This model states that educational experience results from the interaction between three elements namely cognitive presence, teaching presence, and social presence (Swan et al., 2009). This is supported by Akyol & Garrison (2017), who showed that there is a strong relationship between collaborative constructivism and higher-order learning outcomes. The strength of the community of inquiry framework is its emphasis on collaborative constructivist approaches for designing learning environments to provide profound and evocative learning experiences. Cognitive presence refers to how learners confirm and construct their understanding through reflection and discourse (Garrison, 2018).

Chemistry has been mentioned among the subjects that are considered significant for the scientific and economic development of countries (Fowotade, 2016). It is considered a fundamental and central science in different working areas such as medicine, pharmacy, biochemistry, engineering, microbiology, textile industry, agriculture, and petroleum products separation (Bhargava, 2016; Shakhashiri, 2010). Nevertheless, chemistry is considered a difficult subject for some learners (Sirhan, 2007). Therefore, chemistry teaching requires teachers to apply effective teaching methods, and sufficient teaching and learning resources to help learners develop sufficient competencies in this subject. However, ineffective teaching methods and insufficient instructional resources are most problematic for effective and successful chemistry

teaching and learning and make it difficult for some learners (Ali, 2012; Ejjidike & Oyelana, 2015). The present study is focused on the review of the existing literature on chemistry knowledge construction through WBL as well as the effectiveness of using different Web tools in teaching and learning chemistry. It also reflects on how the WBL could be used in the process of teaching and learning chemistry in Rwanda.

## 2 Research questions

1. What does the literature say about the WBL and its application in teaching and learning chemistry?
2. Is WBL an effective method that should be applied in teaching and learning chemistry subjects?
3. Does WBL help learners to construct knowledge in chemistry and understand chemistry theories and practices?

## 3 Methodology

There are two standard types of review such as systematic and non-systematic or narrative (Baumeister & Leary, 1997). A literature review compiles, classifies, and evaluates what other researchers have written on a particular topic (Ramdhani et al., 2014). The researchers adopt synthesis of the literature because it offers more of a reflection and critique of the concept in question, and is engaged by authors to more clearly contextualize their research within the existing literature and to present their opinions, perspectives and approaches. The synthesis of the literature is also useful to understand the state of knowledge on a bigger topic, a literature review needs to synthesize various subtopics. This review shows a broad understanding of WBL and its effectiveness in teaching and learning chemistry. It summarizes the results from different research papers, books, and other literary types published on WBL, and its effectiveness in teaching and learning chemistry across different countries of the world. Different electronic databases were used including Scopus, ERIC, ISI, academia, web of science, digital library, and Google Scholar and we conducted as many searches as possible. The sources of articles that were downloaded and their percentage are shown in Fig. 1 below.

We have downloaded one hundred twenty-eight documents including 124 articles and 4 books. Among 124 articles downloaded come from different electronic databases 65 (52.41%) come from Scopus, 16 (12.90%) Web of Science, 14 (11.29%) ISI, 12 (9.677%) ERIC, 8 (6.45%) Google Scholar, 6(4.83%) academia and 3 (2.41%) Wiley library. The books were downloaded from different sources including 1 book downloaded from Amazon, 1 book from GALILEO Open learning materials, 1 book from VDOC Pub Library, and 1 book from Rib Hub. The literatures were chosen based on the quality of the publisher and significance of the study.

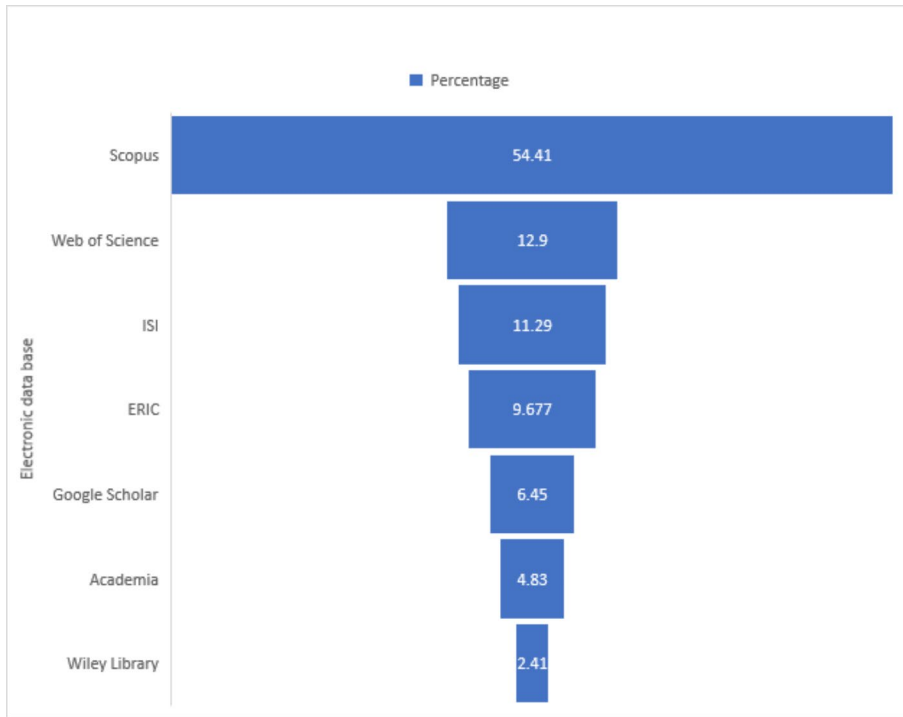


Fig. 1 The source of the electronic database and their percentage

#### 4 Method of constructing knowledge in web-based learning

Online learning knowledge is created through a social constructivist approach (Picciano, 2013). The social construction of knowledge does not depend on the learning environment, how knowledge is constructed and confirmed and terms of retrieving or remembering knowledge (Ulbert, 2014, Cole, 1996). Therefore, all knowledge carries social and cultural meanings. Even what appears to be solitary learning has social character since people learn as members of social and cultural groups, and what they learn is related to social practices that are enacted in communities without relying on the geographical environment (Gee, 2008).

The social construction of learning presents learning as a social and cultural process that occurs in the context of human relationships and activities (Amineh & Asl, 2015). Socio-cultural learning affects how students learn through active collaborative activities (Van Dijk, 2009). Vygotsky's theory of social constructivism proposed that progress depends on the interface between individuals and materials that the culture offers to help form their view of the domain (Zhou & Brown, 2014). According to this theory, cultural tools pass from one person to another through three means typically imitating or reproducing, instruction by a teacher and use of these instructions by self-learning and collaborative learning (Tomasello, 2016). Social-cultural learning theory combines the social world and cognitive development. Cognitive development based on Vygotsky's idea leads learners to centered and constructivist learning.

In addition, teacher-student and student-student interaction are the key aspects of creating and assisting new ideas (Zhou & Brown, 2014). In brief, social learning theories focus on the acquisition of knowledge, and learning is positioned with constructivism in activities, interactions, practice, and knowledge construction.

According to Addams et al., (1999), the community of inquiry model believed that the educational system must respond to the learner's and society's needs. He also argued that the cognitive presence of learners must be at the heart of the educational experience. The students actively construct and confirm meaning through collaboration and the social constructivist method (Swan et al., 2009). Construction and confirmation of knowledge and understanding may result from the learner's personal critical judgment, but ideas are generated through the collaboration process within the community.

Social learning theory deeply accentuates the social or cultural character of learning. It takes place through active collaboration and not on any single individual means that learners learn in cultural activities or social practices that make them engaged (Rothrock, 2010). However, people cannot participate or learn to contribute to cultural activities or practices on their own. Effective participation in cultural practices requires coordinated activity among members of the cultural community about how learning occurs and helps the learner construct the knowledge (Torres-Velásquez, 2000). The facilitator helps the learner to improve his or her understanding of the content rather than instructing him/her. Learners need to be more active than passive (Alzahrani & Woollard, 2013).

According to Gold et al., (1999), knowledge is a product of a human and constructed through social and cultural learning processes. These authors argued that learning is an active social process. Meaningful learning occurs when learners are engaged in social activities. Four general perspectives inform how learning could be facilitated within a framework of social constructivism (Gredler & Margaret, 2009):

1. **Cognitive tool:** It focuses on the strategies that develop and foster cognitive skills where learners are engaged in social learning activities involving hands-on experience and a product from the group is yielded (Kirschner & Erkens, 2006).
2. **Ideas based on social constructivism:** Here, learners are discussing collaboratively any idea of a concept from various subjects. This enlarges learner vision and critical thinking skills during the construction and confirmation of knowledge and understanding (Ulbert, 2014).
3. **Pragmatic or emergent approach:** This method is used when there is a challenge to be solved in the classroom from individual personal views and views of the whole class (Gredler & Margaret, 2009).
4. **Transactional or situated cognitive perspective:** This method focuses on the relationship between learners and their environment where learners interact socially with themselves and the teacher in the environment. When the learning environment and social relationships among people change, an individual task and the way that the knowledge is constructed may also be changed (Gredler & Margaret, 2009).

This theory assumes that knowledge, understanding, significance, and meaning are developed in coordination and collaboration with other human beings. According to (Schunk and Mullen, 2012) social constructivist teaching approaches emphasize reciprocal teaching, peer collaboration, cognitive apprenticeships, problem-based instruction, web quests, anchored instruction, and other methods that involve learning with others. Knowledge construction through WBL is a result of the potential interaction between teacher and learner. Individual change takes place through personal cooperation of tasks, redefinition of membership, and personal commitment to the social-cultural practice of community (Mukama, 2014). Information and communication technology (ICT) plays an important role in building knowledge within a group of learners and creating a network between local and global communities, it takes into account diversity and intercultural education (Ala-Mutka, 2009).

## 5 Usefulness and importance of web-based learning in teaching and learning Mathematics and sciences

This section describes the importance and usefulness of web-based learning in different subjects including mathematics and sciences subjects including physics and biology. Research showed that web-based learning is a significant method of teaching and learning different subjects. The research showed that the use of web-based resources helps students to learn mathematics independently as students can repeat and relearn the material that has been delivered anywhere and anytime (Kartika, 2018). The use of the e-learning method has a positive influence on motivation, autonomy, participation, and mathematical concepts compared to the traditional method of teaching. The use of a web-based learning strategy leads to improvement in students who are studying mathematical subjects (Moreno-Guerrero et al., 2020). Web-based learning provides clear guidance and increases efficient understanding of the human body in biology (Astuti et al., 2020). In addition the research conducted by Kaur (2017) in three secondary schools in Amritsar city, showed that students achieved a higher level of learning in biology subjects when taught through web-based instructional strategy as compared to their counterparts. Physics students have a positive perception of using a web-based environment as it helps them to access any time, and students are willing to use web-based learning in other courses (Muhametjanova & Akmatbekova, 2019). In addition Alias et al., (2013) indicated that web-based learning increases the performance, interest, and motivation of physics students. This is in agreement with the study conducted by Vania et al., (2018) that showed the use of Edmodo as a web-based learning tool increased students' performance and motivation in thermal physics.

## 6 Overview of web-based learning and chemistry teaching and learning

Web-based learning (WBL) is an approach that uses the internet to deliver a broad array of solutions that enhance the instructional process (Poon et al., 2004). Meaningful learning takes place when learners gain new knowledge linked to the existing one (Lorenzo et al., 2012). WBL is designed for implementing learning theories and combines web, media, human-computer, and knowledge interaction (Hadjerrout, 2006).

Designing web-based learning tools requires the following steps: (1) Examining and analyzing the principles and theories, (2) Exploring the instructional context concerning instructional design and learning environments, (3) Synthesizing a framework for designing the web-based learning model, (4) Designing the web-based learning, model and (5) Evaluating the efficiency of the web-based learning model (Deejring, 2014). Web-based technology involves the use of multimedia and use of interactive technology. According to (Chiriac, 2022) design, a web-based learning model involves the following: (1) Strategic dimension design, (2) Constructivism in web-based learning, (3) Features of web-based learning, and (4) Practical perspective. For strategic dimension design, the author points out the vision and mission of a web-based learning environment. Constructivism in web-based learning involves thinking about types of constructing or learning theories that help students to understand, retain, and share knowledge. Features of web-based learning and web-based environments are designed based on organizational, technological pedagogical, and contextual statements. Practical perspective at this stage content is created and the web is used for the practical purpose of teaching.

At the time when the internet started to be used, people applied WBL to change the world and online learning pedagogical strategies also started to grow (Bezhovski & Poorani, 2011). The application of WBL started early in the 19th century when in 1840 Isaac Pitman taught a symbolic form of writing to his learners by using correspondence email (Epignosis, 2014). During the 20th century, the personal computer began to push online learning systems and WBL was more developed (Lee, 2016).

Schools decided to deliver online courses for helping students facing the problem of attending school due to geographical location and time limits (Appanna, 2018). In 2000, some businesses started to train their employees by using online training (Bezhovski & Poorani, 2011). Today web-based learning has become an important educational resource where students easily access online information and collaborate with their peers and teachers without restrictions on time and environment (Epignosis, 2014). It had the basic layout that is used in modern e-learning methods, comprising of graphic elements, text with graphics, forums, and chat rooms (Shimura, 1996). In Web-based learning, lessons or instructions are provided using electronic devices such as computers, or any other electronic devices that support the learning process such as a tablet, mobile or iPad. It is interactive learning in which learning materials are displayed online and provide timely automatic feedback to the learners' activities.

Not only does Web-Based Learning help students share their learning problems without the constraint of time and place, but it also helps instructors to create collaboration with experts from different subjects (Torres & Rama, 2018). The utilization of a website in teaching helps the teacher to assess students' conceptual understanding

of the subject matter (Din, 2018). WBL increases students' satisfaction, participation, self-confidence, engagement, and motivation (Poon et al., 2004). The use of WBL has a positive impact on the process of learning or delivering content and creates attractive learning. Furthermore, it is more learner-centered (active learning), overcomes social isolation and financial constraints, and improves students' outcomes (Kay, 2011; Nordin, 2008). WBL serves as novel instructional teaching and learning method (Wasim et al., 2014) and helps students to achieve their learning objectives and get improvement in chemistry theory and practice (Brown et al., 2018).

According to the literature consulted here, some countries have adopted Web-Based Learning in teaching chemistry in their institutions whereas others have a steady growth of Web-Based Learning in the teaching of chemistry (Mccarty et al., 2006). The countries in North America, Europe, and Australia utilize more web-based resources in chemistry teaching and learning than the rest of the world (Palvia et al., 2018). The North American countries use more the WBL in chemistry teaching and learning due to high technology development, internet infrastructures and facilities, the dominance of the English language, the high economic strength of the educational sector and stakeholders, and advanced universities (Kentnor, 2015). Although the European countries also have well-developed WBL in teaching chemistry some countries face linguistic barriers and the United Kingdom (UK) is the one that employs Web-Based chemistry learning and teaching more than other European countries (Casu et al., 2015). Most institutions offer more Web-Based teaching and learning resources in computer and information science and education courses than other subjects. A study conducted at the University of Twente in the Netherland indicated that the use of WBL helps students to understand the molecular and symbolic model in chemical science (Vermaat, 2016).

In Asia, WBL in teaching chemistry is mostly applied in three ways: Massive Open Online Courses (MOOCs) currently growing in China, India, Malaysia, and the Philippines, Intelligent Tutoring Systems (ITS), and Learning Analytics (LA) (Lim, 2018). In Latin America, Web-Based Learning in teaching chemistry (Theo, I prefer that you capitalize Web Based Learning when spelling it out and then use "in teaching chemistry" – but you need to be consistent in what you capitalize – I am not sure I caught them all) are used by limited institutions due to the shortage of resources, low capacity of teachers and low social acknowledgment (Torres & Rama, 2018). Some African countries like South Africa adopted WBL in teaching chemistry while but it is still limited in the other countries of Africa due to some challenges including lack of advanced technology and institutional development (Bagarukayo & Kalema, 2015). Based on the study conducted in Kenya, online learning and teaching in East African countries are still facing both economic and infrastructural challenges (Nyerere et al., 2012). In some sub-Saharan African countries, students desire to study chemistry by applying face-to-face rather than online learning, and this leads to a negative perception of online education. However, the recent study by Kotoua, Ilkan, & Kilic (2015) proved that the use of the internet could significantly lead to a positive change in students from sub-Saharan African countries for their chemistry and other sciences.



## 7 Web-based learning as grounded in the community of inquiry model to enhance chemistry learning and teaching

The community of inquiry is grounded in the work of John Dewey (Addams et al., 1999). It is the process of online learning aimed that educational experience results from the interaction between three elements namely cognitive presence, teaching presence, and social presence (Swan et al., 2009). Community of inquiry, also called computer-mediated conferencing (CMC) affords a great student-student and student-teacher interactivity (Moisey et al., 2008). Further, it is highly responsive and offers a high degree of freedom in terms of place and time to engage the interaction and discussion (Grooms, 2003). According to (Garrison, 2018), this model presents an interaction between cognitive presence, social presence, and teaching presence.

The current review focused on cognitive presence toward teaching and learning as it refers to the way that learners confirm and construct their understanding through reflection and discourse (Garrison, 2018). The main aim of cognitive presence is to develop and strengthen critical thinking and analysis, but also to build and confirm knowledge; this is a defining characteristic of cognitive presence (Gutiérrez-Santuste et al., 2015). It is composed of four phases that are triggering event, exploration, integration, and resolution (Garrison, Anderson, & Archer, 2001).

- a) **Triggering event:** It is the first process of the cognitive presence model, in which the issues or problems faced by learners are identified and solved (Garrison & Kanuka, 2004). During the teaching and learning process, the trigger event corresponds to the tasks, work, or problems that the teacher gives to learners to be performed.
- b) **Exploration:** This is the second phase of the cognitive presence model in which learners need to understand the nature of the problems or issues and explore them by using different sources of information (Akyol & Garrison, 2017). This phase takes place between individual reflection and discourse and involves brainstorming and the exchange of ideas among learners. This phase ends by allowing learners to select relevant information required to solve any issue or problem.
- c) **Integration:** This phase consists of building knowledge and understanding from information made in the exploratory phase (Garrison et al., 2001). From integration, learners analyze ideas generated and think about the application of those ideas to solve the issue or a problem that is under investigation. This phase is facilitated by a teacher or instructor (teaching presence) to provide comments and additional information for avoiding misconceptions and providing probing. This is because sometimes learners' answers are correct but insufficient and need more clarification, and it is necessary for confirming cognitive development and strengthening critical thinking skills in learners (Kanuka & Garrison, 2017).
- d) **Resolution:** This is the last stage of the cognitive presence model in which learners use integrated ideas to solve the problem or apply newly constructed meaning in different situations for solving issues (Garrison et al., 2001).

Successful creation of cognitive presence in an online community of learners has indicators in each phase (Kilis and Yildirim, 2019), Redmond (2014). They are the

sense of puzzlement and recognize the problem for triggering event category. For the exploration category, the indicators are information exchange, divergence, suggestions, brainstorming, intuition, and leaps. For the integration category, the indicators are connecting ideas, applying new ideas, solutions, and synthesis (Garrison et al., 2001). For the resolution category the indicators are application, testing, and defending (Alavi & Taghizadeh, 2013). In addition, those indicators add divergence within the single message and online community (Redmond, 2014).

Different studies were conducted about the community of inquiry in chemistry education. The study conducted by Winfield (2016) about the community-based interactive engagement in organic chemistry courses showed that teaching by using online learning management promotes self and peer advocacy, and the performance of students using online courses was higher compared to those that used traditional teaching and learning methods. The study conducted by Luna et al., (2015) about Collaboration in the Cloud for Online Learning Environments in a chemistry laboratory, indicated that working in the online community increases the interaction and quality of laboratory reports in comparison to traditional collaboration. The research carried out by Díez-Pascual et al., (2019) about the application of wikis as a collaborative tool in teaching chemistry and Telecommunication System Engineering proved that students who were highly committed to wikis perform better than others, and chemistry students performed better than students in Telecommunication System Engineering due their strong connection and commitment to wikis. According to Mccollum (2019), the community of inquiry of students in online collaboration helps them to solve problems in organic chemistry.

The study conducted by Oskay & Dinçol (2016) on internet-assisted application toward the cognitive structure of chemistry teachers in bonding and hybridization revealed that there is a significant difference in students' cognitive structure in the experimental group. Concerning the research conducted by Barak & Dori (2005) on enhancing undergraduate students' chemistry understanding through project-based learning in an IT Environment, there was no significant difference between the experimental and control group students in both variables but the analysis of covariance of the post-test and the final examination showed that experimental group students significantly scored at a higher level in both the post-test and final examination. According to Mumba et al., (2015), teaching using an online community increases students' conceptual understanding of chemical reactions, chemical kinetics, chemical equilibrium, atomic structure, acids and bases, and gas laws.

## **8 Web-based learning is the construction of knowledge in chemistry and the understanding of chemistry theories and practices**

WBL promotes students' conceptions of learning and improves learning capacity for students (Lakonpol et al., 2015). Hence, WBL influences a more conceptual understanding of chemistry subjects and is effective in learning chemistry at the tertiary level (Sudha & Amutha, 2015).

The research showed that the use of computer applications has a positive impact on teaching and learning chemistry. The study conducted by (Pyatt, 2014) showed

that computer software is important to teach and assess the writing of chemical reactions and balancing chemical reactions, and writing types of chemical reactions. The use of ChemsSketch and PhET computer software increases student's conceptual understanding of the representation of the chemical structure of ozone, water, carbon dioxide, and methane molecules, it was also found that PhET software is effective in teaching polarity of molecules, electronegativity, molecular geometry, physical and chemical properties of the molecules (Silva et al., 2015; Julboev et al., 2021) found that computer software such as ChemDraw, Isis/Draw, ChemBio-Draw, HyperChem, Gaussian, Chemofis, and Crocodile Chemistry creates the basis for increasing students' interest in Chemistry, transferring and consolidating knowledge. With the increase of technologies, web 2 Web 2.0? be consistent) tools (browser and online) were developed.

The study conducted by Romero, Espinosa, & Hernández, (2019) about the effectiveness of implementing Web 2.0 tools in organic chemistry lectures on students' understanding of basic concepts of organic chemistry, revealed that the application of web-based tools increases students' academic performance, and was found to be useful in teaching and learning organic chemistry (Sudha & Amutha, 2015). WBL supports meaningful learning of chemistry in the context of learning chemistry (Pernaa & Aksela, 2008). According to Dori & Barak (2003), students who used WBL significantly perform better in the learning of the geometric structure of molecules and their related physical and chemical properties than those who did not use it. Regarding Marfuatun & Hardiningtyas (2018), WBL is an effective approach for teaching thermochemistry or chemical thermodynamics.

The study conducted by (Chirleşan, 2017) showed that Web 2.0 tools increase students' motivation and achievement, and visualization of chemistry. Further, development results in the development of Web 3.0 tools. Web 3.0 is termed an intelligent web or semantic web with technologies like big data, linked data, cloud computing, 3D visualization, augmented reality, and more to make passive learners into active learners in the learning process (Dominic et al., 2014). The study conducted by (Merchant et al. 2012) revealed that the use of a Web 3.0 tool stimulates (do you mean "raises scores on a chemistry test" or do you mean "simulates a chemistry test" ) a chemistry learning test, the Purdue Visualization of Rotations Test (PVRT).

The study conducted by Sudha & Amutha (2015) on the effectiveness of Web-Based Instruction (WBI) in learning and teaching chemistry at the tertiary level revealed that the use of WBI increases students' performance in the acid and acid derivatives for their nomenclature, formulas, functional groups, structures, characterization and reactions in comparison with the traditional mode of teaching. Research conducted by Inci et al., (2008) on the effect of web-based project application on students' attitude toward chemistry found that there was a significant difference between pre-and post-test in favor of post-test, and students' attitude toward chemistry was increased after operation of Web-Based project. The study conducted by Fynewever (2014) making a comparison between the effectiveness of paper-based homework and Web-Based homework in teaching general chemistry evidenced that the Web-Based homework was more effective as it reduces time spent for grading, recording, and returning papers to teachers. The added value of Web-Based homework included instantaneous feedback and the ability to resubmit assignments. According to Bin

(2014), Web-Based cooperative learning in college chemistry teaching will contribute to a new way of teaching in that it helps students to develop critical thinking and problem-solving in chemistry.

According to Jayakumar (2017), WBL provides a great opportunity and brings a more concrete experience to students than traditional chemistry teaching methods. This was in agreement with other authors such as Lovatt et al., (2007) who surveyed the interaction of chemistry students with Online Learning Management, and found that the learners who accessed web-based resources (self-test quizzes and notes) performed better in the summative assessment than those who did not, and students who were motivated to use web-based (capitalize when you are talking about a specific program like WBL and don't capitalize when you are talking about general web-based stuff) resources did better in their examination. However, according to (Inci et al., 2008), students' performance in chemistry is correlated to their attitude toward their ability to use information technology. The students who had a positive attitude toward the use of information technology displayed higher performance in chemistry than others. This was in line with the study conducted by Jayakumar (2017) about the effectiveness of online learning in teaching chemical bonding for the first year of higher secondary school, it was proved that there was a significant association between the expected and observed frequencies for the quality of pictures and video in online learning of chemistry.

Frailich, Kesner, and Hofstein (2007) studied the influence of web-based chemistry learning on students' perceptions, attitudes, and achievements. This study revealed that the web-based learning environment has a significant and potential enhancement of understanding of chemistry concepts, theories, and practices, students' attitudes and interests, and the students' awareness regarding the relevant aspects of chemistry to daily life. (Kaur, 2017) investigated context-based e-learning in chemistry and the results revealed that students positively responded to the learning resource, enjoyed the course, and found the teaching methodology and the presentation interesting and helpful. In addition, the assessment marks were comparable with those from other modules taken by the same students in the same academic year and high performance was observed (in-both groups?).

In a study conducted by Ouaradaoui et al. (2012) on the impact of ICT on chemistry and physics classes in middle schools in Morocco, the control classes (taught by using standard teaching method) and experimental classes (taught by using ICT-based teaching method) were taught by the same teachers with assistance from ICT engineers and technicians for experimental classes. The results revealed that there is a high positive impact of ICT-based education in chemistry and physics education in middle schools. The study also found that the proper pedagogical application of ICT tools in chemistry and physics education is a factor to be taken into consideration for better classroom performance in chemistry and physics, and advised teachers to integrate ICT into their daily teaching practices. Another study on the effect of web-based project applications on students' attitudes towards chemistry has been investigated by (Inci et al., 2008). The results showed that the web-based project applications positively increase students' attitudes toward chemistry, and students' attitudes towards chemistry were a significant predictor of students' performance in a chemistry course. Arasasingham et al. (2005) assessed the effect of web-based learn-

ing tools on students understanding of the concept of stoichiometry by using the software program called Mastering Chemistry Web (MCWeb). In this study, one student section used the MCWeb instructional software as homework (MCWeb group) while the other ones used the text-based homework (non-MCWeb group). Different assessments from this study showed significantly better performance for the students in the MCWeb group over the students in the non-MCWeb group. In addition, the KTS (what is this?) analysis was done and revealed that both groups made a significant achievement in their conceptual understanding of stoichiometry but the MCWeb group showed more improvements than the non-MCWeb group. This study found that MCWeb was more successful in teaching stoichiometry concepts, particularly to introductory chemistry students.

## 9 Authors' perspectives on the use of WBL in teaching and learning chemistry

Based on the findings of this review, it seems that a WBL is potential innovative teaching and learning of science, especially chemistry and it could be applied to help learners not only construct knowledge in chemistry but also to develop different skills. If the WBL methodology is used, the curriculum should be designed in a way that teachers will be aware that in addition to teaching concepts of chemistry using the face-to-face methodology, there are other ways or techniques in teaching and learning chemistry such as WBL. One critical concern is that this new approach will be used and yields the same results as it has been reported by different studies.

This review shows the positive contribution of WBL in teaching chemistry and it should be helpful, especially in this period of a covid-19 pandemic where face-to-face classes are not possible. Further, as technology continues to advance, besides the WBL, there are other forms of online learning and teaching known as social media like radio, television, Facebook, WhatsApp, Microsoft teams, Webex, Skype, and Zoom, that are friendly and familiar to young people in a different context. If the WBL has contributed to the successful learning of science featuring chemistry, the question brought by this review is how social media have been used in this period of covid-19 pandemic and how it contributes to the learning and teaching of chemistry. Undertaking such a study is worthwhile because online methods were abruptly adopted as there was no other option to keep students learning at their homes. Therefore, the outcomes of the study would inform the policymakers or decision bodies to adopt such innovative methods in the educational systems of their countries but also inform the classroom practitioners of the best practices to comply with when planning and delivering online teaching.

## 10 A critical reflection on WBL in teaching and learning chemistry in Rwanda

To make WBL more effective in the Rwandan context, it should be applied in teaching and learning the concepts of chemistry such as organic chemistry, inorganic chemistry, physical chemistry, analytical chemistry, and biochemistry. This is suggested based on what can be practical in the Rwandan context. Further, this is supported by different research findings with an emphasis that any approach is effective when it responds to students' needs. The study conducted by (Iyamuremye et al., 2021) on one hundred thirty-eight senior five chemistry students and four chemistry teachers from the two secondary schools at Kicukiro District in Kigali city, Rwanda about the effectiveness of web-based discussion in teaching and learning organic chemistry. It revealed that web-based discussion is a potential and effective tool that increases student performance. In addition, web-based students and teachers had a positive perception of web-based discussion in organic chemistry class as it helped them interact with each other, share knowledge and experience, monitor participation, encourage active learning, improve the quality of communication, and helped students to search for additional information. This was also supported by Iyamuremye et al., (2022) who found that there was very high statistically significance difference in mean score between students learned with web-based discussion compared to the traditional method of teaching.

One study conducted by (Nsabayezu et al., 2020) about teachers' perceptions towards the utilization of WhatsApp in supporting teaching and learning of chemistry during the COVID-19 pandemic in Rwandan secondary schools illustrated that WhatsApp is effective for teaching chemistry and supporting students learning. This application promotes students' motivation, engagement, collaboration, interaction, participation, and ubiquitous learning. Further studies could examine the effectiveness of the use of WBL in chemistry teaching and learning in Rwanda and its contribution to the implementation of competency-based curriculum (CBC) approaches as CBC is implemented in Rwanda education system since 2015.

Web-Based Learning, one of the online learning resources, as informed by this literature, has contributed to the effective learning of science and chemistry. Since this review does not reveal more outcomes brought by this methodology in the teaching and learning of chemistry in the context of Rwanda, further studies should consider the use and effectiveness of this innovative method in the learning and teaching of chemistry in Rwanda.

## 11 Conclusion and recommendation

Effective utilization of Web-Based Learning in teaching and learning chemistry should help students to construct knowledge in an online community of learners. The development of cognitive presence requires interaction between social presence and teaching presence. WBL needs continuous guidance and facilitation. It is important in the teaching and learning process as it supports a paradigm shift from teacher-centered to learner-centered education and engages students to learn on their own and

supports the connection of learners with others. Effective use of WBL is one of the best methods in teaching and learning chemistry as it helps students in the acquisition of knowledge and academic outcomes.

The authors proposed that a greater number of educational institutions should apply WBL in chemistry teaching and learning because it makes the process of teaching and learning more effective, especially in this period of covid-19 where face-to-face education is problematic to students and teachers. It should be better if chemistry educators are encouraged to use this teaching and learning approach in their instruction. This technique is encouraged to be tried in Rwanda's education system as the country is experiencing a significant advance in smartphone computer-based technology.

**Data Availability** Data are available in a public (institutional, general, or subject specific) repository that issues datasets with DOIs.

## Declarations

**Conflict of interest** The authors declare that they have no conflicts of interest.

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