Education and Information Technologies (2024) 29:13763–13785
https://doi.org/10.1007/s10639-023-12411-2

Effects of technology-assisted chemistry instruction on students' achievement, attitude, and retention capacity: A systematic review

Derejaw Yesgat Woldemariam[1] · Hailu Shiferaw Ayele[2] · Dereje Andargie Kedanemariam[3] · Solomon Melesse Mengistie[4] · Belete Bedemo Beyene[2]

Received: 30 May 2023 / Accepted: 8 December 2023 / Published online: 22 December 2023

Abstract
This systematic review aims to provide evidence-based literature on the impacts of technology-based instruction on students' academic achievements, attitude, and recalling capacity. The review was made based on the Preferred Reporting Items for Systematic and Meta-Analysis (PRISMA) review methodology. To achieve this aim, 583 prior studies from 2013 to 2022 from ERIC and Google Scholar databases were collected. After the exclusion of some studies using PRISMA criteria, 16 studies were included for analysis. Content analysis was employed on the selected literature. The review revealed that technology-integrated teaching positively affected students' academic achievement, attitude toward chemistry, and retention capacity. The review result also confirmed that similar benefits were observed from both male and female students in technology-based instruction. This systematic literature review highlights the existing research gaps observed in the field of the impacts of technology-integrated teaching on students' achievement, attitude, and retaining chemistry content. Thus, it is likely to conclude that technology-integrated chemistry instruction improves students' academic achievement, attitude, and retention capacity. It is also possible to conclude that technology-based instruction is gender-friendly. Most of the research has been done in high school using a quasi-experimental design, the researchers recommended that further research in middle schools on different chemistry topics using different research designs (e.g., Design-Based Research) in doing research in this area.

Keywords Academic achievements · Attitudes · Retention · Perception · Technology-based teaching

Extended author information available on the last page of the article

1 Introduction

Chemistry as a secondary school subject attempted to provide students with chemical literacy and chemical culture, as well as to promote critical thinking, problem-solving skill, and evaluative skill (Hofstein & Mamlok-Naaman, 2021), and to be useful, interesting, and enjoyable subject (Kwangmuang et al., 2021). Chemistry differs from other sciences in that it can be felt in almost every aspect of people's daily lives. That is, the food, clothes, and cleaning and drinking supplies we use, all involve chemistry. To have all those applications, students are need to have a clear understanding of the concepts and applications of chemistry.

Students, on the other hand, have been frequently struggled to recognize the manifestation of chemistry as a science in everyday happenings that they observe or experience. As a result, students may find it challenging to apply chemical topics to a range of human activities (Pekdağ et al., 2013; Yadigaroğlu et al., 2017). Learning is concerned with how we perceive and grasp the world, and it includes mastering challenging principles, comprehending arguments, recalling factual information, accumulating knowledge and abilities, and developing desired behavior in specific situations (Mulenga & Kabombwe, 2019).

Learning chemistry for secondary school students is often complex and difficult, as it demands to visualizing and conceptualize indistinguishable and intangible particles such as, the atom, molecule, ions, and the interaction of these particles (Demissie et al., 2013). The particulate nature of matter is fundamental to almost every topic of chemistry. As a result, chemistry students are expected to understand scientific ideas at the particle level of matter in a way that can be used to explain the properties of matter and various types of chemical changes that occur in a wide range of chemical phenomena (Demissie et al., 2013). Particulate level scientific understand of matter is the basis of explanations of atomic structure, chemical bonding and structure, chemical reactions, chemical equilibrium and kinetics, etc.

Numerous studies revealed that the abstract and complicated nature of chemistry is what gives rise to misconceptions about chemistry concepts in general (Tsaparlis et al., 2018). Besides the difficulty and abstract nature of chemistry, the problem persisted due to the one-way flow of dense cognitive content information from teachers to students. Students were left with a lack of understanding as a result of this kind of information flow, allowing them to focus on memorizing basic facts. Students' attitudes, perceptions, and interests are all satisfied when the material to be learned is clear and understandable (Duarte & Escobar, 2008). As a result, making abstract and complex concepts clear and down to earth is unquestionable in any instructional act. These allow students to relate the material they are learning to personally meaningful contexts and/or prior knowledge they already have. Making learning materials appropriate helps students clearly and thoroughly understand concepts. It also makes learning pleasurable and ongoing, improves their attitude toward learning and retention capacity of material they learned, and leads to improved academic achievement and more organized mental models. The student's greater inventiveness and comprehension allow them to fully comprehend the various components of the learning assignment using prior knowledge, which frequently allows them to tackle new problems effectively and develops their problem-solving skills (Duarte & Escobar, 2008).

Today, scholars emphasize how technology-based instruction makes it easier to use a variety of visual tools to illustrate abstract scientific processes. Chemistry, in particular, has contributed significantly to changing and improving life in a variety of fields as a result of technology integration into chemistry instruction. Technology-based teaching methods, such as animation, simulation, video, etc. can visualize abstract and difficult concepts. Technology-based instruction is essential for visualizing particulate (microscopic and sub-microscopic) ideas of chemistry and improves academic achievement, attitude, and retention capacity.

According to Olakanmi (2015), a web-based computer simulation is a computer program that combines text with one or more of the following (music, video, pictures, 3-D graphics, animation, or high-resolution visuals) to help learners understand it better. Hence when teaching and learning process uses interactive simulations, both learners and teachers can benefit. As a result of technology-based learning, chemistry teachers may find it easier to instruct using a variety of representations, such as photos, drawings, simulations, films, audio, and so on. It is also true that students benefit from instruction supported by technology.

The use of simulations, animations, and the ability to present models at the particulate and sub microscopic levels on computers is thought to have several advantages in science and technology education. According to Demissie et al. (2013) and Olakanmi (2015) application of computer-based models in the classroom has the potential to improve students' understanding of chemistry on four levels: macroscopic, microscopic, symbolic, and chemical process. These researchers also revealed that visual representations improved beginner learners' understanding of chemistry ideas. Students who learned using dynamic computer-integrated models outperformed their counterparts (who lacked this experience) in terms of comprehending the composition and representations of matter using illustrations (Chang et al., 2010).

Even though technology-integrated teaching of chemistry has a positive effect on understanding chemistry concept at a microscopic and sub-microscopic level, failure to use technology as a serious medium of instruction (technology addiction) affects students' academic achievement negatively (Talukder et al., 2015). In a technology addiction, students were too busy with nonacademic issues like social media and may give little time to academic issues. Other studies also support the finding that technology-integrated instruction has a negative effect on pupils' writing and grammar skill (Raja & Nagasubramani, 2018). Modern technology-integrated teaching affects students' imaginations negatively, reduces students' thinking ability, and decreases students' writing skills. Some scholars also believe that excessive use of technology harms students' physical and mental health (Alhumaid, 2019; Raja & Nagasubramani, 2018; Unser, 2017). Technological advancements may also erode people's capacity for interpersonal interaction and effective communication.

This review examined the effect of technology-based instruction referring to numerous research studies. The current review examined the impacts of various technology-integrated instruction methods on pupils' achievement, attitude, and retention capacity. This included the studies' interventions applied during the study, design of the study, sample size, focused application areas/settings, and measurable features. The results and findings of the included research articles were analyzed to shed light on the effects of technology on learning chemistry content.

Many researchers have showed interest in checking effect of technology-integrated instruction on students' achievement, attitude, and recalling capacity in schools. So far, those studies have been conducted using different research designs in different settings and using different types of technology-integrated teaching mechanisms (e.g., simulation, animation, V-Lab, etc.). Besides, the studies were come up with contradictory findings. For this reason, it is difficult to attain clear picture of impact of technology-based teaching on students' achievement, attitude, and retention capacity. Hence, this paper is aimed at highlighting major findings about impacts of technology-integrated teaching on learners' achievement, attitude, and recalling capacity.

2 Research methodology

This study employed Preferred Reporting Items for Systematic Reviews and Meta-Analysis, which was used to conduct systematic review (Page et al., 2021). It was used to thoroughly scan all available literature on the issue to address the purpose of the study, and to this end the researchers employed various inclusion and exclusion criteria to find the reports to be included in the literature review, and then organize the findings. The literature search for appropriate literature was conducted across the Educational Resource Information Center (ERIC) and Google Scholar which are the two largest academic literature databases. Google Scholar is a free service that allows customers to easily search for scholarly literature and connect them with the resources that libraries provide. It is also an academic search engine that indexes the full text of scholarly literature published in a variety of formats and fields (Halevi et al., 2017). ERIC is a fantastic academic search engine that specializes in educational material. These are the primary reasons for selecting the ERIC and Google Scholars databases as our data sources. The PRISMA includes the following three key steps (planning, searching, and study selection):

Planning Using a PRISMA, the major research questions and the aim of the review was used as a target to propose and search for articles. At the planning stage, the major research questions guided how searching for articles were implemented. The major research questions that were considered were as follows:

1. Do technology-based instructions have statistically significant effect on students' academic achievement?
2. Do technology-based instructions have statistically significant effect on students' attitude towards chemistry?
3. Do technology-based instructions have statistically significant effect on students' retention capacity?

Search Describing the database used for literature search, search terms used, inclusion/exclusion criteria used, and the process of searching for and selecting literature. The method for searching for articles was devised with the research objectives and the goal of the systematic literature review in mind. Narrowing the focus from a major concept to the essential idea of the review aids in the construction of an effective search strategy. The search began with ‘technology-based instruction’ alone, as a search string will create a large number of published articles from diverse application domains that are unlikely to be connected to the review’s goal and will confuse the search. Redefining the search approach as ‘technology-based teaching’ AND ‘students’ academic accomplishment’ decreased the likelihood of deviating from the subject of the evaluation. Initially, the articles were retrieved from Google Scholar and ERIC using these search terms. To include any additional relevant studies, the following keywords were used to retrieve the articles from the databases: ‘computer assisted instruction’ OR ‘computer assisted learning’ AND ‘students’ achievement’ OR ‘students’ attitude’ OR ‘students’ perception’ and narrowed to ‘impacts of technology-based chemistry teaching on learners’ achievement AND effect on students’ attitude AND perception to chemistry’. Articles from the last 9 years (2013–2022) were utilized for the study as effects of technology-based chemistry instruction on pupils’ achievement, attitude, and retaining of chemistry concepts to manage the article and have recent data in the region.

Study selection The retrieved articles were initially selected based on aspects such as the quality of an article regarding the topic that the researcher intended. Selection of the relevant research articles was done using the main title of ‘effects of technology-based teaching on students’ performance, effect on students’ attitude and retention of chemistry concepts’ was searched for using the ERIC and Google Scholar search engines. Analyzing article abstracts aided in comprehending the keywords and article selection. The following criteria were used to eliminate irrelevant articles:

When choosing the best-fit journals, the purpose of the study and the years of publication of the papers were considered. In this review, studies that are not listed in beallslist.net which are reputable journals and publication years ranging from 2013 to 2022 were used. The evaluation of literatures on impacts of technology-based teaching chemistry was used as the eligibility criteria for the review. In the review, the exclusion criteria include unrelated papers to the topic, duplication, and pieces of paper or abstract-only papers are rejected. The paper was rejected when it was difficult to see the entire text. The analysis excluded papers that did not focus on chemistry and studies whose scopes had nothing to do with the current evaluation’s subjects. All articles available in languages other than English were also barred.

Selection results Using keywords, title, and year of publication, 583 journal articles (see Fig. 1) were discovered using the ERIC and Google Scholar search engines.

The inclusion of unclear concepts, lack of a concluding statement, and other factors, as well as the above exclusion criteria, resulted in 20 articles being acceptable for review. Finally, four articles were removed due to duplication, leaving us with 16

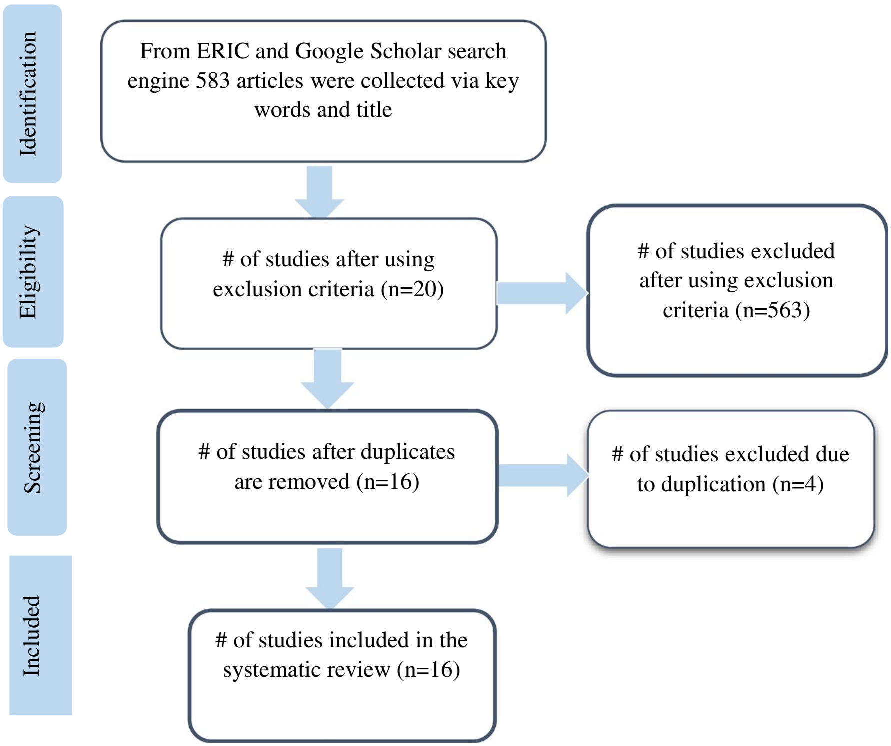

Fig. 1 Procedure of the systematic review process

publications for our review. These 16 studies were subjected to a full-text analysis. The findings were divided into several categories, including number of authors, year of publication, intervention/technology types used, application, brief summaries, features measured, sample size, research design, and outcomes of findings.

3 Results and discussions

3.1 Overview of the reviewed articles

Table 1 describes the details of selected studies with regard to the author/authors with publication year, the intervention that was applied during the studies, the design that the researcher/researchers used during their research, the type and number of the sample that the researchers used during the study and the setting where the research was conducted.

Table 2 describes the details of selected studies. In the table the title of the paper, the focus of the study or aspects measured by the researchers, the

Table 1 Summary of literature in the review

No	Author	Intervention type	Research design	Sample size	Setting
1	Pekdağ (2020)	Video-based teaching	Pre-post-test control group quasi-experimental design	61 students: 32, experimental and 29 control group	High school, Grade 9
2	Olakanmi (2015)	Web-based simulation	Pre-and post-test experimental design	66 students:32 experimental and 34 control	First-year secondary students
3	Mihindo et al. (2017)	Computer-Based Simulations instruction	Solomon's four non-equivalent control group design	175 students	Secondary school students
4	Suleman et al. (2017)	Different technological instruction	Pre-and posttest equivalent groups experimental design	50 students (25 students in each group)	High school
5	Nkemakolam et al. (2018)	Computer simulation instruction	Quasi-experimental research design	78 students 38 experimental, 40 control	Secondary school
6	Jabeen and Afzal (2020)	Computer simulation	Experimental post-test-only control group design	115, 55 male and 60 female	Secondary school
7	Cevahir et al. (2022)	Animation-Based Worked Examples	Quasi-experimental design "none equivalent control group"	94 students	High school
8	Unal and Yerlikaya (2021)	Social network-supported instruction	Quasi-experimental design	83 students	Not Defined
9	Çinar and Çepni (2021)	Technology based instruction	Quasi-experimental pre-posttest design	273 students	Elementary school students
10	Yanarates (2022)	Animated instruction	Quasi-experimental model	82 students	Teacher's collage
11	Yesilyurt et al. (2014)	Technological instructions	Survey research design	533 teacher trainers	University teacher trainer
12	Iyamuremye et al. (2022)	Web-based discussions	Quasi-experimental designs (one group pre- and posttest design)	138 students and 4 teachers	Secondary school
13	Agrahari and Singh (2013)	ICT instruction	Pretest posttest equivalent group experimental design	220 students	High school
14	Ratamun and Osman (2018)	VLab was developed using interactive & multimedia elements	Quasi-experimental design	147 students	4th grade, elementary school

Table 1 (continued)

No	Author	Intervention type	Research design	Sample size	Setting
15	Kurniawati et al. (2021)	ICT-based learning media	Mixed method with an exploratory design approach	100 students	Secondary school
16	Miller et al. (2021)	Immersive virtual reality was used to teach Organic Chemistry	Experimental research design	113 control group and 111 experimental group	University students

Table 2 Summary of revised literatures with respect to title, focus area, study design, and major findings

No	Title	Study Focus/Aspects Measured	Instrument type/Design	Outcomes/ Major findings
1	Video-based instruction on safety rules in the chemistry laboratory: Its effect on student achievement	Development of video-based instructions about laboratory safety rules and evaluating the effect of video-based teaching instruction on students' achievement.	Students in both groups were given an achievement test on safety rules.	Student's achievement who received video-based training outperformed those who received traditional instruction.
2	The effects of web-based computer simulation on students' conceptual understandings of the rate of reaction and attitude toward chemistry	The experimental group's students were introduced to a web-based computer simulation tool that simulates chemical reaction rates. Students were allowed to use the exercise on their laptops.	Rates of Reactions Knowledge Test', 'Chemistry Attitude Scale' and 'Class Activity on Rate of Reaction'	Statistically significant difference was observed between the controlled (conventional instruction) and experimental group (web-based computer simulation instruction). No gender difference in using simulation (both males and females are benefited).
3	Effects of Computer-Based Simulations Teaching Approach on Students' Achievement in the Learning of Chemistry	The treatment which was done for the experimental group was not clearly defined.	12 structured short answer questions with a total of 50 marks	Computer-based simulation has a significant positive contribution to the performance of students taught and gender does not affect students' achievement in chemistry.
4	Effects of ICT on Students' Academic Achievement and Retention in Chemistry	Teachers of the experimental group used computers, the internet, Skype, chemistry CDs, other software, and emails for teaching.	50 multiple-choice questions	ICT positively affects students' achievement and retention.
5	Effect of Computer Simulations on Secondary School Students' Academic Achievement in Chemistry in Anambra State	The experimental group was taught using online Physics Education Technology (PhET) interactive simulations.	Teacher-made test tagged Chemistry Achievement Test (CAT)	Computer simulation was more successful than the lecture approach in improving students' chemistry achievement; with no gender bias.
6	Effect of Simulated Chemistry Practical on Students' Performance at Secondary School Level	The experimental group performed chemistry practical in the chemistry laboratory supplemented with simulation.	Observation, Written work, Viva, Practical notebook & interview	Practical laboratory supplanted with simulation has a positive effect on students' written, oral and practical performance.

Table 2 (continued)

No	Title	Study Focus/Aspects Measured	Instrument type/Design	Outcomes/ Major findings
7	The Effect of Animation-Based Worked Supported with Augmented Reality on the Achievement, Attitude, and Motivation	The experimental group students all had smartphones that could run argumentative reality applications and the students' example/study is supported by animation.	An achievement test, instructional materials motivation survey, and AR attitude scale test	There was a high level of positive correlation between achievement, interest, and motivation with simulation teaching.
8	The effect of using social networks in the inquiry-based general chemistry laboratory course	Experimental group one addressed basic science processing skills in an inquiry-based and experimental group two used inquiry and social networks in the laboratory.	Attitude towards general chemistry laboratory scale, and Science Process Skills (SPS) perception scale	Social networking integration into the laboratory process enhanced the students' attitudes and perceptions towards the laboratory more than simple inquiry type.
9	The impact of science teaching based on the Science Technology Society (STS) approach to elementary school students	For the experimental group, various exercises were planned based on the STS approach to motivate students to ask questions and discuss with their classmates.	The Creative Thinking Skills Scale, Science and Technology Course Attitude Survey, and Achievement Test	Students in Science Technology Society (STS) classes could increase their imaginative thinking skills, attitudes toward science courses, and academic success.
10	The effect of animated teaching on science teacher candidates' Chemistry achievements and learning persistence	Image editing software, presentation applications, some Web 2.0 tools, and Flash and comparable animator applications were used for the experimental group animation activities.	General chemistry achievement test	Teaching using animation has a positive effect on achievement and learning persistence, this is more significant in females than males and equally benefits all grade levels.
11	The effect of technological devices on student's academic success: Evidence from Denizli	The survey focuses on whether the student has a cell phone if the student connects to the internet via a cell phone, the number of TVs at home, and if the kid has a computer at home and connects to the internet through a computer at home.	Achievement test from higher education	Students who have computers and have a connection to the internet at home have been found more successful in academic achievement.

Table 2 (continued)

No	Title	Study Focus/Aspects Measured	Instrument type/Design	Outcomes/ Major findings
12	Web-based discussions in teaching and learning: Secondary school teachers and students' perception and potentiality to enhance students' performance in Organic Chemistry	Experimental group students are allowed to create and login to universal chemistry network software and every student was able to create or comment on the given Organic Chemistry topic.	The interview	Applying web-based potentially and effectively enhances students' performance in Organic Chemistry.
13	The impact of ICT on the Achievement of Students in Chemistry at the Secondary Level	The type and the procedure of the intervention were not clearly described.	Chemistry achievement test	The ICT program is more effective than the traditional teaching approach in terms of the achievement scores.
14	The effectiveness of virtual lab compared to the physical lab in the mastery of science process skills for chemistry experiment	To compare the effectiveness of the virtual lab with that of the physical lab, VLab was developed using interactive elements, multimedia like video, and simulation for the experimental group while the other group perform lab in the real lab.	Science Processing Skill Test (SPST)	The effectiveness of virtual labs has a statistically significant effect compared with physical labs. The physical lab is better than Vlab. And gender does not affect the preference for physical lab and virtual lab.
15	Information and Communications Technology (ICT) based on chemistry instructional learning design for students with multiple intelligence	Three phases were held, namely the needs analysis phase, the design phase and the making of ICT-based instructional learning, and the product trial phase.	Questionnaires and interviews	ICT-based instructional design created must be structured to support 5 capabilities (logical-mathematical, interpersonal, intrapersonal, verbal-linguistic, and extra-spiritual intelligence).
16	Immersive virtual reality for Organic Chemistry: Impacts on performance and grades for first-generation and continuing-generation university students	The intervention group offered VR, and the control group not offered VR. A total of 61 out of the 106 students from the intervention group opted to participate in at least one of the VR activities.	Achievement test	There was an upward trend in performance linked with IVR activities.

instruments that the researchers used during the study, and the outcomes or major findings that the researchers revealed were described.

This systematic review was tried to assess different aspects: research design, intervention types, research questions, sample and sampling techniques, research settings, and major findings or outcomes of the studies were some of the aspects that the researchers were interested to review.

3.1.1 Research design

Research design is an overall strategy researchers choose to integrate different components of the study in a coherent and logical manner. It ensures to effectively address the research problem. It is acts as a blueprint for the collection, measurement, and analysis of data. As it can be seen from Table 1, among the 16 included studies, nine studies were conducted using quasi-experimental design [1, 3, 5, 7, 8, 9, 10, 12, and 14] and five studies were formulated through pure experimental design [2, 4, 6, 13, and 16], one study was conducted using survey research design [11], and one remaining study was conducted using a mixed method with exploratory design approach [15]. Among the nine quasi-experimental studies, only one study [3], was conducted using a special type of quasi-experimental design called Solomon four non-equivalent control group design. This research design removes the effect of confounding variables that affect the outcomes of the study and hence it is better than a simple quasi-experimental design.

Figure 2, disclosed that most of the studies in the area were done using quasi-experimental research design and to bridge the observed gaps the authors forward using other research designs-mixed research design, Solomon four group designs, etc.

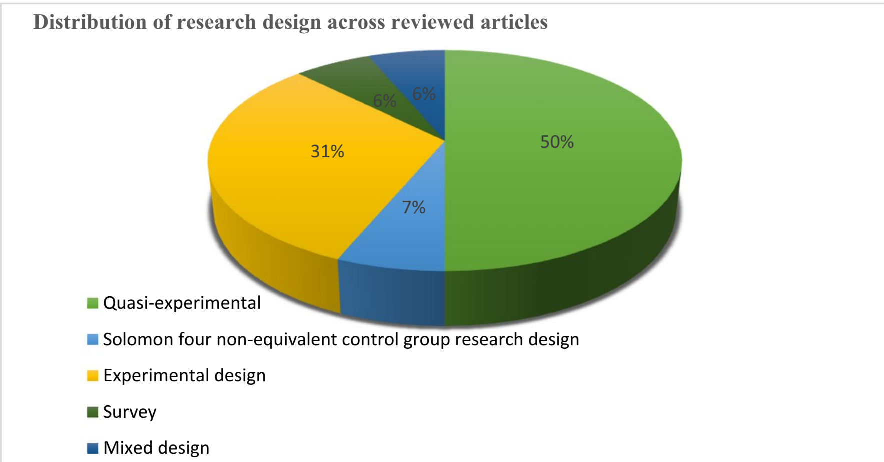

Fig. 2 Pie chart showing the distribution of research design in the reviewed studies

3.1.2 Intervention types

There are different types of technology-based teaching methods or tools: Screen readers, voice-to-text systems, MP3/MP4 players, cell phones and smart computer-assisted instruction, animations, simulations, e-readers, online learning, web 2.0 applications, webinars, interactive whiteboards, video-conferencing, augmented reality, etc., but most of the reviewed studies used only specific types of technology-based teaching methods. As it can be seen from Table 1, intervention type section, most of the reviewed articles used virtual laboratories, simulations, and animations as an intervention.

3.1.3 Settings of the reviewed articles

As shown in Fig. 3, the majority ten of 16 studies reviewed on the effects of technology-based education were conducted in secondary schools. Three of 16 studies, were conducted at the tertiary level (college or university), two of 16 studies at primary school, while one of 16 studies had an unclear setting. This distribution suggests that the effects of technology-based teaching were not adequately evaluated at the primary levels.

As one can confirm from the review results, most of the studies about technology-based teaching were concentrated at secondary schools, while primary and tertiary levels were not given emphasis, and these can be taken as a gap in the area (impacts of technology-assisted instruction on learners' achievement, attitude and retention capacity).

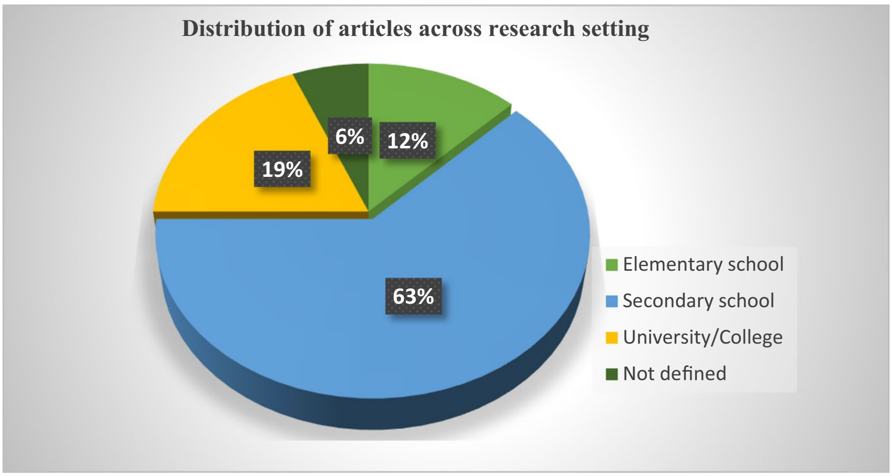

Fig. 3 Pie chart showing the distribution of research settings in the reviewed studies

3.2 Major findings of the reviewed articles

3.2.1 Impacts of technology-integrated instruction on pupils' achievement

Most reviewed studies [1, 2, 3, 4, 5, 6, 7, 9, 10, and 13] were aimed to answer whether technology-based teaching affects students' academic performance. Their findings demonstrated that technology-based instruction improved students' performance in chemistry courses. Simulations, videos, web-based lessons, animations, and other standardized lessons can assist teachers who are having difficulty with their lessons and significantly improve student comprehension and exam scores. All the above studies used technology-based chemistry teaching packages designed specifically for classroom instruction to generate interest on the ground, which is typically difficult for teachers to deal with successfully in the classroom. Pekdağ (2020) aimed to see effect of video-assisted instruction on students' laboratory rules achievement. In this study, the posttest mean scores of the experimental and comparison groups showed a statistically significant difference, $t(59) = 12.51$, $p < 0.05$. This result indicates that learners in the experimental group scored superior on achievement test ($M = 83.00$, $SD = 7.08$) than students in the comparison group ($M = 65.00$, $SD = 3.83$). This tends to imply that students who received video-based instruction had developed a better understanding of the laboratory rules.

Immersive virtual reality (IVR) has shown to impact Organic Chemistry achievement and grades of first- and continuing-generation university students (Miller et al., 2021). The results of the study showed that a non-first-generation university were more common in scoring better grades in the intervention section compared to the control section. Poor grades, on the other hand, were less common in the intervention sections. The Mann-Whitney test, however, showed that the letter grades distributions across sections was not statistically significantly different. First-generation children performed better in the intervention sections than in the control section. First-generation students, on the other hand, had significantly fewer failing grades in the intervention sections compared to the control sections. The comparison of intervention and control groups of non-first-generation students and first-generation students, using Mann-Whitney test showed that the mean rank of the intervention part was higher for first-generation students than the mean rank of non-first-generation university students. The rank between the control and intervention portions was barely statistically different ($U = 653$, $\rho = 0.042$) for first-generation students, but it was not statistically significant ($U = 1774$, $\rho = 0.888$) for students who were not first-generation. The study depicts the different effects of the virtual reality intervention on first-generation and non-first-generation students.

The findings of Agrahari and Singh (2013) revealed that groups with different socioeconomic structures and organizational climates had different effects on students' academic performance. This implies that groups with no prior experience with technology more influenced by technology-based instruction than students with prior experience. Although group had not previously received instruction using technology-based teaching methods, prior exposure to one through the media may have protected them from its negative effects. In support of this, a descriptive survey study by Yesilyurt et al. (2014) was conducted. The study found a statistically significant difference in the achievement scores between the students who have and who do not have an internet connection from their home computer.

In alternate dimension, Ratamun and Osman (2018) attempted to investigate whether a virtual reality laboratory (conducting laboratory using technology-based) was better than that of the physical laboratory. Their investigation confirmed that the physical laboratory effectively maximizes students' mastery of science process skills more than the virtual laboratory, but other studies (such as, Aşıksoy and Islek (2017), Bogusevschi et al. (2020) confirmed that virtual laboratory maximizes learners' understanding more than the physical laboratory because students permit numerous experiments that are difficult to execute in real laboratories due to dangers.

In this review, Kurniawati et al. (2021) analyzed how technology-based chemistry instructional design affects students' intelligence. The instructional design for technology-based learning must be structured to support five capabilities: verbal-linguistic intelligence, extra-spiritual (interpersonal) intelligence, and intrapersonal intelligence. In this study, however, researchers chose to prioritize spatial-visual intelligence over extension-spiritual intelligence. As a result, studying abstract concepts in chemistry requires intelligence as it may be difficult to understand the existence of atoms, chemical bonds, and chemical reactions without first seeing them. To promote student learning with multiple intelligences, technology-based instructional design can be used to increase student understanding, support students with multiple intelligences, and avoid time constraints when presenting the subject.

Some reviewed articles including Olakanmi (2015), Mihindo et al. (2017), Nkemakolam et al. (2018), and Yanarates (2022) were assessed to check whether technology-based teaching benefit was gender dependent. The findings depicts as no statistically significant differences in posttest mean performance scores between male and female students (Nkemakolam et al., 2018; Olakanmi, 2015). No statistically significant difference was reported between male and female students taught chemistry using computer simulation and taught using the lecture method, demonstrating that technology-based teaching benefits both genders equally. This is consistent with Ani et al. (2021) study, which found no statistically significant difference between male and female students' achievement in science. This result shows that e-learning is gender-inclusive. Ratamun and Osman (2018) in their study confirmed that male and female students performed better in the physical laboratory than in the virtual laboratory. There was no difference between male and female students in their performance in both physical and virtual laboratories. However, the ANCOVA post-test scores revealed that male students outperformed their female counterparts (Mihindo et al., 2017). This implies that male students benefit more from technology-based instruction than female students.

On the contrary, Yanarates (2022) revealed a gender difference in serviced teachers' post-test achievement test scores of treatment and control groups. Females benefited from this imbalance. This indicates that female participants in the study outperformed their male counterparts. According to other research outside of those in this review (for example, Egbodo (2016), Jairus et al. (2017) when taught with a technology instructional package, both male and female students performed relatively better in chemistry. As a result, gender did not affect performance in chemistry classes conducted using technology-based instruction. In contrast, Anagbogu and Ezeliora (2008) study discovered as female learners outperformed their male counterparts. In addition, Ishaq et al. (2020) found a significant mean difference in achievement between male and female students. Furthermore, the findings of the study showed that the use of technology-based instruction made a difference in the achievement of male and female students.

Many researchers and experts like Tolani-Brown et al. (2011), Demissie et al. (2013) out of those reviewed revealed a positive impacts of technology-assisted teaching on learners' achievement. Study conducted by Frailich et al. (2007), demonstrated that the experimental group (students learned through animations, computerized models, and applets) understood chemical bonding concepts better compared to the comparison counterparts. These findings are consistent with previous research studies (Ardac & Akaygun, 2004; Sanger & Badger, 2001). They revealed that pupils who were exposed to animations and visualizations in their chemistry courses understood chemical ideas better than those who were not.

According to Tukura et al. (2020), a noticeable difference was observed in the level of achievement among learners who taught using e-learning and those who were instructed via traditional instruction. The finding is consistent with findings of Nwafor (2014) which looked at impacts of multimedia instruction on the achievement and motivation of biology students in Port Harcourt, Nigeria. According to the findings, learners who learned biology through multimedia outperformed over who only received lectures. Moreover, the findings of the study contradicted with Tukura et al. (2020), who conducted a similar study in United States. The study aimed to explore how e-learning affected the teaching of English, the arts, and mathematics. The findings showed no discernible difference in performance between learners taught through e-learning and taught using the traditionally. This difference might be due to differences in context where those studies were conducted.

3.2.2 Effect of technology-based teaching on students' attitude

In addition to assessing the impacts of technology teaching on students' academic achievement, some of the reviewed studies were aimed to assess whether technology-based teaching has an impact on students' attitudes and perceptions toward chemistry (Cevahir et al., 2022; Çinar & Çepni, 2021; Iyamuremye et al., 2022; Olakanmi, 2015; Unal & Yerlikaya, 2021). The results of these reviewed studies discovered a significant difference between shifts in mean scores of attitudes and perceptions of the treatment and control groups, favoring the treatment counterparts. This shows that technology-based teaching in general and technological instructions used by the researchers in particular positively increased students' attitudes and perceptions towards chemistry. Other studies like Agrahari and Singh (2013) also supported the fact that technology-based teaching creates an interest in students' mind during their learning.

Jabeen and Afzal (2020) claimed that technology-based teaching influences students' oral presentations, oral confidence, and oral originality. According to their findings, chemistry teacher candidates who received laboratory training through computer-assisted simulation demonstrated greater creativity and confidence, successfully completed their practical labs, and were able to present their work more fluently than those who completed their laboratory work in a traditional laboratory setting. Significant difference in the "Confidence-Satisfaction" sub-motivation dimension ratings after the intervention between students who studied with animation-based work examples and those who studied with straightforward on-paper work examples (Cevahir et al., 2022). In the 'Confidence-Satisfaction' sub-dimension of motivation, significant difference in favor of students studying through animation-based worked examples as compared with students instructed via simple on-paperwork examples was observed.

Several studies aimed on use of virtual laboratories in teaching science, particularly in chemistry were conducted. Josephsen and Kristensen (2006) evaluated responses of undergraduate chemistry learners on a simulation laboratory environment. The result confirmed that the pupils preferred to learn with simulation tool. They tended to enjoy working with it, they found it motivating, and they realized that it created a lot of experience. Winberg and Berg (2007) created a computer-simulated pre-lab to teach acid-base titration lab activity. The finding of the study confirmed that experimental group learners showed positive attitude towards learning the content.

According to Frailich et al. (2007), learners' perceptions, and attitudes of treatment group (students learned with web-based instruction) showed more interest and favorable attitudes towards chemistry studies than students in the comparison group. The study assessed that treatment group students' interests and attitudes after completing the web-based activities. The study depict that the treatment group learners had good attitudes regarding the internet activities they had completed. To summaries, learners in the treatment group were satisfied with their chemistry studies and with the activities on the website. As Carpi (2001), properly designed web-based instruction increase student interest and success in science education. Hence, attitude results certainly show that the treatment group students' net attitude change was significantly more positive than the control group students' attitude changes.

3.2.3 Effect of technology-based teaching on students' retention

This review attempted to determine whether technology-based instruction affects students' ability to retain information. According to Suleman et al. (2017) and Yanarates (2022), there was statistically significant difference in retention score between comparison and treatment groups. In retention test, experimental group outperformed over the control group. The study on effects of technology on students' retention revealed that technology was found more effective on students' retention as compared to traditional methods. It has shown that technology-based teaching techniques supported students' permanent learning. Yesilyurt et al. (2014), in their descriptive survey design study, supported that having access to technological tools (computer, mobile, internet) at home increased the retention of students' learning. According to their findings, computer-assisted instruction not only increased student achievement but also assisted students in developing higher-level thinking skills and learning through comprehension rather than memorization. Students who use computers and the internet as a result improve their conceptual knowledge and self-learning abilities. Improving these skills have a significant impact on a student's achievement and retention. The findings are consistent with those of Israel (2016), who discovered that when students were taught using technology, their retention scores were better than when they taught using conventional methods.

Out of the reviewed literature, some studies supported the significance of technology-based teaching for students' retention. According to Tukura et al. (2020), a substantial difference was reported in retention between students who were taught science via e-learning and who were taught by lecture. The finding was supported by Treviño et al. (2003), which examined how Caucasian sophomore grade nine science students perceived the use of interactive multimedia. According to Zubaidah et al. (2017), they investigated how interactive multimedia affected secondary school students' achievement and retention by gender difference. Females can retained more information than their male counterparts. Tukura et al. (2020) revealed no statistically significant difference in retaining information between male and female who were taught fundamental science using e-lesson. The finding contrasted the findings of Thomas and Stockton (2003), which confirmed that e-learning is not gender friendly. The findings of the study revealed that female students retain more information.

4 Conclusions and recommandations

4.1 Conclusions

According to the findings of this systematic review, technology-based instruction has positive impact on student's achievement, attitude toward learning chemistry through developing students' concept maps and hence increases students' retention ability. Concept maps support students to meaningfully integrate new information into existing cognitive structures. It also helps learners to extract meaning from the information through manipulation. Even if there is a contradiction that males and females benefited differently through technology-based teaching, the majority of the studies revealed that both males and females benefited similarly (with no gender bias) in technology-based instruction. While some other studies revealed that males and females benefited differently through technology-based instructions.

Technology-based teaching is an umbrella term for communication devices or applications, comprising radio, television, cellular phones, computers, network applications, Power Point presentations, animations, and simulations etc., however, most of the studies only used simulation and animation-based teaching mechanisms. In short, findings supported the benefits of incorporating various technologies into chemistry teaching and learning. Finally, in this review, majority of the study were done on effect of technology-based instructions at secondary school level using quasi-experimental research design. Other scholars who need to do their research in the area may use this information as a gap and conduct other studies using other types of intervention that are not in the above list.

4.2 Recommendations

Standing on the above conclusion, the following recommendations were forwarded:

1. The main recommendation of this study is that chemistry instruction should strive for high-quality education for students by providing an appropriate learning environment through the support of appropriate technology (such as animation, simulation, video) integrated learning methods. This is because a good learning environment increases students' ability to invent new meanings as the information, they learn in these settings allows them to reorganize and acquire true knowledge.
2. Learning chemistry should give opportunity for students to participate in activities and use their experiences by providing an appropriate learning environment in which they can construct their meaning. Animation, simulation, and video are among some of the common technologies to create appropriate learning environments. Teachers and students can apply these technologies instructional technologies such as animation, simulation, and video to make abstract and complex concepts visible and learnable, as well as increase students' interests, performance, and retention. As a result, it is recommended that appropriate technology-based teaching be used by curriculum developers, textbook writers, and classroom chemistry teachers to ultimately ensure students' effective participation and learning of chemistry.
3. It is also recommended that teachers should use technology-based teaching in conjunction with appropriate student-centered learning strategies to engage students, improve their learning abilities, and pique their interest in learning chemistry's abstract and difficult concepts. As a result, teachers' dedication to incorporating technology-based instruction must be taken as a sound instructional innovation at schools.
4. Finally most of the reviewed literature is focused on secondary schools and quasi-experimental research design. It is better to explore the effect of technology-based teaching on other middle schools and other research design other than quasi-experimental design (e.g., design-based research) to find full-picture of the effect of technology-based teaching and Solomon's four-group experimental research design to overcome the effect of confounding.

Data availability The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest No conflict of interest.

References

Agrahari, A., & Singh, S. (2013). The impact of information and communication technology (ICT) on achievement of students in chemistry at secondary level of CBSE and UP Board in India. *International Journal of Science and Research, 2*(8), 126–129.

Alhumaid, K. (2019). Four ways technology has negatively changed education. *Journal of Educational and Social Research, 9*(4), 10.

Anagbogu, M., & Ezeliora, B. (2008). Prospects and problems of Nigerian women in science and technology of national development. *Ghana Journal of Development Studies, 5*(2), 17–26.

Ani, I. M., Obodo, C. A., Ikwueze, C. C., & Festus, I. T. (2021). Effect of gender on basic science students' academic achievement in secondary schools in Enugu education zone, Enugu state, Nigeria. *UNIZIK Journal of Educational Research and Policy Studies, 2*(1), 9–14.

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317–337.

Aşıksoy, G., & Islek, D. (2017). The impact of the virtual laboratory on students' attitudes in a general physics laboratory. *International Journal of Online Engineering, 13*(4), 20–28.

Bogusevschi, D., Muntean, C., & Muntean, G.-M. (2020). Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school. *Journal of Computers in Mathematics and Science Teaching, 39*(1), 5–18.

Carpi, A. (2001). Improvements in undergraduate science education using web-based instructional modules: The natural science pages. *Journal of Chemical Education, 78*(12), 1709–1718.

Cevahir, H., Özdemir, M., & Baturay, M. H. (2022). The effect of animation-based worked examples supported with augmented reality on the academic achievement, attitude and motivation of students towards learning programming. *Participatory Educational Research, 9*(3), 226–247.

Chang, H. Y., Quintana, C., & Krajcik, J. S. (2010). The impact of designing and evaluating molecular animations on how well middle school students understand the particulate nature of matter. *Science Education, 94*(1), 73–94.

Çinar, S., & Çepni, S. (2021). The impact of science teaching based on science-technology-society (STS) approach to elementary school students. *Educational Policy Analysis and Strategic Research, 16*(4), 198–217.

Demissie, T., Ochonogor, C. E., & Engida, T. (2013). Effects of technology driven pedagogy applications on the comprehension of complex and abstract concepts of chemical equilibrium. *African Journal of Chemical Education, 3*(2), 57–75.

Duarte, S. A., & Escobar, L. A. (2008). Using adapted material and its impact on university students' motivation. *Profile Issues in Teachers Professional Development, 9*(1), 63–87.

Egbodo, B. A. (2016). Effect of computer-aided instruction on junior secondary students'achievement and retention in basic science. Being a dissertation submitted to postgraduate school, Benue state university, makurdi in partial fulfilment of the requirements for the award of masters' degree in science education, Unpublished M. ED in science education Thesis.

Frailich, M., Kesner, M., & Hofstein, A. (2007). The influence of web based chemistry learning on students' perceptions, attitudes, and achievements. *Research in Science & Technological Education, 25*(2), 179–197.

Halevi, G., Moed, H., & Bar-Ilan, J. (2017). Suitability of Google scholar as a source of scientific information and as a source of data for scientific evaluation—Review of the literature. *Journal of Informetrics, 11*(3), 823–834.

Hofstein, A., & Mamlok-Naaman, R. (2021). The laboratory in chemistry learning and teaching: 50 years of development, implementation, and research. In A. Hofstein, A. Arcavi, B. Eylon, & A. Yarden (Eds.), *In long-term research and development in science education* (pp. 3–28). Brill. https://doi.org/10.1163/9789004503625_001

Ishaq, K., Azan, N., Zin, M., Rosdi, F., Abid, A., & Ijaz, M. (2020). The impact of ICT on students' academic performance in public private sector universities of Pakistan. *International Journal of Innovative Technology and Exploring Engineering, 9*(3), 1117–1121.

Israel, O. N. (2016). Effects of mathematics innovation and technology on students performance in open and distance learning. *Research in Pedagogy, 6*(1), 66–75.

Iyamuremye, A., Mukiza, J., Nsabayezu, E., Ukobizaba, F., & Ndihokubwayo, K. (2022). Web-based discussions in teaching and learning: Secondary school teachers' and students' perception and potentiality to enhance students' performance in organic chemistry. *Education and Information Technologies, 27*(2), 2695–2715.

Jabeen, F., & Afzal, M. T. (2020). Effect of simulated chemistry practicals on students' performance at secondary school level. *Journal of Education and Educational Development, 7*(1), 119–139.

Jairus, E., Christian, U., Ogwuche, A., Thomas, O., Tyavlum, T., & Ode, E. (2017). Impact of mobile phone usage on students' academic performance among public secondary schools in Oju local government area of Benue state. *Ijsrm Human, 6*(3), 104–118.

Josephsen, J., & Kristensen, A. K. (2006). Simulation of laboratory assignments to support students' learning of introductory inorganic chemistry. *Chemistry Education Research and Practice, 7*(4), 266–279.

Kurniawati, Y., Wigati, M. R., & Hasri, S. (2021). Information and communications technology (ICT) based of chemistry instructional learning design for students with multiple intelligence. *Journal of Physics: Conference Series, 1779*(1), 012–062.

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon, 7*(6), e07309.

Mihindo, W. J., Wachanga, S., & Anditi, Z. (2017). Effects of computer-based simulations teaching approach on students' achievement in the learning of chemistry among secondary school students in Nakuru Sub County, Kenya. *Journal of Education and Practice, 8*(5), 65–75.

Miller, M. D., Castillo, G., Medoff, N., & Hardy, A. (2021). Immersive VR for organic chemistry: Impacts on performance and grades for first-generation and continuing-generation university students. *Innovative Higher Education, 46*, 565–589.

Mulenga, I. M., & Kabombwe, Y. M. (2019). Understanding a competency-based curriculum and education: The Zambian perspective. *Journal of Lexicography and Terminology, 3*(1), 106–128.

Nkemakolam, O. E., Chinelo, O. F., & Jane, M. C. (2018). Effect of computer simulations on secondary school students' academic achievement in chemistry in Anambra state. *Asian Journal of Education and Training, 4*(4), 284–289.

Nwafor, B. (2014). The relative effects of synchronized multimedia on the academic performance and motivation of senior secondary school biology students in Port Harcourt, Nigeria. *Journal of Science Teachers Association of Nigeria, 40*, 49–64.

Olakanmi, E. E. (2015). The effects of a web-based computer simulation on students'conceptual understanding of rate of reaction and attitude towards chemistry. *Journal of Baltic Science Education, 14*(5), 627–640.

Page, M. J., Moher, D., Bossuyt P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L. , Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Wilson, E. M., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. *BMJ, 372*(4), 160–178.

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

Pekdağ, B., Azizoğlu, N., Topal, F., Ağalar, A., & Emine, O. (2013). Kimya bilgilerini günlük yaşamla ilişkilendirme düzeyine akademik başarinin etkisi. *Kastamonu Eğitim Dergisi, 21*(4), 1275–1286.

Raja, R., & Nagasubramani, P. (2018). Impact of modern technology in education. *Journal of Applied and Advanced Research, 3*(1), 33–35.

Ratamun, M. M., & Osman, K. (2018). The effectiveness of virtual lab compared to physical lab in the mastery of science process skills for chemistry experiment. *Problems of Education in the 21st Century, 76*(4), 544–560.

Sanger, M. J., & Badger, S. M. (2001). Using computer-based visualization strategies to improve students' understanding of molecular polarity and miscibility. *Journal of Chemical Education, 78*(10), 1412–1416.

Suleman, Q., Hussain, I., ud Din, M. N., & Shafique, F. (2017). Effects of information and communication technology (ICT) on students' academic achievement and retention in chemistry at secondary level. *Journal of Education and Educational Development, 4*(1), 73–93.

Talukder, M. S., Alam, M. J., & Apu, M. A. I. (2015). The impact of ict on students'performance: A case study on undergraduate university students. *Manarat International University Studies, 4*(1), 137–147.

Thomas, J., & Stockton, C. (2003). Socioeconomic status, race, gender, & retention: Impact on student achievement. *Essays in education, 7*(1), 1–16.

Tolani-Brown, N., McCormac, M., & Zimmermann, R. (2011). An analysis of the research and impact of ICT in education in developing country contexts. In J. Steyn & G. Johanson (Eds.), *In ICTs and sustainable solutions for the digital divide: Theory and perspectives* (pp. 218–242). IGI Global.

Treviño, L. K., Brown, M., & Hartman, L. P. (2003). A qualitative investigation of perceived executive ethical leadership: Perceptions from inside and outside the executive suite. *Human Relations, 56*(1), 5–37.

Tsaparlis, G., Pappa, E. T., & Byers, B. (2018). Teaching and learning chemical bonding: Research-based evidence for misconceptions and conceptual difficulties experienced by students in upper secondary schools and the effect of an enriched text. *Chemistry Education Research and Practice, 19*(4), 1253–1269.

Tukura, C., Adamu, A., & Kanu, J. (2020). Effects of E-learning on retention and performance of basic science and technology students in Minna, Niger state. *International Journal of Research and Scientific Innovation, 7*(11), 33–38.

Unal, A., & Yerlikaya, Z. (2021). The effect of using social networks in the inquiry-based general chemistry laboratory course. *International Journal of Progressive Education, 17*(6), 16–31.

Unser, C. E. (2017). A study on the positives and negatives of using technology in the classroom. *Undergraduate Honors College Theses 2016-*. 18. Retrieved 2022-12-06, from https://digitalcommons.liu.edu/post_honors_theses/18

Winberg, T. M., & Berg, C. A. R. (2007). Students' cognitive focus during a chemistry laboratory exercise: Effects of a computer-simulated prelab. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 44*(8), 1108–1133.

Yadigaroğlu, M., Demircioğlu, G., & Demircioğlu, H. (2017). Fen bilgisi öğretmen adaylarının kimya bilgilerini günlük hayatla ilişkilendirebilme düzeyleri. *Ege Eğitim Dergisi, 18*(2), 795–812.

Yanarates, E. (2022). The effect of animated teaching on science teacher candidates' chemistry achievements and learning persistence. *Educational Policy Analysis and Strategic Research, 17*(1), 108–126.

Yesilyurt, M. E., Basturk, R., Yesilyurt, F., & Kara, I. (2014). The effect of technological devices on student's academic success: Evidence from Denizli. *Journal of Internet Applications & Management/İnternet Uygulamaları ve Yönetimi Dergisi, 5*(1), 39–47.

Zubaidah, S., Fuad, N. M., Mahanal, S., & Suarsini, E. (2017). Improving creative thinking skills of students through differentiated science inquiry integrated with mind map. *Journal of Turkish Science Education, 14*(4), 77–91.

Authors and Affiliations

Derejaw Yesgat Woldemariam[1] · Hailu Shiferaw Ayele[2] · Dereje Andargie Kedanemariam[3] · Solomon Melesse Mengistie[4] · Belete Bedemo Beyene[2]

✉ Derejaw Yesgat Woldemariam
yesgatderejaw@gmail.com

1 Bahir Dar University, Bahir Dar, Ethiopia

2 College of Natural Sciences, Department of Chemistry, Bahir Dar University, Bahir Dar, Ethiopia

3 College of Natural Sciences, Department of Chemistry, Debre Birhan University, Debre Birhan, Ethiopia

4 College of Education and Behavioral Sciences, Bahir Dar University, Bahir Dar, Ethiopia