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Research article

Examining the utilization of web-based discussion tools in teaching and learning organic chemistry in selected Rwandan secondary schools

Aloys Iyamuremye [a,b,*], Innocent Twagilimana [a,b], Francois Niyongabo Niyonzima [a,b]

[a] *University of Rwanda-College of Education, Kayonza, Rwanda*
[b] *African Center for Excellence for Innovative in Teaching and Learning Mathematics and Science (ACEITLMS), Kayonza, Rwanda*

A R T I C L E I N F O

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A B S T R A C T

In recent years, the teaching and learning of organic chemistry have frequently faced challenges due to limited student engagement and participation. Consequently, there is a growing demand for innovative teaching methods to tackle these issues. In this context, web-based discussions have emerged as a hopeful approach to enhance students' engagement and foster critical thinking skills. Therefore, the present study investigated the level of adoption of web-based discussion tools in teaching organic chemistry in Rwandan secondary schools for addressing the challenge of limited student engagement and participation. A quantitative research approach relying on a survey questionnaire was used to collect data from 133 secondary school chemistry teachers in Kamonyi and Gasabo districts. The findings indicate that 78 % of teachers do not use web-based discussion tools, while 22 % have integrated these tools into their teaching. The preferred platforms among users include WhatsApp groups, Google Docs, and Google Classroom. Additionally, the study highlights key organic chemistry topics such as alkanes, polymers, polymerization, and alcohol that can be effectively taught through these tools. Statistical analysis using ANCOVA did not show significant differences in the use of web-based discussion tools based on factors like school location, teachers' age, school ownership, and teaching experience, with p-values of 0.817, 0.234, 0.380, and 0.051, respectively. However, the borderline significance related to teaching experience ($p = 0.051$) suggests a potential trend. A significant difference was observed in terms of gender, with male teachers more likely to use these tools ($p = 0.015$). The study offers valuable insights into the factors influencing the adoption of web-based discussion tools in Rwanda, offering useful guidance for educators and curriculum developers to create more engaging and inclusive chemistry lessons.

1. Introduction

Education is fundamental to the societal development, and access to quality education is crucial for the growth and development of any nation. In Rwanda, as in many other countries, there is an increasing demand to enhance the quality of education, especially in the

* Corresponding author. University of Rwanda-College of Education, Kayonza, Rwanda.
E-mail address: aloysiyamuremye@gmail.com (A. Iyamuremye).

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fields of science and technology [1]. Organic chemistry education has undergone significant transformation over the years, evolving from traditional lecture-based methods to more interactive, student-centered approaches. In the early 20th century, organic chemistry instruction primarily relied on lecturing, textbook readings, and rote memorization of chemical reactions and mechanisms [2]. This passive approach was effective in delivering theoretical content [3]. Later on, laboratory work was integrated into the curriculum as a complementary activity, providing hands-on experience, but it was often disconnected from the theoretical concepts covered in lecturing [4]. During second half of the century, the use of visual aids, such as ball-and-stick models and reaction mechanism diagrams, became more prominent, helping students better visualize molecular interactions and mechanisms [5].

With the advent of technology in education, organic chemistry teaching began incorporating computer-based tools and software in the 1990s, allowing for molecular modeling and simulations that enhanced students' ability to grasp complex chemical structures and reactions [6]. More recently, approaches have shifted towards active learning methods such as peer instruction, flipped classrooms, and Project-Based Learning (PBL) to foster deeper understanding and engagement [7–12]. Web-based discussions, in particular, have emerged as a powerful tool for fostering collaborative learning, enabling students to discuss challenging concepts, ask questions, and work through problems together, both inside and outside of the classroom [13]. These modern approaches emphasize the importance of conceptual understanding, critical thinking, and collaboration, reflecting broader pedagogical shifts in STEM education aimed at improving student outcomes.

One key development is the increasing integration of digital tools, such as augmented reality (AR) and virtual reality (VR), which allow students to explore molecular structures and reaction mechanisms in immersive, 3D environments. These technologies offer unprecedented opportunities for students to visualize complex concepts and interact with them in ways that were previously impossible [14–17]. Additionally, the utulization of artificial intelligence (AI) and Machine Learning (ML) in personalized learning platforms is gaining traction, enabling strong feedback and adaptive learning paths that address individual students' needs and learning styles [18–21]. These tools hold great potential for enhancing students' engagement and learning outcomes in organic chemistry.

Looking ahead, the future of organic chemistry education is likely to be shaped by the expansion of collaborative, technology-enhanced learning environments. For instance, the rise of web-based collaborative platforms that support real-time problem-solving and discussion is likely to continue. These platforms, combined with the increasing use of flipped classrooms and peer instruction, will further support active learning and critical thinking. Furthermore, as the demand for interdisciplinary approaches grows, we can expect organic chemistry education to integrate more real-world applications and connections to fields like materials science, environmental chemistry, and biotechnology. These developments suggest that future organic chemistry education will prioritize deeper conceptual understanding, foster collaboration, and leverage cutting-edge technologies to create dynamic, student-centered learning experiences. However, the research indicates that the majority of secondary school teachers in developing countries, including Rwanda, tend to emphasize memorization rather than deeper understanding [22–24]. Traditionally, Rwanda has relied on conventional teaching methods, which often limit students' opportunities to grasp scientific concepts effectively [25]. To address this issue, Rwanda has been implementing significant education reforms, transitioning from a Knowledge-Based Curriculum (KBC) to a Competence-Based Curriculum (CBC) since 2016. This shift is crucial, as the CBC emphasizes active learning, critical thinking, and the development of practical skills. These elements are essential for preparing graduates to meet the demands of the job market and become effective problem solvers [26].

In view of the above, the different past studies conducted in Rwanda have revealed that traditional teaching methods for organic chemistry in Rwandan secondary schools often depend on didactic lectures and rote memorization which may fail to adequately engage students or facilitate deep conceptual understanding [27–32]. The researchers have identified some challenging concepts that are difficult to teach and learn in organic chemistry. For instance, Farheen [33] argued that drawing and representation of organic compounds as difficult topics in organic chemistry. Adu-Gyamfi and Asaki [34] added the properties of organic compounds as challenging concept in organic chemistry. Smith [35] illustrated aromaticity, reaction types, and reaction mechanisms as difficult topics in organic chemistry. In addition, Musa and Onu [36] mentioned reaction synthesis and mechanism, instrumentation, structure and properties, and classification of organic compounds as challenging organic chemistry topics difficult to teach and learn.

It was found that traditional teaching methods are effective in delivering foundational knowledge, but may not always offer sufficient opportunities for students to involve in critical thinking, collaborative learning, and real-time problem-solving [37,38]. To overcome this problem, web-based discussions provide a platform where students can exchange ideas, ask questions, and clarify misunderstandings outside the confines of a traditional classroom [39]. This approach promotes active learning and supports peer-to-peer interaction, which has been shown to enhance both student engagement and conceptual understanding, particularly in subjects that require significant cognitive investment like organic chemistry [40–43].

Web-based platforms have transformed organic chemistry education by providing a wealth of information and interactive tools [44]. Thus, it is now a common place for students to access course materials and study at their rhythm [45]. The research illustrated that web-based discussion educational tools such as Moodle, Google Classroom, Canvas, Edmodo, Flipgrid, Slack, Facebook, WhatsApp groups, Disqus, Microsoft Team, and Piazza help students to understand difficult organic chemistry concepts [46–49]. Hence, these web-based resource tools support students by allowing them to interact and discuss with peers in the classroom and after classroom sessions. The use of web-based discussion tools also engages students with their peers and teachers via discussion boards, chat rooms, and video conferencing facilities [50].

The research has also illustrated that web-based discussion tools are not only important for students but also for teachers [30,51]. In this regard, Prestridge [52] illustrated that the use of web-based discussion tools increases teachers' technological skills in using ICT resources. In addition, Martín-Sómer et al. [53] recognized the importance of web-based tools as the best way of making learning changes from passive to active learning. Furthermore, Bragg et al. [54] highlighted that web-based discussion improves teachers' mode of assessment and providing feedback. Furthermore, a web-based discussion enables teachers to connect with their peers, share best practices, and exchange resources and ideas [55]. Hence, this approach can lead to improved teaching methodologies, better lesson planning, and ultimately a more effective learning experience for students.

Different previous studies have also shown that the use of web-based discussion tools increases students' conceptual understanding of complex organic chemistry concepts. For instance, Blonder and Rap [56] explained that integrating Videos and visualization links help students to understand abstract organic chemistry concepts. This was also confirmed by Immanuella and Redhana [57] who found that the use of Moodle, Canvas, and Google Classroom increases students' understanding of organic chemistry concepts such as reaction mechanism and application of organic compounds. Hashim and Hanibah [58] illustrated that students who were exposed to Google Classroom as a web-based discussion tool performed better in organic chemistry than their fellows who used a traditional method of discussion. The use of Rain Classroom and WeChat platforms improves students' conceptual understanding of complex organic chemistry concepts [59]. Hence, it is better to motivate secondary school students to learn and understand organic chemistry concepts through the use of modern innovative approaches.

This study is grounded to connectivism theory, which highlights the importance of technology and networks in the learning process. According to connectivism, learning is not confined to the individual; rather, it is distributed across various networks of people and resources [60]. In our research, web-based discussion tools play a pivotal role in facilitating connectivism learning. These tools create an interactive environment where students can actively engage with course materials, collaborate with each other, and access external resources, thereby fostering knowledge creation through their connections [61]. In addition, connectivism posits that learners are not passive recipients of information; instead, they are active participants who construct knowledge through their interactions with their learning environment. In this context, web-based discussion tools serve as instruments that encourage social collaboration and knowledge co-construction among learners, aligning perfectly with connectivism principles. The interactive nature of these discussions also promotes self-directed learning and learner autonomy, which are key aspects of connectivism's focus on active participation in the learning process [62]. Hence, by engaging in web-based discussions, students can connect with peers, educators, and external experts, thereby broadening their networks and gaining access to diverse perspectives and sources of knowledge.

It is widely acknowledged that the success, acceptance, and effective implementation of online teaching and e-education through technology depend on a variety of internal and external factors [63]. The literature identifies several teacher-related elements that can influence the adoption and use of technologies, especially online discussion tools. These factors include gender, technological literacy, technological pedagogical content knowledge (TPACK), geographic location, attitudes, beliefs, motivation, habits, self-efficacy, performance expectations, as well as computer experience and proficiency [64,65]. Additionally, external factors such as institutional structure, workplace culture, available resources, social conditions, the perceived value of technology, feasibility of use, competitive advantage, and institutional preparedness significantly impact the integration and implementation of web-based discussion tools [66–68]. Furthermore, the availability of professional development courses for teachers and the necessary online resources and infrastructure also play a crucial role in technology integration within teaching [69,69]. Therefore, addressing these factors effectively can lead to numerous positive outcomes in education, particularly in the field of organic chemistry.

Based on the Rwandan CBC, organic chemistry is taught in senior two (eighth grade), senior three (ninth grade), senior five (eleventh grade), and senior six (twelfth grade). At the ordinary level (from senior one to three), students engage in chemistry for four periods per week. In contrast, the advanced level (from senior four to six) entails seven periods of chemistry per week. It should be noted that, in the Rwandan education system, a period refers to a 40-min time slot. Table 1 shows the content to be covered in each grade, key unit competencies, and the period allocated to each unit.

The Rwandan chemistry curriculum suggests different teaching approaches for organic chemistry. For example, in senior two (eighth grade) the curriculum suggests group discussion, lecturing, practical work, and research. The main resources to be used in grade eight are chemistry laboratories, charts, textbooks, and ICT tools such as computers and projectors. However, the ICT tools suggested were supposed to be used for abstract concepts and for certain experiments that cannot be conducted in school laboratories due to safety concerns through animation and simulation [72]. In senior three (ninth grade), the suggested approaches are group discussion, practical work, lecturing, research, and field visits [72]. At the advanced level, different teaching approaches were also suggested by Rwanda Basic Education Board (REB). For instance, in senior five (eleventh grade) the proposed approaches are group discussion, research, practical work, lecturing, field visits, and Project-Based Learning (PBL) [73]. In senior six, the suggested approaches are group discussion, case study, group discussion, lecturing, practical work, and research [73]. For successful implementation of the CBC, embracing modern technologies presents innovative ways to improve the teaching and learning experience [74].

In the context of the employment of web-based discussion tools in Rwandan secondary schools, REB is striving to provide in-service and pre-service professional development training courses to advance their technical proficiency. For instance, REB is implementing different initiatives designed that give Continuous Professional Development (CPD) training program to mathematics and science teachers to equips them the skills and knowledge necessary to use technology in teaching and learning [75]. In this regard, the current report showed that the utilization of the internet in Rwandan secondary schools is at 52.9 % [76]. In addition, 66.9 % of households own a mobile phone in Rwanda [77]. This indicates that students and teachers can use web-based discussion tools in schools and after class in their homes. To achieve this, Rwanda launched the One Laptop Per Child (OLPC) initiative in 2008, aiming to provide primary school children with laptops to enhance learning opportunities through the use of technology [78]. In addition, in 2016, Rwanda introduced the Smart Classroom Initiative (SCI) which equipped secondary schools with ICT tools like projectors, computers, and interactive whiteboards to enhance teaching and learning experiences [79]. Each school received 100 computers for students and two for teachers. The distribution of computers follows a non-random approach, as schools must first verify their access to electricity. Each computer is equipped with internet connectivity and includes educational materials to facilitate lesson preparation. These computers are designed for computer science subject and other subjects, particularly STEM for encouraging teachers to use them for their lessons

Table 1
Organic chemistry content taught in Rwandan secondary schools.

Grade	Key unit competency	Unit	Number of periods per unit	Total periods
Senior two	To be able to compare the properties of organic and inorganic compounds and explain the uses of alkanes in daily life	Properties of organic compounds and uses of alkanes	18	18
Senior three	To be able to relate the properties of alkenes and alcohols to their functional groups.	Structure and properties of alkenes and alcohols.	15	31
	To be able to explain the properties of carboxylic acids.	Carboxylic acids.	6	
	To be able to explain the origin of petroleum products and the application of polymers.	Petroleum products and polymerization.	10	
Senior five	The learner should be able to apply IUPAC rules to name organic compounds and explain the types of isomers for organic compounds.	Introduction to organic chemistry	7	150
	The learner should be able to relate the physical and chemical properties of the alkanes to the preparation methods, uses, and isomerism.	Alkanes	10	
	The learner should be able to relate the physical and chemical properties of the alkenes and alkynes to their reactivity and uses.	Alkenes and alkynes	22	
	The learner should be able to relate the physical and chemical properties of halogenoalkanes to their reactivity and uses.	Halogenoalkanes (alkyl halides)	17	
	The learner should be able to compare the physical and chemical properties of alcohols and ethers to their preparation methods, reactivity, and uses.	Alcohols and Ethers	22	
	The learner should be able to compare the chemical nature of carbonyl compounds to their reactivity and uses.	Carbonyl compounds	22	
	The learner should be able to compare the chemical nature of the carboxylic acids and acid halides to their reactivity.	Carboxylic acids and acyl halides	17	
	The learner should be able to relate the functional groups of esters, acid anhydrides, amides, and nitriles to their reactivity, preparation methods, and uses.	Esters, acid anhydrides, amides and nitriles	22	
	The learner should be able to relate the chemical nature of the amines and amino acids to their properties, uses, and reactivity.	Amines and amino acids	11	
Senior six	The learner should be able to relate the chemistry and uses of benzene to its nature and structure.	Benzene	15	50
	The learner should be able to relate aromatic ketones, aldehydes, carboxylic acids, and amines to their chemical activity	Derivatives of benzene	21	
	The learner should be able to relate the types of polymers to their structural properties and uses.	Polymers and polymerization	14	

Source: [70,71].

preparation and students' activities [80]. In this context, the utilization of web-based discussion tools is among the new technologies that have been incorporated into the Rwandan basic education system since 2000 [81].

The utilization of online discussion forums, chat rooms, and social media groups has grown in popularity as a means of promoting engagement, teamwork, and information exchange between professors and students [82]. McNeil et al. [83] proved that via the use of web-based discussion tools in organic chemistry education, students actively participate in the lesson by posing questions, exchanging ideas, and getting feedback from their peers. This encourages analytical thinking, the ability to solve problems, and a greater comprehension of organic chemistry concepts. This was also confirmed by the research conducted by Mahande [84] which showed that web-based discussion tools make it easier for students to explore the practical uses of organic chemistry and share various points such as multimedia elements with their colleagues to improve their conceptual understanding and visualization. However, different factors may intervene in this increase in students' conceptual understanding including class size, geographical location, quality of discussion, topic of the discussion, level of student involvement, and specific learning objectives [85–88]. Thus, the effective use of web-based discussion tools should consider other intervening variables into consideration. This was also supported by Richards-Babb [89] who found that the increase in average scores in organic chemistry depends on the design of web-based discussion tools. This indicated that students who used these tools increased their test scores but this depends on the design of the system. These results were also appreciated by Haley et al. [90] who highlighted that the structure of the web-based discussion gives students more flexibility and enhances their performance in organic chemistry topics that require a high level of complex reasoning abilities. Tang et al. [91] identified that deeper learning and comprehension of organic chemistry concepts are facilitated by the usage of web-based discussion forums. This was also confirmed by Jia [92] who showed that students who were involved in a web-based discussion performed better in the exams and assignments than students who participated in traditional group discussion. Therefore, the literature revealed that the use of web-based discussion forums increases students' problem-solving, and critical thinking skills, and encourages students to apply the principles of organic chemistry to real-life applications.

In the context of Rwandan secondary schools, where access to advanced laboratory facilities and instructional materials may be limited, web-based discussions present a cost-effective solution to enhance the quality of organic chemistry education [93]. By harnessing digital technologies, teachers can bridge the gap between theoretical concepts and real-world applications. This research endeavors to fill a significant gap in the literature by providing empirical evidence on the effectiveness of web-based discussions in strengthening students' conceptual understanding of organic chemistry in Rwandan secondary schools. By clarifying the mechanisms through which digital discourse fosters learning outcomes, the study aims to inform pedagogical practices and curriculum development strategies in chemistry education. Ultimately, the findings of this research have the potential to catalyze transformative changes in how organic chemistry is taught and learned, paving the way for more inclusive and interactive educational experiences in Rwanda and beyond. Thus, the following are specific research objectives to be achieved.

In our study, the use of web-based discussions is grounded in the increasing need for interactive, student-centered learning environments that facilitate deeper engagement with complex subjects like organic chemistry. The main objective of this study was to examine the usage of web-based discussion in teaching and learning organic chemistry. In this context, the study seeks to investigate and analyze the current situation of the utilization of web-based discussion in teaching and learning organic chemistry in Rwandan secondary schools by emphasizing the following variables that are gender, geographical location, school ownership, working experience, and age. Understanding demographic and other contextual factors in web-based discussions is crucial in this study for designing inclusive educational strategies.

2. Research questions

a) To what extent do Rwandan secondary school chemistry teachers use web-based discussion tools in teaching and learning organic chemistry?
b) Is there any statistically significant difference in the use of web-based discussion tools in terms of location, gender, experience, age, and school ownership?
c) What are the organic chemistry concepts which can be taught through the use of web-based discussion tools?

3. Hypothesis

- **Null hypothesis (Ho)**: There is no statistically significant difference in the use of web-based discussion with regard to gender, geographical location, school ownership, working experience, and age.
- **Alternative hypothesis (H_1)**: There is a statistically significant difference in the use of web-based discussion with regard to gender, geographical location, school ownership, working experience, and age.

4. Methodology

This section outlines the approach employed to investigate the research questions, providing a detailed description of the research design, data collection methods, and analytical procedures. The selection of participants, instruments used, and the procedures for data collection and analysis were carefully designed to ensure the reliability and validity of the findings.

4.1. Research design

The study used the descriptive research design. Bloomfield and Fisher [94], argued that a descriptive design is used to develop a theory, pinpoint problems with existing practice, justifying the current practice, make conclusions, or determine what others are doing in similar situations. In the context of this study, a descriptive research design was useful to gather data, analyze them, and draw conclusions to characterize and comprehend the extent of using web-based discussion in teaching and learning organic chemistry in Rwandan secondary schools.

4.2. Research approach

A quantitative research approach was used to collect and analyze data. In this line, an online survey questionnaire was used to collect quantitative data. The survey was comprised of two parts. The first part covered the demographic information of the participants while second is concerned with the current usage of web-based discussion tools in teaching and learning organic chemistry.

4.3. Population and method of sampling

The target population included all secondary school chemistry teachers located in the Gasabo and Kamonyi districts of Rwanda. Appendix 1 offers a detailed description of the geographical aspects of these districts. The study implemented a census sampling technique, which involves using the whole population as the sample [95]. In this regard, a total of 133 secondary were involved in this research. This sampling method was chosen to ensure comprehensive representation of the target population, providing accurate and detailed information about the frequency and nature of the phenomena being studied [96,97]. Table 2 displays the demographic information of the participants involved in the study.

From Tables 2 and it is important to acknowledge that demographic factors may significantly influence this study. Specifically, gender, geographical location, school ownership, work experience, and age are important characteristics to examine, as they can substantially impact the adoption and effectiveness of web-based discussion tools. In this regard, gender might reveal differences in access and attitudes towards technology, while location (per-urban, rural, urban) can highlight disparities in technological infrastructure and resources. Furthermore, school ownership (government-aided, government, private) can affect the availability of funds and support for technology integration. Moreover, the working experience and age of participants are essential to understand varying levels of comfort and familiarity with web-based tools, as more experienced or older teachers might have different perspectives compared to their younger or less experienced counterparts. Thus, by examining these variables, the study can provide a comprehensive understanding of the factors that enhance or hinder the use of web-based discussion tools, leading to more targeted and effective interventions.

During the selection of teachers, the inclusion and exclusion criteria were applied. The inclusion criteria were chemistry teachers who teach organic chemistry and schools that have access to the necessary web-based discussion tools such as schools that have electricity, computer laboratories, and internet connectivity. Additionally, schools must be located within the selected regions for the study (Gasabo and Kamonyi districts). The exclusion criteria were schools without electricity, computer laboratories, and internet connection, teachers who do not teach organic chemistry, and schools outside the targeted regions.

4.4. Research instrument

The survey questionnaire was employed to collect data for this study. This instrument was developed by a team of four researchers

Table 2
Demographic information of participants.

Demographic items	Category	Number (n = 133)
Gender	Male	103
	Female	30
Location	Rural	103
	Urban	26
	Per-urban	4
Age	Under 25 years	3
	25–32 years	63
	33–40 years	57
	above 40 years	10
School ownership	Private	6
	Government	60
	Government aided	67
Working experience	Less than 1 year	7
	1–3 years	44
	4–6 years	26
	7–9 years	17
	10 and above	39

from the University of Rwanda - College of Education (UR-CE). These researchers includes one associate professor in biochemistry, one senior lecturer in ICT in education, and two PhD students in chemistry education. This questionnaire aimed to assess current level of using web-based discussion tools in teaching organic chemistry. Additionally, it sought to identify organic chemistry concepts that could be effectively taught using these tools. Furthermore, the survey explored the types of web-based discussion platforms utilized by chemistry teachers when instructing organic chemistry concepts. Overall, this survey-based descriptive approach was designed to provide a comprehensive understanding on extent to which chemistry teachers are using web-based discussion tools.

4.5. Method of data analysis

A quantitative approach was used to analyze collected data. The analysis focused on five variables: gender, location, school ownership, work experience, and age. For gender, the following codes were assigned: female = 1 and male = 2. For location, the codes were: peri-urban = 1, rural = 2, and urban = 3. In terms of school ownership, the codes were government-aided = 1, government = 2, and private = 3. Furthermore, work experience was coded as follows: less than one year = 1, 1–3 years = 2, 4–6 years = 3, 7–9 years = 4, and above 10 years = 5. Lastly, age was coded with the following categories: under 25 years = 1, 26–32 years = 2, 33–40 years = 3, and above 40 years = 4.

The collected data were analyzed by using descriptive and inferential statistics with the aid of Excel 2016 and SPSS V.25 software. Before beginning an analysis, we verified the parametric test assumptions (continuous data, sample of at least 30, normality of data, and equality of variances). Since we had over 30 participants in the sample, and the Kolmogorov-Smirnov and Levene tests for equality of variances supported the hypotheses ($p > 0.05$). In addition, kurtosis, skewness, and normality curves were used to test the normality of data. In this context, we obtained the kurtosis of $+1$, skewness of -0.55, and bell-shaped normality curve. Thus, we utilized the analysis of covariance (ANCOVA) as a parametric test to analyze whether or not there is a statistically significant difference in the use of web-based discussion in different contexts.

4.6. Validity and reliability of the research instrument

Both Validity and reliability were considered in our study. Validity is defined as the extent to which a measurement accurately reflects what it is intended to measure [98]. To ensure content validity, the research instrument was reviewed and approved by researchers from the University of Rwanda's College of Education. This validation process involved six experts from various expertise, including an Associate Professor in Biochemistry, a senior lecturer in ICT in education, a lecturer in English education, a lecturer in chemistry education, and two PhD students in chemistry education. Additionally, the Content Validity Ratio (CVR) proposed by Lawshe [99] was used to evaluate each test item.

$$CVR = \frac{ne - \left(\frac{N}{2}\right)}{\frac{N}{2}}$$

CVR is obtained from the number of panel members who indicate "essential" (ne) and the total number of panel members (N). The final decision to retain an item based on the CVR is contingent upon the number of panel members. For this study, the CVR for the research instrument was calculated to be 0.87, which exceeds the minimum acceptable value of CVR at $p = 0.05$. This indicates that the research instrument is valid. In addition, to ensure reliability, the questionnaire was piloted with 60 chemistry teachers who shared the same characteristics as those in the main study. Subsequently, Cronbach's alpha was calculated, yielding a reliability coefficient of 0.72. Therefore, the research instrument was deemed reliable for data collection.

4.7. Ethical consideration

The researchers obtained ethical clearance letter approval from the ethical committee in the University of Rwanda - College of Education (UR-CE) with ref number RC/ET/April 01, 2024 in April 2024. The aim and purpose of the study were explained to the participants before the research started. Informed consent was obtained from each participant in May 2024 before their involvement in the study, ensuring voluntary participation. The principles of confidentiality and anonymity for the data collected were strictly upheld throughout the process.

5. Results interpretation

This section describes the extent to which the web-based discussion tools are used by teachers. It also present an analysis of statistical data regarding to the level of significance of using web-based discussion tools with regard to gender, geographical location, school ownership, working experience, and age. Furthermore, the organic chemistry topics that can be taught by using web-based discussion tools were also discussed. The results are structured and presented in alignment with the predefined research questions.

5.1. Extent of using web-based discussion in teaching and learning chemistry organic chemistry

The results in Fig. 1 show that a significant majority of chemistry teacher (78 %) do not use web-based discussion tools in their teaching. On the other hand, 22 % of the surveyed teachers claimed to use web-based discussion tools in their teaching.

Fig. 2 shows the extent to which web-based discussion tools are used in teaching and learning organic chemistry per week. The results showed that most of teachers at the percentage of 50 % don't use web-based discussion in their teaching in a week. According to the results 21 %, 9 %, 3 %, and 11 % of them use web-based discussion once, twice, three, and more than three per week, respectively. The results also showed that most teachers at the extent of 54 % did not use web-based assessment in their teaching while 32 %, 4 %, 5 %, and 6 % used web-based assessment once, twice, three, and more than three times per week, respectively. Furthermore, the study investigated the extent to which chemistry teachers incorporate web-based discussion and assessment tools in teaching and learning. In light of this, the results revealed that most of them at the percentage of 60 % don't use the incorporation of web-based discussion and assessment while 28 %, 3 %, 5 %, and 5 % use web-based discussion once, twice, three, and more than three per week, respectively.

This study also looked at the ICT resources used by chemistry teachers during web-based discussions. The results in Fig. 3 showed that most teachers (55 %) use laptops during their teaching. 43 % of them participated in web-based discussions by using their smartphones. It's interesting to note that only 2 % of surveyed teachers reported utilizing tablets during web-based discussions.

The results in Fig. 4 reflects the chemistry teachers' preferred web-based discussion platforms used for teaching organic chemistry. The information displays the web-based discussion tools used by chemistry teachers are Facebook, Moodle, Google Classroom, Google docs, and WhatsApp.

The results in Fig. 4 illustrate that Google Classroom is used by chemistry teachers at a percentage of 28 % through sharing resources, assigning homework, and facilitating discussions. In addition, the 26 % usage implies that chemistry teachers often use Google Docs to distribute lecture notes, worksheets, and other educational materials. Remarkably, only 2 % of chemistry teachers use Facebook to discuss organic chemistry concepts. Significantly, chemistry teachers use WhatsApp at a high rate of 37 % for communicating organic chemistry topics with the students. Moreover, Moodle is being used by 7 % of chemistry teachers in organic chemistry classes.

5.2. Descriptive analysis of the usage of web-based discussion in teaching organic chemistry based on school location, age, experience, school ownership, and gender

Table 3 shows a descriptive analysis of the results on the usage of web-based discussion in different contexts including location, age, experience, school ownership, and gender. In this context, we rated the mean score from the Likert out of 15. In addition, the standard deviation was also computed.

The descriptive statistics presented in Table 3 provide insights into the current usage of web-based discussion across different demographics. In terms of location, teachers in per-urban areas exhibit the highest mean usage score of 6.25, followed by those in rural (5.34) and urban (5.19). Regarding age groups, the youngest cohort (under 25 years) has the highest mean usage score of 13.66, while the older age groups show slightly lower scores, with those above 40 years having a mean score of 12.20. Based on the teachers' working experience, teachers with 7–9 years of experience demonstrate the highest mean usage score of 6.88, whereas those above 10 years exhibit the lowest mean score of 4.92. According to the school ownership, the analysis showed that teachers who worked in public schools have the highest mean usage score of 6.83, followed by government schools (5.60) and government-aided schools (5.11). For gender, male teachers tend to have a higher mean usage score (5.78) compared to females (4.70). Hence, these statistics highlight variations in web-based discussion usage across different demographic factors, indicating potential areas for further investigation or targeted interventions.

5.3. Inferential analysis of the usage of web-based discussion in teaching organic chemistry based on school location, age, experience, school ownership, and gender

Before analyzing the inferential statistics, the normality of the data was checked. The results in Table 4 show that the value

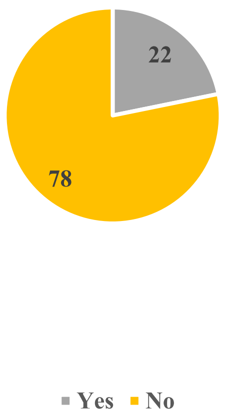

Fig. 1. Extent of using web-based discussion in teaching organic chemistry.

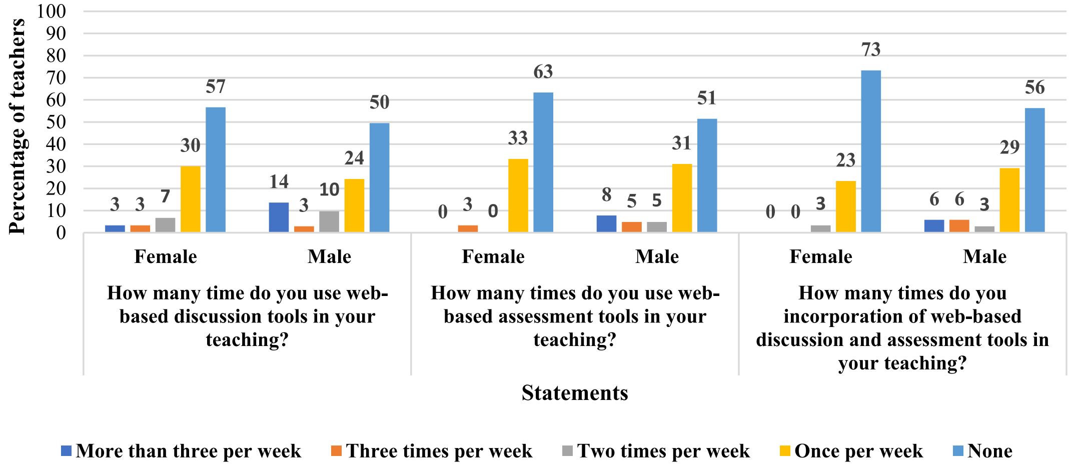

Fig. 2. Current level of using web-based discussion in teaching and learning organic chemistry per week.

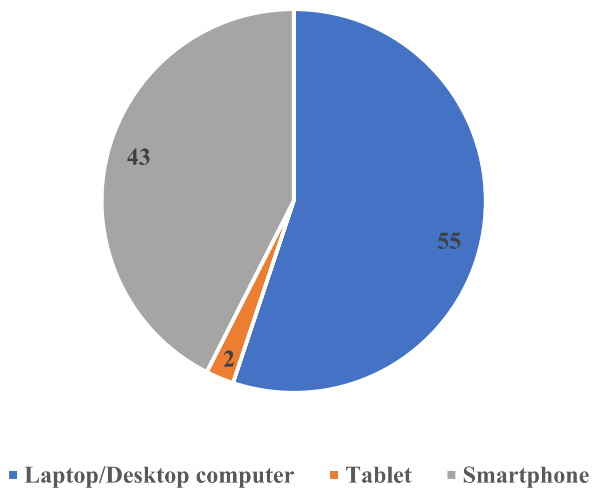

Fig. 3. ICT tool used by teachers during web-based discussion.

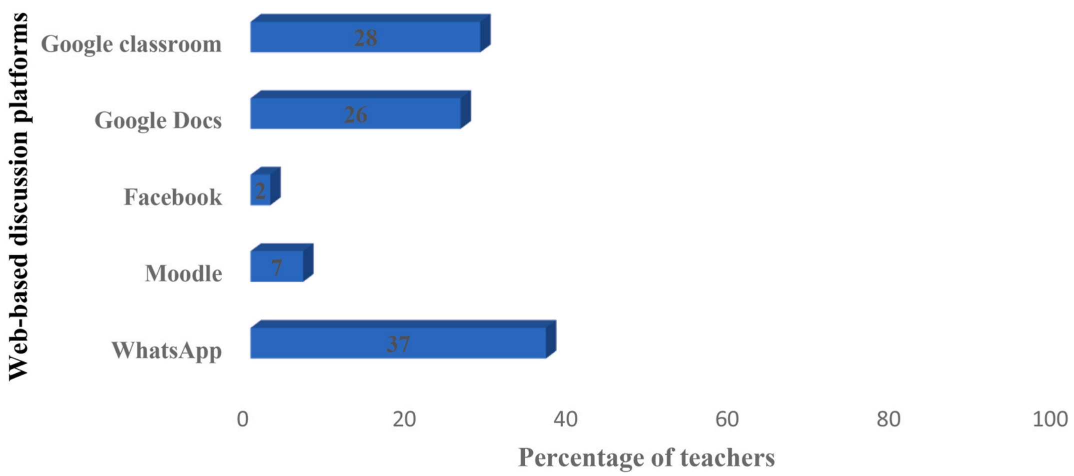

Fig. 4. Web-based platforms used by teachers in teaching and learning organic chemistry.

Table 3
Descriptive statistics on the usage of web-based discussion in teaching organic chemistry.

Location	Variable	N	Mean	Std. Deviation
	Per-urban	4	6.25	3.40
	Rural	103	5.34	3.28
	Urban	26	5.19	2.13
	Total	133	5.34	3.07
Age	18–25 years	3	13.66	1.52
	25–32 years	63	12.93	1.58
	33–40 years	57	12.40	1.95
	Above 40 years	10	12.20	1.98
	Total	133	12.66	1.79
Working experience	Above 10 years	39	4.92	2.68
	1–3 years	44	6.02	3.51
	4–6 years	26	4.50	2.71
	7–9 years	17	6.88	3.98
	Less than one year	7	4.14	1.34
	Total	133	5.41	3.19
School ownership	Government aided	67	5.11	3.04
	Government	60	5.60	3.38
	Public	6	6.83	2.85
	Total	133	5.41	3.19
Gender	Female	30	4.7	1.62
	Male	103	5.78	2.25
	Total	133	5.54	2.16

skewness was −0.558, which indicates that the data is slightly negatively skewed but still approximately symmetric. The standard error of skewness was 0.21, suggesting that the estimate of skewness is reliable. The kurtosis value calculated was +1, which is less than the expected value of +3 for a normal distribution. This suggests that the data are relatively flatter or less peaked than a normal distribution. The standard error of kurtosis is 0.417, indicating that this value is also reliable. Thus, the results suggest that the data are approximately symmetric with a moderate degree of flatness, and there are no significant deviations from normality, allowing for the use of parametric statistical tests.

In addition, the normality curve was used to test the normality of the data. Fig. 5 presents the normal distribution curve which was generated as part of the analysis. The bell-shaped curve provides visual confirmation of the data's normal distribution.

To know whether there is a statistically significant difference in the utilization of web-based discussion across different variables, the analysis of covariance (ANCOVA). Table 5 displays that chemistry teachers' geographic location, age, and school ownership factors do not influence the use of web-based discussion tools. This lack of statistical significance shows that these factors did not play a significant influence in deciding whether or not teachers participated in web-based discussion tools with p-values of 0.817, 0.234, and 0.38, respectively. Although the influence of working experience on the usage of web-based discussion tools was not statistically significant at the standard p-value threshold of 0.05, the borderline significance ($p = 0.051$, df = 138) shows a notable trend. In contrast, the analysis also revealed that gender variable has an influence on the adoption of using web-based discussion tools. In this sense, the obtained p-value was 0.015 with df of 131. This suggests a significant difference in the use of web-based discussion tools in terms of gender in favor of male teachers.

5.4. Organic chemistry concepts teachable via web-based discussion

Teachers were asked to write organic chemistry concepts that can be taught by using web-based discussions. The results in Fig. 6 shows that most teachers preferred alkane, introduction to organic chemistry, polymer and polymerization, alcohol, and carboxylic acid at percentages of 84 %, 78 %, 72 %, 64 %, and 58 %, respectively. However, stereochemistry, amide, amino acid, and saponification were chosen at low extents at the percentages of 11 %, 13 %,17 %, and 24 %, respectively.

Table 4
Descriptive analysis of normality of data.

N	Valid	133
	Missing	7
Skewness		−0.558
Std. Error of Skewness		0.21
Kurtosis		1
Std. Error of Kurtosis		0.417

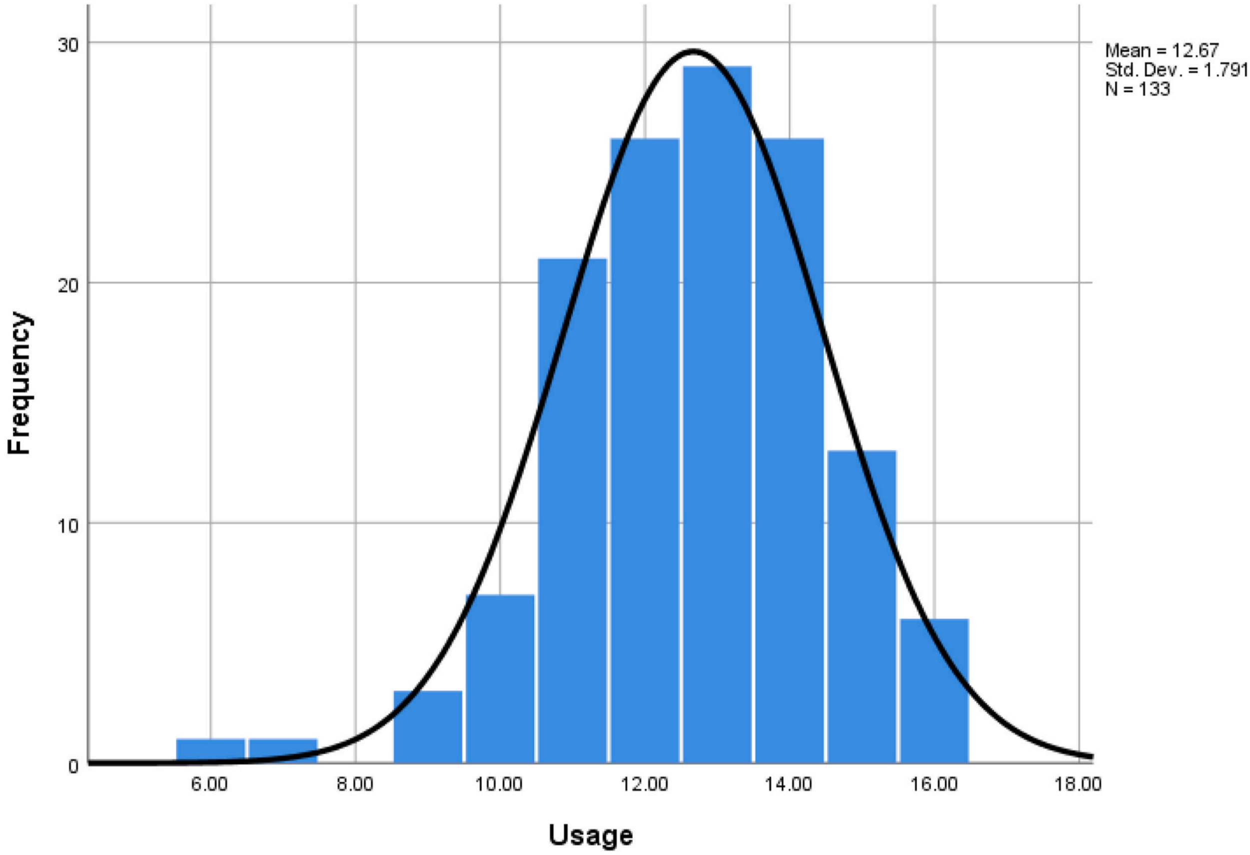

Fig. 5. Normality curve of data.

Table 5
Inferential statistics analysis on the extent of using web-based discussion tools in teaching organic chemistry.

Analysis of covariance (ANCOVA)						
Variables	Groups	Sum of Squares	df	Mean Square	F	Sig.
Location	Between Groups	3.884	2	1.942	0.203	0.817
	Within Groups	1246.206	130	9.586		
Age	Between Groups	13.712	3	4.571	1.439	0.234
	Within Groups	409.732	129	3.176		
Experience	Between Groups	95.387	4	23.847	2.432	0.051
	Within Groups	1254.868	128	9.804		
School ownership	Between Groups	19.978	2	9.989	0.976	0.38
	Within Groups	1330.278	130	10.233		
Gender	Between Groups	27.422	1	27.422	6.052	0.015
	Within Groups	593.601	131	4.531		

6. Discussion

The present study assessed the utilization of web-based discussion in teaching and learning organic chemistry in Rwandan secondary schools. The results illustrated that small percentage of teachers don't use web-based discussions in teaching and learning. This proves the existence of a low level integration of technology in Rwandan secondary schools. In this regard, the low use of technology may be caused by insufficient ICT infrastructure [100]. In addition, Habiyaremye et al. [101] illustrated that inadequate access to current educational technology, high-speed internet connection, adequate hardware & software, digital and online learning opportunities hinder the effective use of ICT resources in Rwandan education. Furthermore, Mushimiyimana et al. [102] showed that the lower use of ICT resources have a direct connection with low teachers' technological skills.

The results also revealed that chemistry teachers use a wide variety of ICT tools during web-based discussions. It was found that they preferred to use laptops in their teaching. While different devices are available and used, the use of laptops may increase the discussions' adaptability and accessibility. The results indicated that teachers prefer to use different web-based discussion tools in their

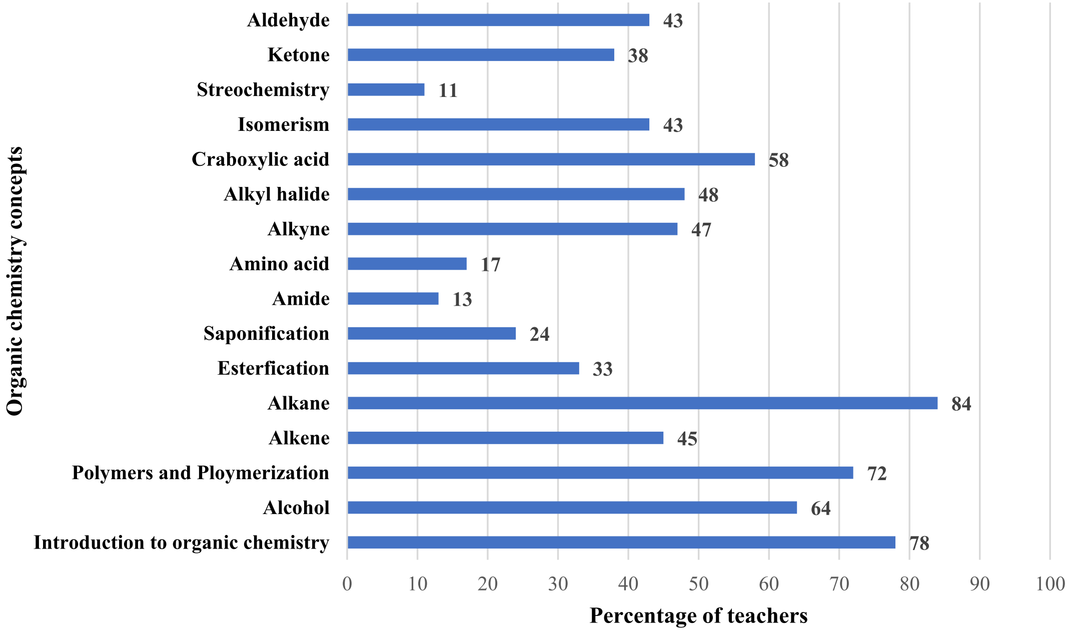

Fig. 6. Organic chemistry concepts teachable via web-based discussion.

teaching. In this regard, WhatsApp was found to be the most popular web-based platform used by teachers. WhatsApp is a popular messaging program, that provides a practical platform for brief exchanges, group conversations, and sharing of multimedia information. Its broad use, accessibility, and familiarity among teachers and students can all be linked to the popularity of cell phones. This was in line with Nsabayezu et al. [48] in their study which showed that WhatsApp promotes a more relaxed and informal learning atmosphere by allowing students to prompt clarification of chemistry concepts. These findings were also supported by Zan [103] who found that most chemistry teachers prefer to use WhatsApp group as a web-based discussion tool in teaching organic chemistry because it increases the students' motivation, strengthens the communication, and encourages information sharing among students. One motivating factor of using this application is because its messages are supported with audio-visual and video content make the discussion more permanent in the platform [104]. De Souza and Kasseboehmer [105] also confirmed the idea that the use of WhatsApp chat groups stimulates an active engagement of the participants and maintains a collaborative learning experience among students and teachers.

The results found that Google Classroom and Google Docs are among popular web-based discussion tools used by chemistry teachers in teaching organic chemistry. This preference is likely due to the strong, collaborative features these platforms offer. This was confirmed by the study conducted Yilmaz and Yasar [106] which found that user-friendly interfaces and collaborative features of Google platforms and Docs make them attractive choices for teachers. Agustina and Purnawarman [107] explained that Google Classroom facilitates seamless assignment distribution, feedback, and communication. Similarly, Google Docs is highly used by many chemistry teachers because it supports real-time collaboration and editing, allowing students and teachers to jointly construct and refine complex chemical structures and mechanisms, and foster a deeper understanding through interactive engagement [108]. The studies highlighted that these tools not only enhance student participation but also support the diverse learning paces and styles within a classroom setting [109–111].

Facebook and Moodle are moderately used. Understanding these preferences of investigating web-based platforms used by chemistry teachers can help design effective instructional strategies and promote meaningful engagement in organic chemistry education. These findings indicate that Facebook's integration into educational contexts influences its widespread use and familiar interface, facilitating informal discussions, and sharing of resources among students [112]. This platform supports the creation of study groups and the dissemination of supplementary materials, fostering a community-like environment that can enhance student engagement. On the other hand, Moodle offers a more structured learning management system (LMS) linked to the students' need, providing comprehensive tools for course management, quizzes, and interactive content delivery [113]. This explains why Moodle's flexibility and support for various educational activities makes it a valuable tool for organizing course materials and assessments, catering to diverse learning preferences. This reflects a balanced approach where both formal LMS like Moodle and social media platforms like Facebook play complementary roles in modern educational strategies. These results are in agreement with the previous research conducted by Rap and Blonder [114] who found that the use of Facebook group in teaching organic chemistry is a promising approach that offers a more dynamic environment for communication among students and teachers. instructor. However, the minimal adoption in this situation may be explained by worries about privacy, diversions, and upholding professional boundaries. The moderate use of these platforms suggests that while they are beneficial, they are often supplemented with other tools to address specific educational requirements in organic chemistry. Hence, understanding these preferences is crucial for designing effective instructional strategies that meet the students' needs and preferences of chemistry educators, ultimately fostering meaningful engagement and enhancing understanding of organic chemistry concepts.

The results of this study also demonstrate the feasibility of using web-based discussions to teach various topics in organic chemistry. Specifically, the findings indicate that topics such as the introduction to organic chemistry, alkane, polymer, and polymerization are particularly amenable to web-based instruction. This is in line with previous research indicating that web-based discussions can be an effective method for teaching organic chemistry concepts such as alkene, Alkane, carboxylic acid, ketone, and aldehyde [115]. This was also supported by Hamid et al. [116] who found that the use of the e-content module for chemistry Massive Open Online Course (MOOC) increases students' understanding of carbonyl compounds. Giri and Dutta [117] also found that the use of online chats is important in visualizing abstract organic chemistry concepts such as carboxylic acids, esters, fats and oils, sugars, and amino acids. Sari et al. [118] also supported the idea that the use of web-based discussion tools motivates students to learn hydrocarbons.

The study revealed that location, age, and school ownership do not significantly influence web-based discussion adoption in teaching and learning organic chemistry. This was supported by El Alfy et al. [119] who found that geographical location did not influence the adoption of technology. Contrarily, Habibi et al. [120] showed that geographical location influenced the use of technology in education. This implies that for the needs of schools, training, and ownership factors need to be discussed before the implementation of web-based discussion tools in education. This inclusivity allows individuals from diverse backgrounds and age groups to engage in online discussion, promoting a more equitable educational experience in a digitally connected world.

The influence of experience on web-based discussion usage was not statistically significant at the conventional *p*-value threshold of 0.05, the borderline significance ($p = 0.051$) indicates a noteworthy trend. This was in line with the previous study done by Mahdi and Al-Dera [121] found a significant difference in using ICT tools based on teachers' working experience. However, Steel and Hudson [122] found that working experience influences the adoption of technology in favor of most experienced teachers. This implies that people with diverse levels of experience may engage in web-based discussions in slightly different ways. Further research into this tendency could help to determine whether more experienced participants use web-based talks in more complex ways, or if other factors, such as familiarity with the online platform's features, are at work. Thus, emphasizes the necessity of taking prior experience into account when creating and guiding web-based discussions.

Furthermore, the study revealed a significant gender-related impact on the use of web-based discussion tools in favor of male chemistry teachers. The obtained results are in agreement with Huffman et al. [123] in their study which showed that male teachers use highly technology in classroom than their fellow female. In addition, Hwang [124] also showed that male teachers have higher technological skills than female teachers. However, Nkundabakura et al. [125] did not find any difference in terms of using technology between male and female teachers. This difference suggests that even though men and women participate and communicate differently in online discussions, they might be using technology in education more equally now. This could be because more people have access to technology and there's a motivation to teach everyone how to use it well. Hence, we need to look closer at how gender affects different parts of using technology, not just how much it is used.

While the findings indeed align with previous research showcasing the effectiveness of web-based platforms for educational purposes, this study offers unique insights into the adoption and preferences of chemistry educators regarding various ICT tools, notably highlighting WhatsApp as the predominant platform. Additionally, the study identifies specific topics within organic chemistry that are particularly conducive to web-based instruction, shedding light on potential areas for further exploration and development in digital pedagogy. Furthermore, the inclusive nature of web-based discussion adoption across diverse demographic factors, coupled with the nuanced analysis of experience levels and gender-related impacts, contributes to a comprehensive understanding of the dynamics surrounding technology integration in education.

7. Conclusion and implication

In light of the growing focus on ICT integration in teaching organic chemistry, this study revealed a notable gap in the adoption of web-based discussion tools in Rwandan secondary schools, with only 22 % of teachers actively utilizing these tools. However, the study underscores the potential of web-based discussions to enhance teaching methods and facilitate meaningful engagement among students, particularly in teaching organic chemistry. While factors such as location, age, and school ownership do not significantly influence the utilization of web-based discussions, gender disparities in participation suggest the need for targeted interventions for female teachers to promote inclusivity and equal opportunities between male and female teachers. The research highlights Rwanda's need for investment in technology infrastructure and teacher training to effectively utilize web-based discussion tools and increase the number of teachers who use web-based resources in the teaching and learning process. Hence, the study calls for a more inclusive approach to technology integration, including increasing female participation in STEM fields, creating a welcoming online learning environment, and providing resources for technology proficiency.

CRediT authorship contribution statement

Aloys Iyamuremye: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Innocent Twagilimana:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration. **Francois Niyongabo Niyonzima:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration.

Data availability statement

The data have been deposited at the Mendeley repository (https://data.mendeley.com/datasets/m6pbpkk3sw/1) with accession numbers: https://doi.org/10.17632/m6pbpkk3sw.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Aloys Iyamuremye reports administrative support and writing assistance were provided by University of Rwanda College of Education. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e39356.

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