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A comparative study of the pedagogical effectiveness of using linear and interactive videos in high school level chemistry teaching

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Abstract In a blended learning system, videos provide autonomous, anticipatory, and random access to content. Despite the rise of educational technologies, the actual effectiveness of interactive videos compared with linear videos remains insufficiently documented in secondary science education, particularly in the teaching and learning of chemistry. The aim of the present experimental research is to address major obstacles in chemistry education, such as overcrowded classrooms and inadequate infrastructure (classrooms, laboratories, materials, and chemical products, etc.), by comparing three teaching methods: two interactive video-based environments (remote and face-to-face) and one face-to-face environment using linear video. Moreover, interactive remote and face-to-face learning were conducted simultaneously. To evaluate student motivation across the three methods, a digital survey was administered via Google Forms after the experimental study was completed. The results indicated that both linear and interactive videos produced similar learning outcomes, regardless of whether they were used in distance or face-to-face contexts. However, learners reported a higher level of satisfaction when they used interactive videos. These findings suggest that there is no significant difference between face-to-face or distance learning with interactive video and face-to-face learning with linear video. The current approach contributes to resolving the challenges posed by overcrowded classrooms and insufficient infrastructure, such as the lack of experimental equipment in school laboratories. The use of educational videos to compensate for missing resources by providing virtual demonstrations accessible to all students also enhances classroom time management, allowing teachers to focus on support and concept clarification. Finally, this strategy helps reduce learning inequalities between well-equipped schools and those facing material shortages.

Keywords: constructivist pedagogy, student engagement, distance learning, education, teaching obstacles

1. Introduction

Within a blended learning system, videos serve as an educational tool that provides independent, proactive, and flexible access to content. However, despite the rise of educational technologies, one critical question remains: the actual effectiveness of interactive videos compared with linear videos is still insufficiently understood in secondary science education. This gap is particularly evident in chemistry instruction, where the complexity of abstract concepts and the lack of experimental resources pose major challenges.

Ever since the 21st century, people have been constantly seeking out the latest technologies to improve their daily lives. Indeed, digital technology has a crucial impact on our lives, particularly on the teaching and learning of sciences such as chemistry (Yazici & Nakıboğlu, 2024). High-quality teaching and learning remain international challenges, particularly in African countries such as Morocco. A lack of infrastructure and overcrowded classrooms hamper adequate learning opportunities (Amin & Mahabeer, 2021). With overcrowded classrooms, teaching methods have become more general and nonindividualized, and this reduces the commitment and motivation of learners (Adsız & Dinçer, 2025). A shortage of material along with an overcrowded classroom leads to burnout and chronic overwork (Körkkö et al., 2024). To overcome these obstacles, digital tools, particularly linear and interactive educational video capsules, are perceived as effective and innovative solutions (Engelbrecht & Borba, 2024). These tools enable learners to benefit from high-quality learning, regardless of their number or geographical location (Maulana, 2025). Research shows that interactive video clips, which include interactive questions and dynamic activities, promote quality learning. They enable learners to better understand the content being taught, and interactive video clips allow them to revise and consult content at their own pace and according to their needs.

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Some studies confirm the effectiveness of integrating technology into education, such as virtual visualization tools, to improve educational learning (Sentriyo et al., 2023). Anthony and Paloma, (2023) demonstrates the relationship between technology leadership standards among educational leaders and the adoption of technology by teachers. The study by Itauna et al. (2023) affirms the value of implementing learners' educational software to improve teachers' understanding and application of the material. In addition, the coronavirus pandemic has accelerated the spread of education technology, demonstrating the effectiveness of online learning platforms such as Telegrams during crises (Krishtofik, 2021). Additionally, the use of information and communication technologies can significantly influence learner engagement and learning experiences, particularly when combined with theoretical frameworks such as connectivism and constructivism (Rohmad & Wahyuni, 2016). Despite the advantages and effectiveness of video capsules in teaching, they present a number of production challenges (Baig & Yadegaridehkordi, 2023; Hennessy et al., 2022). The development of interactive and linear video clips requires highly advanced technical and pedagogical skills, and this can make the work of teachers difficult, as they not only have to produce video clips but also monitor the engagement and progress of learners (Chang et al., 2023). The main question is how to use interactive and linear educational videos to remedy the lack of infrastructure and overcrowded classrooms. To date, most research has focused on pedagogical benefits such as improving learning outcomes and learner engagement (Doerner & Horst, 2022). It is essential to take into account the various factors illustrated in the literature and to recognize the benefits and challenges of integrating digital technologies into education, such as software and online tutorials, to promote innovation and develop new teaching practices (Itauna et al., 2023). By making use of these pieces of information, teachers can make informed decisions about how to select and use technologies to effectively improve their teaching and learning experience.

Research on flipped classrooms, which highlights the qualities of using video clips to improve learning, has indicated that the integration of educational videos has had a very positive effect on student engagement, as shown in previous research (Krishtofik, 2021; Maulana, 2025). Furthermore, creativity and effectiveness in learning, oral practice and achievement are improved by the use of vlogs in teaching sciences, including chemistry (Chen et al., 2022).

The previous results show the considerable importance of video-based learning in chemistry classrooms for refining experiments and improving students' academic performance. However, crucial issues such as the impact of video capsules on the management of overcrowded classrooms and poor infrastructure remain underresearched, and further research is needed to fill these gaps. For the previously mentioned reasons.

The main objective of the current study is to enhance teaching and student learning by examining how video clips can help address the issues of overcrowded classrooms and the severe shortage of infrastructure for teaching redox reactions to first-year mathematics and science students. To this end, the study focuses on the following questions:

(1) What is the contribution of interactive and linear educational video clips to improving chemistry teaching and learning in the context of overcrowded classrooms and a lack of infrastructure in Morocco?

(2) Which learning method is most effective at strengthening student engagement and success in reducing oxidation in the first year of the mathematics bachelor's program: interactive video in the classroom, interactive video at a distance, or linear video in the classroom?

2. Materials and Methods

2.1. Sampling

Three groups of 20 first-year Baccalaureate, Mathematical Sciences, French option students were used in the present study. The first group received a linear video capsule in the classroom, while the other two groups used an interactive video capsule, one in the classroom and the other via distance learning. These last two interventions took place simultaneously. To ensure that the students were able to understand the material properly, the work was carried out in the morning.

2.2. Pretest

To measure the students' prior knowledge, a pretest on redox reactions was developed and administered before the start of the course (Craig et al., 2023; Gomez-del Rio & Rodriguez, 2022). The pretest was designed to assess students' knowledge of several key concepts: tests for recognizing a few ions, the concept of chemical transformation and advancement, and the ability to write down the chemical formulae of ions and chemical reactions. The pretest was administered to all three groups of students. It consisted of 25 questions, 11 of which were multiple-choice questions, and was designed to assess the degree of knowledge acquisition. According to Bloom's taxonomy, it targets cognitive knowledge and understanding. The second part, in the form of 14 open questions, focuses on the manipulation of knowledge in more difficult situations. These two types of assessments recover the chemistry prerequisites of the common core level and the first semester of the first year of the baccalaureate level. Students had 60 minutes to complete the pretest.

2.3. Learning sequences

To enrich the content of the learning sequences for the three groups, CAPCUT software (Windows version 3.9.0.1459) was used to create a linear video clip illustrating two chemical experiments. The first experiment demonstrates the oxidation of a zinc blade when it is immersed in a copper sulfate solution ($CuSO_4$). Two beakers were prepared for this demonstration: the first containing both the zinc slide and the $CuSO_4$ solution and the second containing only the $CuSO_4$ solution, which served as a control. After two and a half hours, a noticeable color change occurred in the first beaker, indicating a chemical reaction, whereas the control beaker showed no change, confirming the absence of a reaction. In the second experiment, the objective was to identify the presence of zinc ions (Zn^{2+}) in the solution in the first beaker. To achieve this, a sample of the solution from the first beaker was added to the first test tube, while a solution of zinc sulfate ($ZnSO_4$) was added to the second. After a few drops of 0.1 M sodium hydroxide (NaOH) were added to each tube, a white precipitate formed in both tubes, indicating the formation of zinc hydroxide ($Zn(OH)_2$) and confirming the oxidation of the zinc plate.

To transform the experiment into an interactive teaching tool, H5P version 1.12 was used to convert the linear video into an interactive video. Various types of questions, such as MCQs, short-answer questions, true/false questions and open-ended questions, were incorporated to engage the students and test their understanding in a dynamic way. In the first session, the linear video was presented live to the first group. For the second session, the video was presented to the other two groups simultaneously, one physically present in the classroom and the other participating remotely via the Zoom version 6.0.10(39647) platform. The hybrid approach ensured a consistent and interactive learning experience for all the students, regardless of their location.

2.4. Posttest

To evaluate the effectiveness of the three tested teaching approaches, we designed a posttest aligned with the educational objectives set out by the Moroccan Ministry of Education (Samuel et al., 2019). The posttest is made up of a varied range of questions developed by a group of teachers with more than 20 years of experience and inspectors to ensure a comprehensive and balanced assessment of students' skills (Liu et al., 2025; Siyam et al., 2025). In accordance with the recommendations of (Vydra & Kováčik, 2024), which emphasize the importance of innovative pedagogical approaches to skills development, the posttest includes 22 multiple-choice questions (MCQs), with 11 questions (Q1 to Q11) being similar to the MCQ questions from the pretest to see if learners have made progress on the same questions between the pretest and the posttest, while the remainder (Q12 to Q22) assess mastery of the new learning objectives, and they also allow us to assess learners' ability to recognize and select the correct answer from several options (Javid, 2014). Finally, the 14 open questions in the posttest were used to assess specific skills taught during the teaching intervention. They are more in-depth than the pretest questions are. To measure learner progress, the answers before and after the teaching intervention are compared, and the open questions in the posttest are prepared such that they present a clear and coherent link with the open questions in the pretest. The open questions in the posttest also address learning objectives, encouraging in-depth reflection and the formulation of reasoned answers, which is essential for cultivating critical thinking and the application of knowledge in a variety of contexts. The diversity of question formats is crucial not only for measuring facts memorization and conceptual understanding but also for assessing students' ability to apply knowledge critically and reflectively, as advocated by contemporary educational frameworks (Hemmati & Ghaderi, 2014). The pretest and posttest were carried out seven days before and after the experimental teaching (Vydra & Kováčik, 2024).

2.5. Surveys to check satisfaction, preference and commitment

An anonymous survey was administered to all three groups of students using the Google Forms platform. The purpose of this survey was to gather students' opinions on the different modes of learning that were studied, such as distance and classroom learning with interactive video capsules and classroom learning with linear video. The form is made up of a number of questions designed to assess several aspects of learning, especially students' engagement and attention, clarity of content, interaction between teacher and student and between students and teacher, content understanding rate, general satisfaction, and so forth. The information gathered from the questionnaire was used to identify the strengths and weaknesses of each learning mode and to develop the best teaching methods to meet the learners' needs.

2.6. Statistical analysis

The data were analyzed using Excel 2019 and GraphPad Prism 9.5.1 software. The significance of the differences between the percentage results was assessed via one-way ANOVA. Tukey's multiple range tests were conducted using GraphPad Prism with a significance level of $p<0.05$ for the multivariable analysis.

3. Results

3.1. Pretest

The graph (Figure 1) shows the learners' correct answers to the multiple-choice questions for the three groups. The nearly equal distribution of correct answers between the three groups indicates that there is no significant difference between them. The variability of answers between questions suggests that some questions were more difficult than others were. However, this tendency is similar for all three groups.

The graph (Figure 2) illustrates the learners' correct answers to the open-ended questions for these same groups. The homogeneity of the correct answers between the three categories of learners indicates that there is no marked difference between the groups. The irregularity of the answers between the statements indicates that some questions are more challenging. The same is true for the three groups of learners.

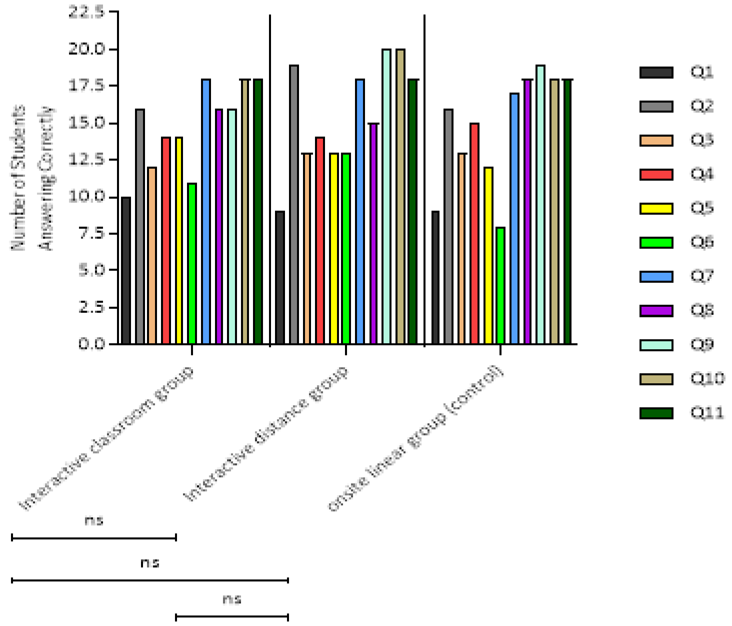

Figure 1 Pretest results for multiple-choice questions (knowledge retrieval).

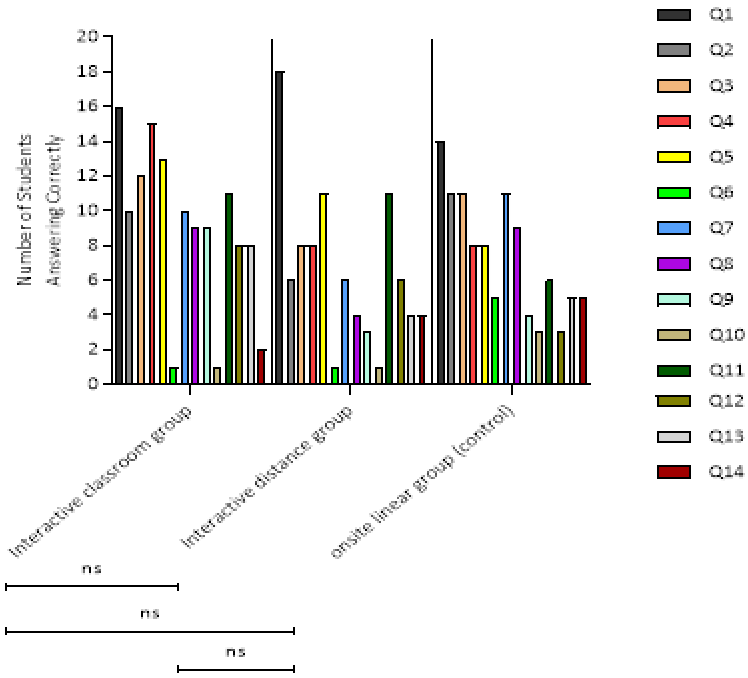

Figure 2 Pretest results for open questions (scientific reasoning and graphic and written communication).

3.2. Posttest

The number of students who answered the 22 MCQs correctly is shown in Figure 3A and 3B. The present study uses three groups of students: group 1 (G1) uses interactive video in the presence, group 2 (G2) uses interactive video at a distance, and group 3 (G3) uses linear video in the presence. The first two learning modes are used at the same time. As seen from the bars on the two histograms for the three groups, there was no difference in performance between the three groups. There was no significant difference between the three modes of learning.

To test the scientific reasoning and analytical method of the three groups, a series of 14 open questions in the form of three exercises was asked. The correspondence of the correct answers, as shown in Figure 4, indicates that the three groups obtained similar results. This means that they achieved similar levels of success when the correct answers were analyzed (Siyam et al., 2025). This homogeneity can be interpreted as an indication that these groups share common characteristics, such as similar levels of understanding, learning styles or access to learning resources (Lu et al., 2024).

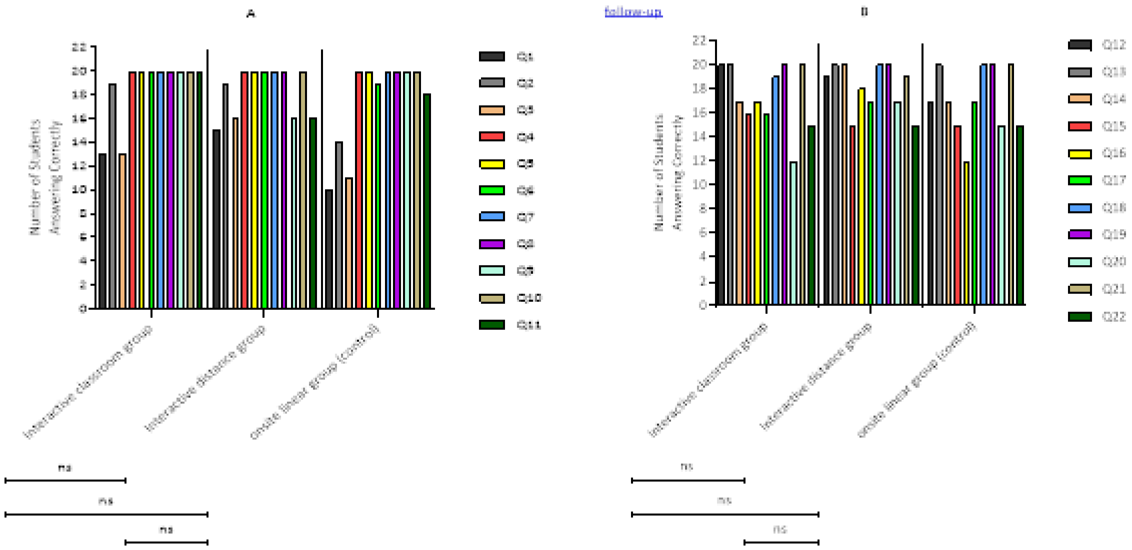

Figure 3 A and B: Learners' correct answers to posttest multiple-choice questions.

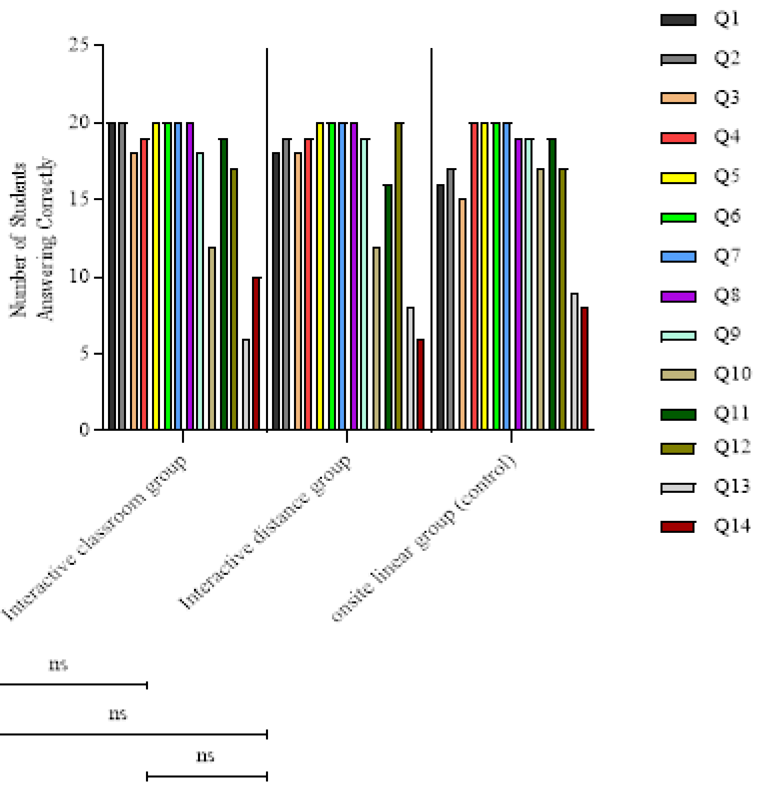

Figure 4 Learners' correct answers to open-ended posttest questions.

3.3. Survey results to check satisfaction, preference and commitment

3.3.1. Learning aspects and learner engagement

The percentages of learners who followed the three learning modes are shown in Figure 5A. A total of 33.33% of the respondents followed distance learning using an interactive video capsule, 33.33% of the learners followed face-to-face learning using an interactive video capsule, and 33.33% of the learners followed face-to-face learning using a linear video capsule. The majority of the learners (91.7%) felt that video capsule learning was very or fairly effective (Figure 5B), 5% felt that video capsules were moderately effective, and 3.3% felt that this learning method was not very effective. According to Figure 5C, 86.7% of the respondents find video capsule learning very favorable or fairly favorable, and only 13.3% are neutral.

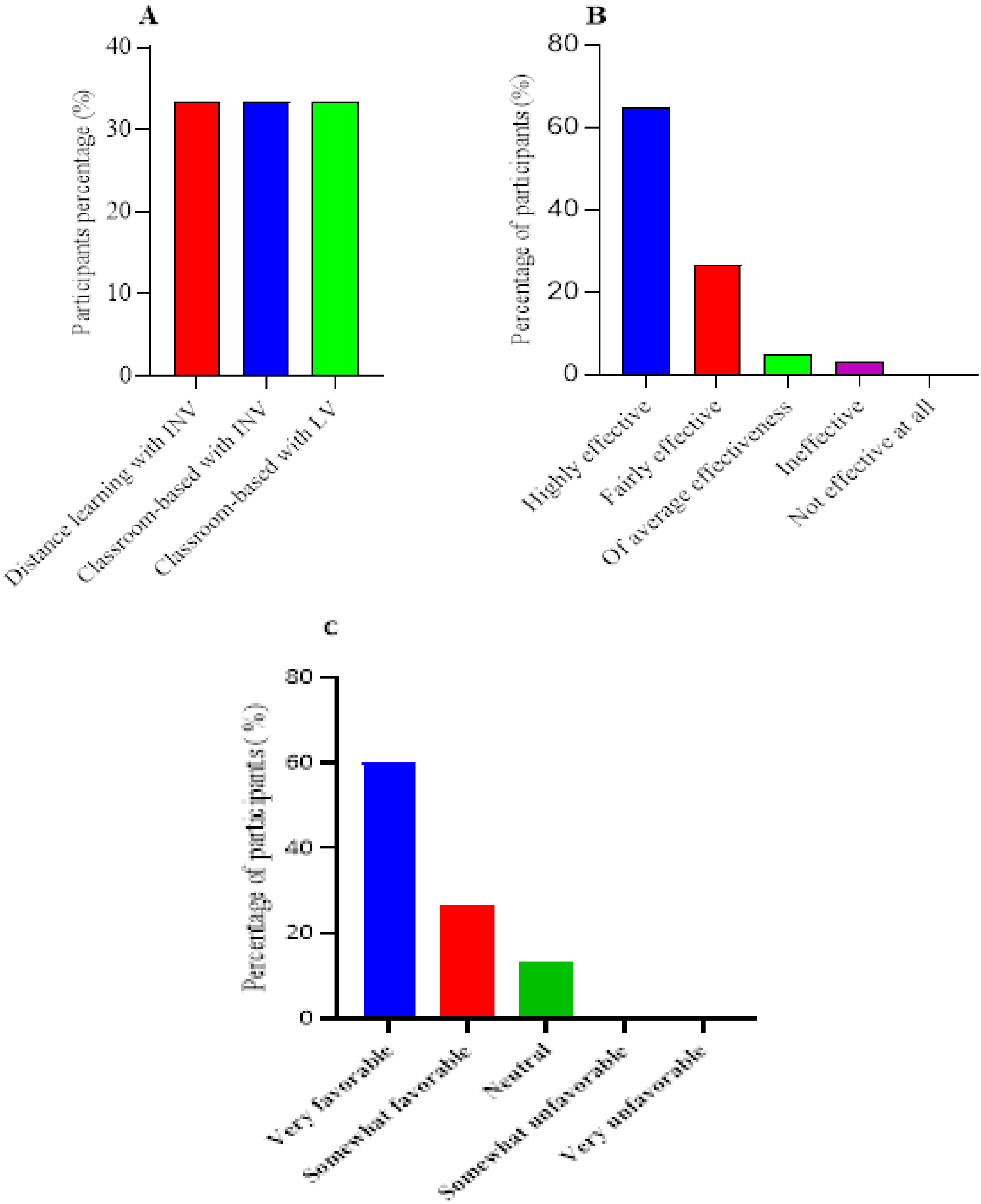

Figure 5 Learning experience and understanding. A: Learning experience, B: Enhancement of understanding, C: Overall satisfaction.

3.3.2. Interactive content and clarity

After viewing the two types of video capsules, linear and interactive, in the classroom or distance mode, a questionnaire was distributed to the learners. The majority of the respondents (91.7%) thought that the content of the video clips was very clear or fairly clear. This finding indicates that the interactive and linear video clips are effective at transmitting information in an accessible way (Figure 6A), but 8.3% thought that the content was moderately clear, which could indicate that there is still a need to improve the presentation and clarity of the content. As shown in Figure 6B, the integration of interactive elements (QCM) appears to play a key role in improving comprehension, with the majority (95%) of respondents claiming that interactive elements are very or fairly useful. This observation highlights that interactive elements are widely accepted by learners. This can imply an effective engagement of the learners, pushing them to become more involved in their learning and encouraging educators to continue to develop this pedagogical practice. However, 5% of the learners find that interactive elements are moderately useful, not very useful or not useful at all. This percentage of learners shows that there is room for improvement to make the interactive elements more capturing and useful for all high school students.

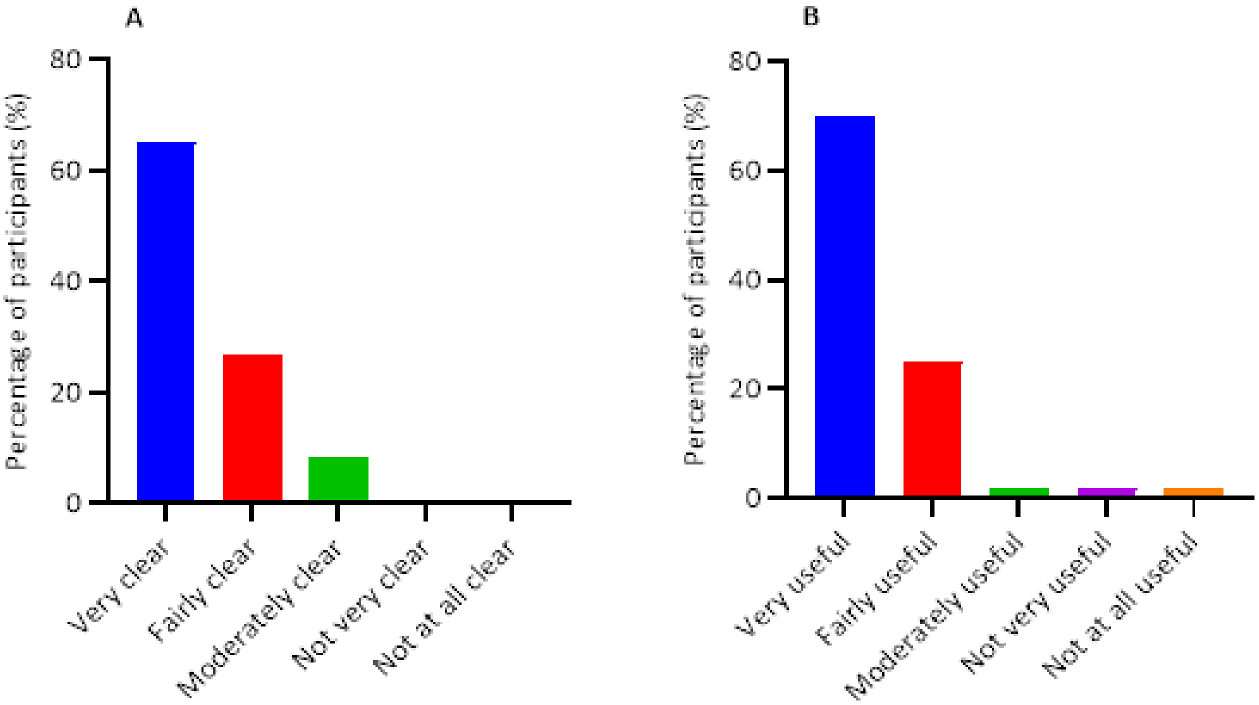

Figure 6 Content and clarity, A: Clarity of content, B: Utility of interactive elements.

3.3.3. Engagement and interaction

The results (Figure 7A) revealed that 95% of the participants were very or fairly engaged during the learning session; however, a small group of students (5%) were not engaged during the session. The present results reveal an important relationship between learners' engagement and their interactions with each other and with their teacher. As shown in Figure 7B, 48.3% of the students were very often able to talk with the teacher during the learning session, and 28.3% from time to time were able to interact with the teacher; however, 23.3% were not able to talk with their teacher, and this last significant rate deserves particular attention. This situation can be explained by a number of factors, such as psychosocial factors and the fact that students who are too shy or lack confidence find it difficult to ask questions or ask for help (Osborne et al., 2025). However, during the session, the group in the distance learning mode encountered connection and hardware problems, which prevented them from communicating with their teacher. As shown in Figure 7C, 20% of the students were very often able to talk with their peers during the learning session, 48.3% were occasionally able to talk with their colleagues, and 31.7% of the students were unable to talk to their peers because of a number of factors, such as a lack of self-confidence or the black color of their skin. They feel embarrassed to interact with their peers for fear of being judged (Daniels et al., 2025). In contrast, in the context of distance learning, most students find it difficult to connect and use communication equipment.

3.3.4. Preference for the learning method

With respect to the preference for the learning mode, according to the results obtained (Figure 8), 43.3% of the learners preferred distance learning with an interactive video capsule, and 41.7% of the learners preferred face-to-face learning with an interactive video capsule. The percentage of learners who prefer classroom learning is very close to the percentage of those who prefer distance learning with an interactive video capsule, which shows that the two previous learning modes have the same preference among learners. However, only 10% of the participants preferred in-class learning with a linear video capsule. This explains why interactive video capsules are such a preferable learning mode. However, 5% of the learners preferred neither of the learning modes, which may indicate that a group of learners does not prefer any of these three approaches.

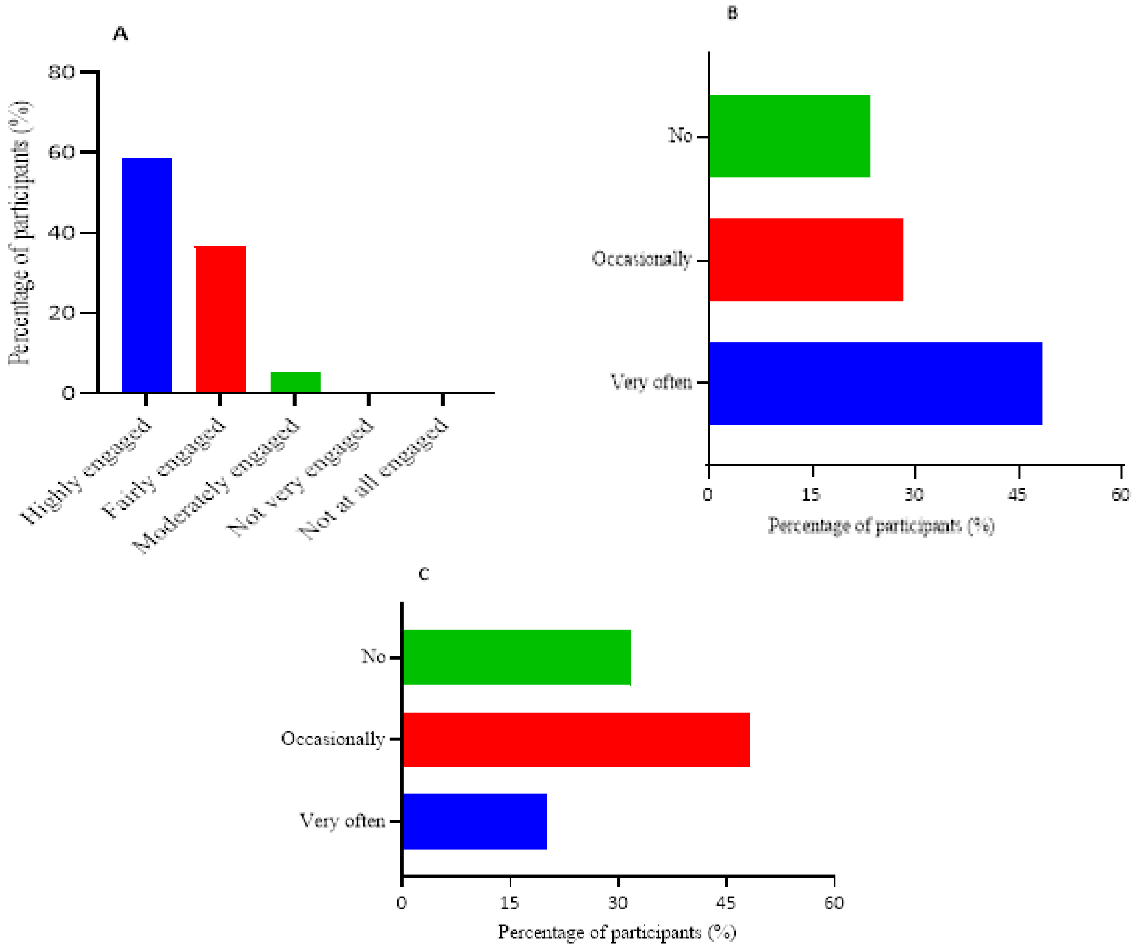

Figure 7 Engagement and interaction, A: Engagement and attention, B: Interaction between teacher and students, C: Interaction between students.

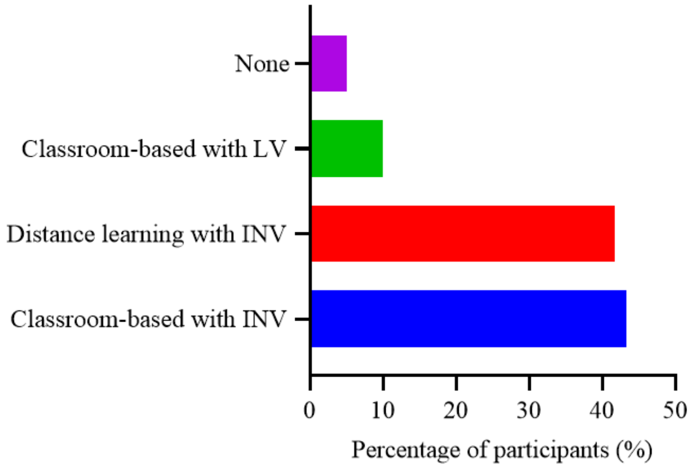

Figure 8 Preference of the learning method.

4. Discussion

The current experimental study seeks to overcome the major obstacles to the teaching and learning of chemistry, such as inadequate infrastructure and overcrowded classrooms (Adsız & Dinçer, 2025). By analyzing the following three modes of learning (classroom-based interactive video learning, distance-based interactive video learning and classroom-based linear video learning), their effects on the teaching and learning of (Achuthan et al., 2021) chemistry can be measured. The results for the learners in the three groups mentioned above reveal that they obtained similar results in the pretest for the multiple-choice questions (Figure 1) and the open-ended questions (Figure 2) (Başgül & Coştu, 2025; Koç & Kanadlı, 2025). The posttest data show significant progress in results in all groups, highlighting the overall performance of the use of educational videos, whether linear or interactive (Adler et al., 2025; Onyeaka et al., 2024). Nevertheless, no statistically significant difference was observed between the three teaching methods, which shows that each method leads to the same result of (Netland et al., 2025; Shang et al., 2025). The strength of this analogy lies in the fact that it offers pedagogical flexibility, enabling teachers to choose the learning method that best suits the resources available and the logistical difficulties involved, without adversely affecting what the pupils have already learned (Barua & Lockee, 2025; Cattaneo et al., 2025).

Although the final assessments were equivalent for the three categories, the detailed results varied. With respect to the results of the multiple-choice question posttest, as represented by the histogram (Figure 2A), the three groups performed almost similarly from Q1 to Q3. However, the classroom interactive group performed slightly better, as confirmed by the studies of Barua & Lockee, (2025) and Kataoka et al. (2025). From Q4 to Q6, there was a decrease in the results of the learners who had undergone the pedagogical intervention using a linear classroom video capsule, while the other two groups maintained a satisfactory level. From Q7 to Q9, the interactive distance group gives the impression of having an improved level of performance compared to the other groups; this finding is similar to the results obtained by Onyeaka et al. (2024) and Wiitavaara & Widar (2025). For questions Q10 and Q11, all three groups experienced an overall decline in the number of correct answers.

With respect to the histogram (Figure 2B), the results also varied among the three groups. From Q12 to Q14, the two interactive groups (classroom and distance learning) obtain similar results, which are slightly higher than those of the linear classroom group (Onyeaka et al., 2024; Photopoulos et al., 2023; Teng et al., 2024). From Q15 to Q17, there was a moderate decrease for all three groups, but the interactive classroom group was superior. From Q18 to Q20, the interactive distance group seems to obtain better results on these questions. For questions Q21 and Q22, there was a decrease for all three groups.

With respect to the results of the open-ended questions, the histogram (Figure 4) represents the learners' correct answers. The number of participants who answered correctly is generally lower than that of the multiple-choice questions posttest. However, the two interactive classes and distance groups are superior to the linear classroom group. These results are in line with what was stated in the study of Anazco et al. (2024). However, there was a variation in performance across the three groups, depending on the questions. From Q1 to Q4, the results of the two interactive groups (classroom and distance learning) are similar, with a slight improvement for the classroom interactive group (Shlenova & Kravchenko, 2025; Tuma, 2021). For questions Q5 to Q8, a gradual decline is noticeable for all three groups, particularly for the linear classroom group. From Q9 to Q11, the number of correct answers improved slightly for the two interactive groups, while the linear classroom group remained below the rankings (Tuma, 2021). There is an overall decrease in the number of correct answers for all three groups from Q12 to Q14. The participants in the two interactive groups (classroom and distance, which were carried out simultaneously) performed slightly better on the multiple-choice and open-ended questions in the posttest, showing that interactivity promotes a better understanding of sophisticated knowledge: This result is consistent with that obtained in the study of MacKenzie et al. (2022); Mayer, (2024) and Tuma, (2021), which underlines the importance of interactivity in intellectual mobilization and the mastery of concepts. The open-ended questions also revealed that learners were more competent in both interactive modes, a result supported by Tuma, (2021). They produced well-constructed and complete answers, whereas learners in the linear mode provided accurate but less developed answers (Al Mamun & Lawrie, 2023).

A poststudy survey using a questionnaire corroborated these descriptive observations. The majority of participants (91.7%) were satisfied with the clarity of the content (Figure 6A), but learners in the interactive modes (classroom and distance learning) strongly valued the dynamic and interactive presentation of the content (Al Mamun & Lawrie, 2023). According to Figure 8, 43.3% preferred interactive distance learning, and 41.7% preferred interactive classroom learning, indicating that interactive learning (classroom and distance) was strongly preferred by participants, a result corroborated by Al Mamun & Lawrie, (2023) and Lohr et al. (2024). Commitment and attention were considered more important for the majority of participants (95%) (Figure 7A). A similar result is supported by that of Vermeulen & Volman, (2024) and Zou et al. (2024). The interactive components were considered beneficial for self-analysis and critical thinking: 95% of the participants were very or fairly engaged during the educational intervention (Figure 6B). This result was confirmed by Zou et al. (2024). The interaction between the learners and the teacher was judged to be one of the main benefits of the face-to-face interactive approach: 76.6% of high school students are able to talk to the teacher often or from time to time and ask questions to clarify their doubts and receive explanations, thereby enhancing their learning (Figure 7B). Similar results were reported by Al Mamun & Lawrie, (2023) and Lohr et al. (2024). A total of 20% of the learners communicate very often with their classmates, 48.3% from time to time and 31.7% are unable to communicate; these exchanges between learners play a vital role in cooperative learning (Figure 7C) (Al Mamun & Lawrie, 2023). When learners work together, they can share ideas, solve problems together and support each other, which strengthens their understanding of concepts and facilitates learning, as recommended by Lohr et al. (2024). The final findings indicate a general similarity between the three pedagogical approaches. Nonquantitative distinctions show that interactive videos, whether face-to-face or online, enhance the learning experience because of their ability to engage students and simplify complicated theories. These observations show that adding interactive elements to digital resources enhances educational outcomes while meeting specific teaching needs (Bergdahl & Sjöberg, 2025; Gu, 2025). These findings are consistent with the studies of Bergdahl & Sjöberg (2025) and Wu (2024), who emphasize the importance of the adaptability of teaching tools and offer encouraging prospects to develop teaching practices.

The results of the current study provide further evidence of the value of interactive methods in chemistry education and the preference of learners for these approaches, whether in face-to-face or distance learning settings. From a constructivist perspective, they promote the coconstruction of knowledge through interaction and cooperation between peers and teachers, thereby enhancing engagement and autonomy (Lippard et al., 2017). Furthermore, cognitive load theory shows that these methods reduce extrinsic load and facilitate the processing of complex concepts, allowing for optimal mobilization of cognitive resources (Sweller, 2018). Within this framework, linear video clips for the progressive structuring of content and interactive videos for actively engaging learners appear to be particularly relevant educational tools for improving conceptual understanding and consolidating learning in the long term.

5. Conclusions

The current research has shown that the integration of linear and interactive videos in the teaching and learning of chemistry, whether at a distance or onsite, can improve the quality of learning. Observations have shown that learners' results were broadly similar, regardless of the type of video used or the mode of teaching (classroom or distance learning). However, it was observed that learners who used interactive videos, whether they used classroom or distance learning, obtained more satisfactory results on certain questions than did learners who used linear classroom videos for the same questions did. The present study highlights the importance of using interactive and linear videos in distance and face-to-face teaching as a means to help solve the problem of overcrowded classrooms and compensate for the significant shortage of experimental equipment.

Both interactive and linear videos have great potential to enrich the process of teaching and learning chemistry. However, their effectiveness can be limited by several obstacles, such as insufficient internet connections or the absence of suitable electronic equipment, such as good-quality computers or smartphones. In addition, the use of linear videos can sometimes lead to superficial learning and a lack of concentration among learners. Furthermore, carrying out the study with a limited number of learners may restrict the generalizability of the results. Future research could explore the impact of interactive and linear videos on a group of learners, which could include learners with specific needs, such as autistic or disabled people. It would also be interesting to study the effects of interactive and linear videos in specific fields, such as medicine, vocational training and language. It would be interesting to study the associations between the use of interactive, linear videos and virtual simulations for an even more engaging approach. Additionally, it will be useful to increase the number of students as well as the specialty and other subjects studied to obtain more detailed results that will provide definitive estimates at the school level.

Acknowledgment

We would like to express our sincere gratitude and deep gratitude to the school principal, as well as to several colleagues working at the school and to the pupils' parents, for their valuable services and support for this remarkable experimental activity.

6. Declarations

6.1. Ethical considerations

Informed consent was obtained from all participants before their involvement in the study. Each participant received a clear and concise explanation of the study's purpose, procedures, and the voluntary nature of their participation. They were explicitly informed that their participation was entirely voluntary and that they could withdraw from the study at any time without any consequences or penalties. The participants were assured that their responses would remain confidential and that their identities would be anonymous in all the reports and publications. The data were securely stored and accessible only to the research team, and all identifiable information was removed during analysis. Additionally, participants were made aware that the data collected would be used solely for research purposes and would not be shared with third parties without their explicit consent.

6.2. Use of artificial intelligence (AI)

The authors declare that the generative artificial intelligence (AI) tools ChatGPT and DeepL were used exclusively for language editing and grammatical improvement. The use of AI did not influence the scientific content, study design, data analysis, data interpretation, results, or conclusions of the manuscript. Full responsibility for the content remains with the authors.

6.3. Conflict of Interest

The authors declare that they have no conflicts of interest.

6.4. Funding

This research did not receive any financial support.

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