Research Article

Influence of video-based instruction on senior two students' understanding of the mole concept

Received: 24/06/26
Revised: 28/09/26
Accepted: 28/09/26
Published:30/09/26

Ezechiel Nsabayezu[1*], Gedeon Habakubaho[2]

[1]Department of Mathematics and Science Education, INES-Ruhengeri, Musanze, Rwanda, P.O.B 155 Musanze

[2]Department of Land Survey, INES-Ruhengeri, Musanze, Rwanda, P.O.B 155 Musanze

Address for Correspondence
Nsabeyezu (e.nsabayezu@ines.ac.rw)

Abstract

Background: Effective chemistry instruction requires innovative and learner-centred approaches that enable students to develop a clear and meaningful understanding of abstract chemical concepts. This study examines the influence of video-based instruction on Senior Two students' understanding of the mole concept. Specifically, the study explores students' perceptions of using video-based instruction to learn the mole concept and identifies the challenges associated with implementing video-based instruction in rural schools. The study is guided by Mayer's Cognitive Theory of Multimedia Learning (CTML), which provides a theoretical basis for understanding how students process and integrate verbal and visual information during learning. **Methods:** A descriptive mixed-methods design was employed, involving 102 participants, including 100 students and two Chemistry teachers from two secondary schools in Burera District, Rwanda. Students were randomly assigned to an experimental group, which received video-based instruction, and a control group, which received traditional instruction. Data were collected through pre- and post-achievement tests, questionnaires on students' perceptions, and semi-structured interviews with teachers, and analyzed using descriptive statistics and thematic analysis. **Results:** Findings revealed that students exposed to video-based instruction achieved significantly higher post-test scores (M = 8.18, SD = 1.00) compared to the control group (M = 6.00, SD = 1.62). The difference between the groups was statistically significant ($t=7.98$, $p < 0.001$). These findings suggest that video-based instruction was effective in enhancing students' conceptual understanding of the mole concept. Students reported that videos enhanced engagement, simplified abstract concepts, and allowed self-paced learning, while teachers highlighted the motivational and cognitive benefits of multimedia resources. However, challenges were noted, including limited access to digital devices, internet connectivity issues, and potential distraction if videos were used in isolation without interactive support. **Conclusion:** These findings indicate that video-based instruction is a promising strategy for enhancing student learning but is most effective when implemented within blended approaches and supported by adequate resources. Schools should provide teacher training to ensure effective integration of videos aligned with curriculum objectives. Future research could examine the long-term effects of video-based instruction, compare its impact across rural and urban settings, and explore the use of emerging technologies such as virtual reality, augmented reality, and artificial intelligence to further enhance science learning.

Keywords: Chemistry education; Cognitive Theory of Multimedia Learning; Video-based instruction; Mole concept.

Citation: Nsabeyezu, E., & Habakubaho, G. (2026). Influence of video-based instruction on senior two students' understanding of the mole concept. *INES Scientific Journal*, 1(1):10-27.
doi:*https://doi.org/10.32677/isj.v1i1.8511*

1 INTRODUCTION

Technology integration has become a key component of educational reform worldwide, reshaping teaching and learning practices (C. Wang et al., 2024). In science education, technology provides innovative ways to facilitate students' understanding of complex and abstract concepts (Krajcik & Mun, 2014). Among the range of digital innovations, video-based instruction has emerged as a particularly effective medium for making abstract and challenging ideas more tangible to learners (Yousef et al., 2014). Unlike static resources, videos can combine text, images, narration, and animations to provide multi-sensory learning experiences that support student engagement and comprehension (Khasawneh, 2024). Online platforms and open educational resources (OER) have further expanded opportunities for teachers to incorporate visual learning strategies in their classrooms, offering a wide range of freely accessible and interactive content (Luo et al., 2020).

Evidence from sub-Saharan Africa shows that video-based instruction can improve chemistry learning and retention. Studies in Lesotho and Nigeria reported significantly better chemistry performance among students exposed to video-based instruction than those taught through conventional approaches (Bohloko et al., 2019; Fabeku & Enyeasi, 2024). However, limited evidence specifically examines video-based instruction for teaching the mole concept among lower-secondary students, particularly in rural schools, leaving a contextual and topic-specific research gap. The adoption of technology-enhanced pedagogies has been comparatively slower due to infrastructural constraints, limited resources, and inadequate teacher preparation (Habarurema et al., 2024). Despite these challenges, increasing investments in digital technologies and policy initiatives across the region are gradually reshaping classroom practices. Kalyani (2024) showed that when technological tools are thoughtfully integrated, they not only improve students' conceptual understanding but also promote learner-centered instruction, which is particularly valuable in science education. This context underscores the need to assess the impact of video-based instruction as an innovative approach to overcoming learning difficulties in complex Chemistry topics.

In Rwanda, the government has prioritized technology-enhanced learning through programs such as the One Laptop per Child (OLPC) initiative, expansion of internet connectivity in schools, and the creation of localized digital resources to support the national curriculum (Fajebe et al., 2013). These efforts aim to foster inclusive and equitable access to digital learning, particularly in science, technology, engineering, and mathematics (STEM) education. In rural Rwandan schools, technology integration is constrained by unreliable internet connectivity, inadequate ICT equipment, limited electricity or backup power, and gaps in teachers' digital skills (Twagilimana et al., 2026; Mushimiyimana et al., 2026). These challenges directly affect video-based instruction because streaming or accessing instructional videos requires stable electricity, appropriate devices, sufficient bandwidth, and teachers who can effectively select, prepare, and integrate digital content into lessons. Evidence from rural schools in Burera also indicates that slow internet, limited access to ICT facilities, inadequate power supply, and insufficient time in smart classrooms constrain technology-supported learning (Mpumuje, 2024). Therefore, the effectiveness of video-based

instruction in rural Rwanda cannot be considered independently of these infrastructural and teacher-related conditions. Consequently, there is a growing need to investigate context-specific strategies that can make the integration of technology both effective and sustainable in rural learning environments (Nsabayezu et al., 2025a).

The mole concept occupies a fundamental role in secondary school Chemistry, serving as the foundation for understanding quantitative relationships in chemical reactions (Dogbey, 2021). Despite its importance, it is consistently reported as one of the most challenging topics for learners, who often struggle with its abstract nature and mathematical demands (Kumar, 2025). Poor understanding of this concept hinders students' progression in advanced Chemistry topics, which in turn affects their overall performance and interest in science-related fields (Ramesh et al., 2021). Traditional teacher-centered methods, which emphasize memorization and algorithmic problem-solving, have been shown to inadequately support deep conceptual understanding (Staver & Lumpe, 1995). This situation highlights the need for pedagogical innovations that can bridge the gap between abstract theory and practical comprehension.

Video-based instruction has been widely recognized as an effective pedagogical tool in science education because it combines visual and auditory modes of communication, thereby enhancing cognitive processing and long-term retention of knowledge (Navarrete et al., 2025). Unlike traditional methods, videos can illustrate abstract scientific phenomena through animations, simulations, and real-life demonstrations, making complex topics more concrete and accessible to learners. In Chemistry specifically, video-based instruction supports the visualization of molecular structures, chemical bonding, and quantitative concepts such as stoichiometry, thus reducing misconceptions and promoting deeper understanding (Pekdağ, 2020). Students' views of video-based chemistry instruction suggest that videos can support understanding by providing step-by-step explanations, visual representations of abstract processes, opportunities for repeated viewing, and control over learning pace (Jordan et al., 2016). This is particularly relevant to the mole concept**,** which students often find difficult because it requires connecting Avogadro's number, molar mass, and chemical quantities (Fernández et al., 2023). Evidence from Rwanda also shows that students have expressed positive perceptions of technology-supported chemistry learning and reported potential benefits for understanding chemistry concepts (Woldemariam et al., 2024). However, direct evidence of Senior Two students' perceptions of video-based instruction specifically for learning the mole concept remains limited, particularly in rural Rwandan schools.

The effectiveness of video-based instruction is also shaped by students' perceptions, which are generally positive in terms of clarity, flexibility, and motivation to learn (Galatsopoulou et al., 2022). Learners appreciate the ability to pause, replay, and review difficult sections at their own pace, which enhances personalized learning. Furthermore, video-based instruction tends to foster greater interest in science by presenting content in an interactive and visually appealing manner. Nevertheless, perceptions can differ according to students' access to technology, their preferred learning styles, and the cultural or linguistic relevance of the instructional materials (Pal & Patra, 2021). These variations highlight the importance of designing video-based learning experiences that are contextually appropriate and inclusive. Despite its potential, the integration of video-based instruction faces considerable challenges in rural settings. Limited infrastructure, such as unreliable electricity and poor internet connectivity, often restricts consistent access to digital learning resources

(Khomyshak, 2024). Additionally, high costs of digital devices and insufficient teacher training hinder the effective use of videos as pedagogical tools. In the Rwandan context, persistent obstacles include language diversity where students may struggle to understand content delivered in foreign languages, and the lack of locally produced, curriculum-aligned video resources. These factors contribute to inequalities in the adoption and outcomes of video-based instruction across different school environments.

Although existing studies indicate that video-based instruction can enhance chemistry learning by improving conceptual clarity, motivation, flexibility, and opportunities for repeated learning, the evidence remains limited regarding its application to the mole concept among lower-secondary students. In particular, little is known about how Senior Two students perceive video-based learning of the mole concept and how rural technological constraints influence its implementation and learning outcomes in Rwanda**.** This gap justifies the present study, which examines the effectiveness, students' perceptions, and implementation challenges of video-based instruction for teaching the mole concept in a rural Rwandan context. Given the centrality of Chemistry in Rwanda's secondary school curriculum and the recognized difficulty of topics such as the mole concept, video-based instruction presents an opportunity to strengthen conceptual understanding in resource-constrained settings (Soltura, 2021). The multimodal nature of videos can bridge the gap between theoretical explanations and practical applications, thereby supporting both teacher-led instruction and student self-learning. Moreover, as Rwanda continues to expand digital infrastructure and prioritize technology-enhanced education, the exploration of video-based instruction offers valuable insights into scalable and sustainable teaching strategies for science subjects (Nsabayezu et al., 2025b). Investigating its influence on students' mastery of the mole concept is therefore timely, as it aligns with national educational priorities while addressing the persistent learning challenges in rural schools.

Against this backdrop, this study examines the influence of video-based instruction on senior two students' understanding of the mole concept in a rural Rwandan school setting. The research situates itself in a context where infrastructural challenges and limited access to digital resources present barriers to effective learning. The study seeks to determine whether video-based instruction can provide a meaningful improvement in students' conceptual understanding. In doing so, it contributes to the ongoing discourse on technology-enhanced learning in developing contexts, offering insights into how video-based pedagogies can support both students and teachers in overcoming challenges associated with complex Chemistry concepts.

2 THEORETICAL FRAMEWORK

The present study adopted the Mayer's Cognitive Theory of Multimedia Learning (CTML), which explains how people learn more effectively from words and pictures together than from words alone (Mayer, 2005). CTML emphasizes that human learning is mediated by three key assumptions: dual-channel processing, limited capacity, and active learning. Dual-channel processing suggests that learners have separate systems for processing visual/pictorial information and auditory/verbal information. Limited capacity highlights that each channel has restrictions on the amount of information it can process at a time. Active learning stresses that meaningful learning occurs when learners engage in selecting, organizing, and integrating information into coherent mental models. This theoretical lens is particularly relevant to teaching the mole concept in Chemistry, which many students find abstract and challenging due to its reliance on mathematical reasoning and invisible phenomena such as particles, moles, and Avogadro's number. Traditional teacher-

centered approaches often overwhelm students with verbal explanations and abstract symbols, increasing cognitive load and leading to misconceptions (Namgyel, 2013). CTML provides a framework for designing instruction that reduces this overload by presenting information through complementary visual and auditory modes. In the case of video-based instruction, animations, diagrams, and narrated explanations can simultaneously illustrate and explain molecular structures, stoichiometric calculations, and the relationship between mass, moles, and particles, making the abstract more concrete (Mayer, 2005).

Furthermore, CTML underscores the importance of coherence and redundancy principles in multimedia learning design. Well-designed instructional videos avoid unnecessary details that can distract learners, focusing instead on essential representations that align directly with learning objectives. For example, a video explaining mole ratios can show step-by-step particle-to-mole conversions alongside narrated commentary, allowing students to process information in manageable segments. This segmentation not only reduces extraneous cognitive load but also enables learners to build meaningful connections between symbolic representations (equations and numbers) and their conceptual meaning (Mayer, 2005). By applying these principles, the study operationalizes CTML in a way that directly supports mastery of the mole concept.

The study reflects CTML's notion of active learning by leveraging the interactive features of video-based instruction. Students can pause, replay, or review specific segments to reinforce understanding, which supports the process of selecting, organizing, and integrating knowledge. This aligns with Mayer's generative processing principle, which argues that learners must actively engage with material to construct meaningful mental models. In the rural Rwandan context, where students often struggle with limited exposure to laboratory experiences, video-based instruction grounded in CTML serves as a powerful tool to bridge the gap between abstract theory and practical comprehension. Thus, the study not only tests the effectiveness of video-based instruction but also demonstrates the applicability of CTML in addressing persistent challenges in science education.

3 LITERATURE REVIEW

3.1 Challenges of teaching the mole concept using video-based instruction

The mole concept remains a fundamental yet challenging topic in chemistry education. Research indicates that students often struggle with grasping the abstract nature of the mole, its relationship to Avogadro's number, and its application in stoichiometric calculations. This difficulty is compounded by the need for strong algebraic skills and an understanding of dimensional analysis. For instance, Fujioka (2017) highlights that high school chemistry students face significant challenges in mastering the mole concept due to these factors. Similarly, Owusu (2020) identify key challenges in learning the mole concept, including difficulties in translating word problems into equations, determining mole ratios, deriving empirical and molecular formulae, and understanding the relationship between stoichiometric coefficients and moles. Addressing these challenges requires a shift from rote memorization to fostering a deep conceptual understanding. Studies suggest that students often rely on memorization rather than conceptual grasp, leading to difficulties in solving problems without the use of formulas. For example, Owusu et al. (2024) found that many students struggle to solve problems without formulas, highlighting a lack of conceptual understanding. Interviews with pre-service teachers confirmed these findings, indicating that students often rely on rote memorization rather than conceptual grasp.

3.2 Effectiveness of video-based instruction in science education

Recent meta-analytic studies have demonstrated the significant impact of video-based instruction on enhancing students' academic performance in science education. A comprehensive meta-analysis by Wang et al. (2024), encompassing 14 empirical studies conducted between 2019 and 2023, revealed a large positive effect size (g = 2.03) for video-based instruction in science and mathematics education. The analysis indicated that video-based instruction substantially improves students' performance across various educational levels, including primary, secondary, and tertiary education. This underscores the efficacy of integrating video resources into science curricula to facilitate better learning outcomes. In the realm of chemistry education, particularly in teaching the mole concept, video-based instruction has proven to be an effective pedagogical tool. A study by Fabeku and Enyeasi (2024) compared the effectiveness of computer simulation and video media instructional packages in enhancing students' performance and retention of chemistry concepts. The findings indicated that both instructional packages significantly improved students' performance; however, the computer simulation package demonstrated a higher effectiveness in enhancing students' retention of chemistry concepts. This suggests that while video-based instruction is beneficial, incorporating interactive elements like computer simulations may further enhance learning outcomes in complex topics such as the mole concept.

Recent research has consistently highlighted the positive influence of video-based instruction on students' learning outcomes in chemistry. For instance, Pekdağ (2020) conducted a quasi-experimental study using pre-test and post-test measures to evaluate the effectiveness of instructional videos. The findings revealed a significant improvement in students' mastery of chemistry content, demonstrating that video-based instruction can effectively address common learning difficulties and enhance conceptual understanding. In addition to improving academic performance, video-based instruction plays an important role in fostering student engagement and motivation, which are essential components of effective learning. Dong (2023) demonstrated that incorporating video-based resources in chemistry instruction enhanced both learning outcomes and student engagement across different teaching modes, including face-to-face, online, and multimodal formats. The interactive and visually appealing nature of videos makes learning more dynamic and helps sustain student interest in complex scientific topics.

The integration of video-based instruction in teaching the mole concept offers distinct pedagogical advantages. Videos can illustrate abstract ideas through visual demonstrations, provide step-by-step guidance in solving problems, and contextualize learning by showing real-life applications of the mole concept (Velázquez-Marcano et al., 2004). This multimodal approach accommodates diverse learning styles, thereby facilitating deeper understanding. Moreover, the ability for students to revisit video resources promotes self-paced learning and reinforcement, which ultimately supports long-term mastery of chemistry concepts.

4 METHODOLOGY

This study employed a mixed-methods quasi-experimental design, integrating quantitative and qualitative approaches to examine the influence of video-based instruction on Senior Two students' mastery of the mole concept. The quantitative component used a pre-test and post-test comparison between experimental and control groups to determine changes in students' conceptual understanding following the intervention, while the qualitative component explored students' perceptions of video-based instruction and the challenges associated with its

implementation (Creswell et al., 2004; Stadtländer, 2009). The quantitative component allowed for the measurement of changes in conceptual understanding through tests and questionnaires for determining the students' perceptions, while the qualitative component, through interviews, provided deeper insights into teachers' experiences (Stadtländer, 2009). The combination of these methods ensured triangulation of data, thereby enhancing the validity and reliability of the findings (Bans-Akutey and Tiimub, 2021).

The study population comprised senior two students and Chemistry teachers from two secondary schools in Burera District, Rwanda. Using Yamane formula, a total sample of 102 participants was selected, consisting of 100 students and two Chemistry teachers. The students were randomly assigned to either the control group, which received traditional teacher-centered instruction, or the experimental group, which was taught using video-based instruction. This sampling approach ensured that both groups were comparable and that any observed differences in outcomes could reasonably be attributed to the intervention.The intervention includes the process that the student in the experimental group studied the mole concepts by using videos related to mole concepts. While the students in control group received their instructions without using Videos from youtube. This was completed in three months.

Data collection instruments included achievement tests, questionnaires, and interviews (Oben, 2021). The achievement tests, administered as pre-tests and post-tests, were designed to measure students' conceptual understanding of the mole concept before and after the intervention. The used research instruments were validated. Questionnaires were used to capture students' perceptions of video-based instruction, focusing on its clarity, accessibility, and impact on motivation. Semi-structured interviews were conducted with the two Chemistry teachers to gain contextual insights into the practicality, challenges, and perceived benefits of integrating video-based instruction in a rural school setting.

4.1 Ethical Considerations

In this study, informed consent was obtained from all participants, and measures were taken to ensure confidentiality and anonymity of the information provided. Participants were treated with dignity and respect at all stages of the research process, in line with ethical standards for educational research.

4.2 Data analysis

The data analysis process involved both quantitative and qualitative techniques (Nassaji, 2015). Quantitative data from the achievement tests and student questionnaires were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed to summarize students' achievement and perceptions of video-based instruction. For the achievement-test data, an independent-samples *t*-test was used to determine whether there were statistically significant differences between the experimental and control groups, while a paired-samples *t*-test was used to examine changes in students' achievement from pre-test to post-test within each group. Where appropriate, the analysis also compared the groups' post-test performance to determine the effect of the video-based intervention. Questionnaire items were coded numerically and analyzed using frequencies, percentages, means, and standard deviations to determine students' perceptions of the clarity, usefulness, flexibility, engagement, and motivational value of video-based instruction. Qualitative data obtained from teacher interviews were analyzed using thematic analysis. The analysis involved transcription of the interviews,

repeated reading of the transcripts to ensure familiarity with the data, initial coding of meaningful statements, grouping related codes into categories, development and refinement of themes, and interpretation of the themes in relation to the quantitative findings. The qualitative findings were subsequently integrated with the quantitative results to provide a more comprehensive understanding of the effectiveness, students' perceptions, and implementation challenges associated with video-based instruction for learning the mole concept.

5 RESULTS

5.1 Influence of video-based instruction on students' understanding of the mole concept

The pre-test results show that students in the experimental group (M = 6.68, SD = 3.11) and the control group (M = 6.97, SD = 3.86) had similar levels of understanding of the mole concept prior to the intervention, with no statistically significant difference between the groups (t = -2.18, p = 0.19). This indicates that both groups started at a comparable baseline. The post-test results revealed a substantial improvement in the performance of students in the experimental group, who received video-based instruction (M = 8.18, SD = 1.00), compared with those in the control group (M = 6.00, SD = 1.62). The mean score difference of 2.18 indicates that students exposed to video-based instruction demonstrated a stronger understanding of the mole concept than those who received conventional instruction. An independent-samples t-test further showed that the difference between the two groups was statistically significant (t=7. 98, p < 0.001). These findings suggest that video-based instruction was effective in enhancing students' conceptual understanding of the mole concept **(Table 1)**.

Table 1: Influence of Video-Based Instruction on Students' Understanding of the Mole Concept

Test	Group	N	Mean	Std. Deviation	t	df	Sig. (2-tailed)
Pre-test	Experimental	50	6.68	3.11	-2.18	99	0.19
	Control	50	6.97	3.86			
Post-test	Experimental	50	8.18	1.00	7.98	99	0.001
	Control	50	6.00	1.62			

5.2 Students' perceptions of video-based instruction for learning scientific concepts

The results indicate that students perceived video-based instruction as highly beneficial in learning the mole concept. A substantial majority of participants agreed that videos made lessons more engaging (80%), enhanced their understanding of abstract concepts (82%), and allowed them to learn at their own pace (82%). These findings suggest that video-based learning provides both cognitive and motivational advantages, enabling students to visualize complex chemical ideas while fostering autonomy in the learning process. The ability to pause, rewind, and replay instructional content appears to give learners greater control over their studies, thereby reinforcing comprehension and retention. Furthermore, video-based instruction was shown to positively influence students' attitudes and confidence. About 74% of the participants agreed that videos increased their motivation to study chemistry and improved their confidence in solving mole-related problems. Only a small percentage of students expressed

disagreement across the items, suggesting that negative perceptions were minimal (Table 2).

Table 2: Students' perceptions of video-based instruction

Item	Strongly Agree (n, %)	Agree (n, %)	Neutral (n, %)	Disagree (n, %)	Strongly Disagree (n, %)
Video-based instruction makes learning the mole concept more engaging.	22 (44%)	18 (36%)	6 (12%)	3 (6%)	1 (2%)
Videos help me understand abstract concepts better than traditional teaching.	24 (48%)	17 (34%)	5 (10%)	3 (6%)	1 (2%)
I feel more motivated to learn when videos are used in teaching.	21 (42%)	16 (32%)	8 (16%)	4 (8%)	1 (2%)
Videos allow me to learn at my own pace (pause, rewind, and replay).	26 (52%)	15 (30%)	5 (10%)	3 (6%)	1 (2%)
Video-based instruction improves my confidence in solving mole problems.	20 (40%)	17 (34%)	8 (16%)	3 (6%)	2 (4%)

5.3 Students' perceived challenges of video-based instruction

The findings indicate that some challenges accompany the use of video-based instruction. Over half of the students (52%) agreed that relying solely on videos may hinder concentration, suggesting that videos should be supplemented with other interactive strategies to sustain attention. In addition, 52% of respondents reported limited access to computer device and internet as a barrier, highlighting infrastructural constraints that could restrict equitable use of video-based learning. These results point to the need for blended approaches and improved resource provision to maximize the effectiveness of video-based instruction.

Table 3: Students' perceived challenges of video-based instruction

Item	Strongly Agree (n, %)	Agree (n, %)	Neutral (n, %)	Disagree (n, %)	Strongly Disagree (n, %)
Relying only on videos may cause difficulty in maintaining concentration.	12 (24%)	14 (28%)	10 (20%)	9 (18%)	5 (10%)
Limited access to devices or internet is a challenge in using videos.	15 (30%)	11 (22%)	9 (18%)	10 (20%)	5 (10%)

5.4 Comparison of students' performance per question

Figure 1 presents the comparison of students' performance per question between the pre-test and post-test. The vertical axis represents the percentage of scores obtained, while the horizontal axis displays the individual test items (Q1–Q20) along with the overall average. The blue bars represent pre-test performance, and the orange bars represent post-test performance. The results indicate variation in students' performance across the individual items following the intervention. The largest improvements were observed in Q3, which increased from 8% in the pre-test to 16% in the post-test, and Q6, which increased from 12% to 19%, while Q9 showed a smaller increase from 16% to 18%. These changes suggest improved performance in the specific content areas assessed by these items and may indicate that students developed a better understanding of some aspects of the mole concept addressed during instruction. However, the relatively small changes observed in Q1, Q13, and Q14 suggest that difficulties persisted in the content areas assessed by these questions. Similarly, performance on Q8 decreased from 15% in the pre-test to 7% in the post-test, indicating that this particular concept remained challenging or that students experienced difficulty applying the relevant knowledge in the post-test context. Such item-level variations demonstrate that students did not experience uniform improvement across all aspects of the mole concept. Overall, the mean percentage score increased from 11.9% in the pre-test to 15.3% in the post-test, representing a 3.4-percentage-point increase in overall performance. This descriptive improvement indicates higher post-test performance; however, item-level differences alone cannot establish that the instructional intervention caused the observed changes. The effectiveness of the intervention should therefore be determined primarily from the appropriate inferential comparison of pre-test and post-test performance between the experimental and control groups. The variation across items further highlights specific areas of the mole concept that may require additional explanation, practice, and reinforcement.

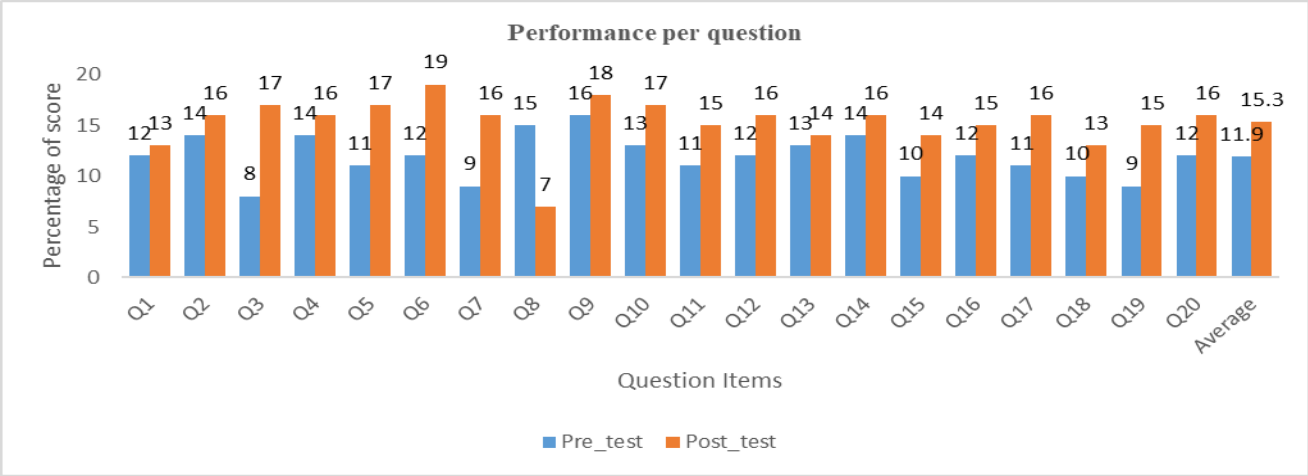


Figure 1: Students' performance per question

5.5 Insights from the chemistry teacher

To gain a deeper understanding of the influence of video-based instruction on students' mastery of the mole concept, semi-structured interviews were conducted with the two Chemistry teachers involved in the study. The interview data were used to complement the quantitative findings by providing contextual explanations for the observed changes in students' achievement between the pre-test and post-test and to triangulate students' reported perceptions of video-based instruction. In particular, teachers' observations provided insights into students' conceptual understanding, engagement, participation, motivation, and learning behaviours during the intervention, while also helping to explain areas in which students demonstrated greater or limited improvement. Furthermore, the interviews identified practical challenges associated with implementing video-based instruction, including technological, infrastructural, and classroom-related constraints. Thus, the qualitative findings provided contextual depth to the quantitative results and students' perceptions, enabling a more comprehensive interpretation of both the effectiveness and feasibility of video-based instruction for teaching the mole concept.

a. Enhanced conceptual understanding

The teachers emphasized that video-based instruction helped students understand abstract aspects of the mole concept more clearly. One teacher explained:

"The videos helped students to see and understand the mole concept more clearly. The visual explanations made some of the abstract ideas easier for them to understand than when we explained them using only the traditional classroom approach." (Teacher 1)

Similarly, the second teacher observed:

"When students watched the videos, they could connect the explanation with the examples presented. This helped them to understand concepts that they previously found difficult." (Teacher 2)

b. Increased student engagement and motivation

The teachers also reported increased student interest and participation during video-based lessons. Teacher 1 stated:

"Students were more interested when the videos were used. They paid more attention and participated more actively in the lesson compared with some of the lessons where we mainly used the traditional method." (Teacher 1)

Teacher 2 similarly noted:

"The videos made the lesson more interesting to the students. They were eager to watch, ask questions, and participate in the activities that followed the video." (Teacher 2)

These observations are consistent with students' positive perceptions of video-based instruction and indicate that the multimedia approach supported greater classroom engagement and motivation.

c. Support for self-paced learning

The teachers further highlighted the flexibility provided by video-based learning. Teacher 1 explained:

"One advantage of the videos was that students could go back and watch the explanation again when they did not understand it the first time. This

was helpful for students who needed more time to understand the concept." (Teacher 1)

Teacher 2 added:

"Students were able to pause and replay parts that they found difficult. This gave them an opportunity to learn at their own pace and review the explanation before attempting the exercises." (Teacher 2)

These accounts indicate that the videos provided opportunities for repeated exposure to difficult content and supported students with different learning needs and levels of prior knowledge.

d. Challenges associated with implementation

Despite these benefits, the teachers identified technological and pedagogical challenges associated with implementing video-based instruction. Teacher 1 reported:

"The main challenge was access to the technology. Sometimes there were problems with electricity or internet connectivity, which made it difficult to use the videos as planned." (Teacher 1)

Teacher 2 similarly explained:

"Using videos requires proper preparation and teacher guidance. If students only watch the video without discussion, questions, or exercises, some of them may not fully understand the concept." (Teacher 2)

These responses indicate that the effectiveness of video-based instruction depends not only on the availability of instructional videos but also on adequate technological infrastructure and active teacher facilitation.

The teachers' accounts provide contextual support for the quantitative findings and students' perceptions. Their observations indicate that video-based instruction contributed to clearer explanations, increased engagement, and opportunities for self-paced learning, while technological limitations and the need for teacher-guided activities remained important implementation challenges.

6. DISCUSSION

This study examined the influence of video-based instruction on Senior Two students' understanding of the mole concept, students' perceptions of the approach, and the challenges associated with its implementation in a rural school context. The findings provide evidence that video-based instruction can support chemistry learning when multimedia resources are integrated with teacher guidance and classroom activities. The quantitative, questionnaire, and teacher-interview findings converged in showing improvements in students' achievement, positive perceptions of video-based learning, and several contextual challenges that may influence its implementation. These findings are discussed below in relation to the study objectives and the relevant theoretical and empirical literature. The quantitative findings indicate that the experimental and control groups were comparable before the intervention, as no statistically significant difference was observed in their pre-test performance. Following the intervention, however, the experimental group demonstrated significantly higher post-test performance than the control group. This finding suggests that exposure to video-based instruction was associated with improved achievement in the mole concept. Because the study employed a quasi-experimental design rather than random assignment, the finding should be interpreted as evidence of an association between the intervention and improved achievement rather than definitive proof of causality.

The observed improvement is consistent with Mayer's Cognitive Theory of Multimedia Learning, which proposes that learners can construct meaningful understanding when verbal and visual information are appropriately integrated through separate but interacting cognitive channels (Mayer, 2009). Video-based instruction may therefore have supported students in linking verbal explanations, visual representations, symbolic expressions, and examples related to the mole concept. This is particularly relevant to chemistry, where learners are required to move between macroscopic observations, microscopic particle representations, and symbolic or mathematical representations. Similar evidence has shown that well-designed educational videos can support learning by presenting difficult content through multiple modes of representation (Ibrahim, 2012; Kay, 2012).

The item-level results provide additional insight into the pattern of students' learning. Improvements were observed in several items, including Q3, Q6, and Q9, although the magnitude of improvement differed across questions. These differences suggest that students may have experienced greater progress in some of the content areas assessed than in others. Conversely, the decline observed for Q8 and the limited changes in Q1, Q13, and Q14 indicate that some aspects of the mole concept remained challenging after the intervention. These findings are important because they show that video-based instruction should not be assumed to address all dimensions of conceptual difficulty equally. Rather, videos may provide an effective representation of content while still requiring follow-up explanation, guided practice, questioning, and formative assessment to address persistent misconceptions and difficulties.

The teacher interviews help explain these quantitative patterns. The teachers reported that visual explanations made some abstract aspects of the mole concept easier for students to understand and that students were able to revisit explanations when they experienced difficulty. These observations provide contextual support for the quantitative improvement and are consistent with students' positive perceptions of the clarity and usefulness of the videos. At the same time, teachers indicated that videos were more effective when accompanied by teacher explanations, questions, and exercises. This finding suggests that the observed improvement was not simply a result of exposure to videos but occurred within a teacher-supported instructional environment. The second objective examined students' perceptions of video-based instruction. The findings indicate generally positive perceptions, particularly regarding clarity, engagement, motivation, and opportunities for self-paced learning. Students perceived the videos as useful for explaining difficult aspects of the mole concept and as providing opportunities to review instructional content. These perceptions were reinforced by the teachers' observations that students appeared more attentive and willing to participate during video-supported lessons.

The finding is consistent with constructivist perspectives, which emphasize active learner involvement and the importance of learners engaging with information rather than passively receiving it (Jonassen, 1995). Video-based instruction can provide opportunities for learners to observe explanations repeatedly and connect new information with existing knowledge. Similarly, Kay (2012) reported that educational videos can support student engagement and learning when appropriately designed and integrated into instruction. However, positive perceptions should not be interpreted as evidence in themselves of improved achievement. Rather, the questionnaire findings complement the achievement results by showing how students experienced the instructional approach.

The teachers' qualitative accounts further suggest that flexibility was an important feature of video-based learning. Students could pause,

replay, and revisit explanations, which potentially supported learners who required additional time to process difficult content. This is particularly relevant in learning the mole concept because students differ in their prior knowledge of chemical quantities, mathematical relationships, and symbolic representations. Nevertheless, self-paced access alone may not guarantee conceptual mastery. Teacher guidance remains important to help students identify misconceptions, interpret representations, and apply the concept to unfamiliar problems.

Although the findings demonstrate potential benefits of video-based instruction, the study also identified challenges associated with implementation. The teachers reported difficulties related to access to digital resources, electricity and internet connectivity, as well as the need for adequate teacher guidance. These challenges are particularly significant in rural schools, where technological infrastructure and access to digital learning resources may be more constrained than in better-resourced settings. The findings therefore demonstrate that the effectiveness of video-based instruction is partly dependent on the conditions under which it is implemented. A video-based intervention that works effectively where electricity, internet connectivity, devices, and technical support are readily available may not produce the same experience in a resource-constrained rural classroom. Consequently, technology integration in rural Rwanda should be designed around the realities of the local context. Offline-accessible videos, locally stored digital resources, shared devices, appropriate lesson planning, and teacher preparation may help reduce dependence on continuous internet connectivity.

The teachers also emphasized that videos should not replace teacher-student interaction. When videos were used without discussion, questioning, exercises, or teacher explanation, students could experience difficulties in maintaining attention or interpreting the content. This finding is consistent with the broader multimedia-learning literature, which emphasizes that multimedia does not automatically produce meaningful learning; instructional design and appropriate learner engagement remain essential (Mayer, 2009). Thus, the findings support a blended approach in which videos function as instructional resources within a broader pedagogical framework rather than as stand-alone teaching tools. Taken together, the quantitative and qualitative findings provide complementary evidence concerning the potential of video-based instruction for teaching the mole concept. The achievement-test results demonstrate changes in students' performance, the questionnaire findings indicate generally positive student perceptions, and the teacher interviews provide contextual explanations concerning students' engagement, conceptual understanding, self-paced learning, and implementation challenges. The convergence of these findings strengthens the interpretation of the study because each data source contributes a different perspective on the instructional approach.

The findings have important implications for chemistry teaching in rural Rwandan secondary schools. First, video-based resources can provide additional representations of abstract chemical concepts and may therefore be incorporated into chemistry lessons where appropriate. Second, teachers should integrate videos with questioning, guided practice, discussion, and formative assessment rather than treating video viewing as a complete instructional strategy. Third, implementation should consider local infrastructural conditions by prioritizing resources that can be accessed offline and reused without continuous internet connectivity. Finally, teacher professional development should include not only technical skills but also pedagogical strategies for selecting, sequencing, and facilitating multimedia resources. The study suggests that video-based instruction has potential to support students' learning of the mole concept, but its value depends on how it is pedagogically integrated and the conditions in

which it is implemented. The findings the refore extend existing multimedia-learning evidence by demonstrating the relevance of video-supported chemistry instruction to a rural Rwandan context while also highlighting the infrastructural and pedagogical conditions that need to be considered when implementing such approaches in resource-constrained secondary schools.

7 CONCLUSION

This study examined the influence of video-based instruction on Senior Two students' understanding of the mole concept, students' perceptions of the approach, and the challenges associated with its implementation in a rural school context. The findings showed that the experimental group achieved significantly higher post-test performance than the control group, indicating that video-based instruction was associated with improved achievement in the mole concept. However, given the quasi-experimental design, this finding should be interpreted as evidence of an intervention-related difference rather than definitive causal proof. Students generally expressed positive perceptions of video-based instruction, particularly regarding conceptual clarity, engagement, motivation, and opportunities to review content at their own pace. Teacher interviews further supported these findings by indicating that videos helped students engage with abstract concepts and revisit difficult explanations. Nevertheless, implementation was constrained by challenges related to digital resources, electricity and internet connectivity, and the need for teacher-guided activities. Overall, the findings indicate that video-based instruction can be a useful component of chemistry teaching when appropriately integrated with teacher support and other classroom learning activities.

Competent of interest

The authors declare that there is no conflict of interest to disclose.

REFERENCES

Bans-Akutey, A., & Tiimub, B. M. (2021). Triangulation in research. *Academia Letters*, *2*(3392), 1–7.

Bohloko, M., Makatjane, T. J., Mokuku, T., & George, M. J. (2019). Assessing the effectiveness of using YouTube videos in teaching the chemistry of group i and vii elements in a high school in Lesotho. *African Journal of Research in Mathematics, Science and Technology Education*, *23*(1), 75–85.

Creswell, J. W., Fetters, M. D., & Ivankova, N. V. (2004). Designing a mixed methods study in primary care. *The Annals of Family Medicine*, *2*(1), 7–12.

Dogbey, R. P. K. (2021). *Using concept mapping strategy to improve the teaching and learning of mole concept in keta Business College*. University of Education, Winneba.

Dong, H. (2023). Supporting faculty's instructional video creation needs for remote teaching: A case study on implementing eGlass technology in a library multimedia studio space. *Information Technology and Libraries*, *42*(2), 1–23.

Fabeku, O. E., & Enyeasi, S. C. (2024). Computer simulation and video media instructional packages in improving learning outcomes of Chemistry students in Ife Central Local Government Area. *Disciplinary and Interdisciplinary Science Education Research*, *6*(1), 1–13.

Fajebe, A. A., Best, M. L., & Smyth, T. N. (2013). Is the one laptop per child enough? Viewpoints from classroom teachers in Rwanda. *Information Technologies & International Development*, *9*(3), pp-29.

Fernández, A. A., López-Torres, M., Fernández, J. J., & Vázquez-García, D. (2023). Student-generated videos to promote understanding of chemical reactions. *Journal of Chemical Education*, *100*(2), 1039–1046.

Fujioka, R. (2017). Investigating the impact of video instruction in a high school chemistry class. *Annual Technology, Colleges and Community Worldwide Online Conference.*., 20–32.

Galatsopoulou, F., Kenterelidou, C., Kotsakis, R., & Matsiola, M. (2022). Examining students' perceptions towards video-based and video-assisted active learning scenarios in journalism and communication courses. *Education Sciences*, *12*(2), 74.

Habarurema, J. B., Limone, P., Bikorimana, E., & Di Fuccio, R. (2024). Technology-Enhanced Learning in Africa: A Challenge and Opportunity? *Africa Education Review*, *20*(6), 20–57.

Ibrahim, M. (2012). Implications of designing instructional video using cognitive theory of multimedia learning. *Critical Questions in Education*, *3*(2).

Jonassen, D. H. (1995). Computers as cognitive tools: Learning with technology, not from technology. *Journal of Computing in Higher Education*, *6*(2), 40–73.

Jordan, J. T., Box, M. C., Eguren, K. E., Parker, T. A., Saraldi-Gallardo, V. M., Wolfe, M. I., & Gallardo-Williams, M. T. (2016). Effectiveness of student-generated video as a teaching tool for an instrumental technique in the organic chemistry laboratory. *Journal of Chemical Education*, *93*(1), 141–145.

Kalyani, L. K. (2024). The role of technology in education: Enhancing learning outcomes and 21st century skills. *International Journal of Scientific Research in Modern Science and Technology*, *3*(4), 5–10.

Kay, R. H. (2012). Exploring the use of video podcasts in education: A comprehensive review of the literature. *Computers in Human Behavior*, *28*(3), 820–831.

Khasawneh, M. A. S. (2024). The Role of the Multi-Sensory Environment in Developing Learning Skills Among Students with Learning Difficulties in the Asir Region. *Kurdish Studies*, *12*(1).

Khomyshak, O. (2024). Video-Based Learning in The Digital Age: Challenges and Opportunities. *Information Technologies and Learning Tools*, *104*(6), 14.

Krajcik, J. S., & Mun, K. (2014). Promises and challenges of using learning technologies to promote student learning of science. *Handbook of Research on Science Education*, *2*(1), 337–360.

Kumar, S. (2025). " Atoms Don't Behave That Way!"–Investigating Student Misconceptions in Stoichiometry and the Mole Concept. *Edumania-An International Multidisciplinary Journal*, *3*(03), 216–239.

Luo, T., Hostetler, K., Freeman, C., & Stefaniak, J. (2020). The power of open: Benefits, barriers, and strategies for integration of open educational resources. *Open Learning: The Journal of Open, Distance and e-Learning*, *35*(2), 140–158.

Mayer, R. E. (2005). Cognitive theory of multimedia learning. *The Cambridge Handbook of Multimedia Learning*, *41*(1), 31–48.

Mpumuje, M. (2024). Information Communication Technology (ICT) Integration in Teaching and Learning in Selected Rural Secondary School in Burera District, Rwanda. *African Journal of Empirical Research*, *5*(2), 453–461.

Mushimiyimana, J. B., Nzabalirwa, W.,

Ndayambaje, I., & Lazareva, A. (2026). Examining teacher educators' technological proficiency and barriers to ICT integration in pre-service teacher education in Rwanda. *Cogent Education*, *13*(1), 2710461.

Namgyel, T. (2013). Teacher-centered instructional delivery affecting students' learning. *Journal of the International Society for Teacher Education*, *17*(2), 60–69.

Nassaji, H. (2015). Qualitative and descriptive research: Data type versus data analysis. In *Language teaching research* (Vol. 19, Issue 2, pp. 129–132). Sage Publications Sage UK: London, England.

Navarrete, E., Nehring, A., Schanze, S., Ewerth, R., & Hoppe, A. (2025). A closer look into recent video-based learning research: A comprehensive review of video characteristics, tools, technologies, and learning effectiveness. *International Journal of Artificial Intelligence in Education*, *1*(1), 1–64.

Nsabayezu, E., Habimana, O., Nzabalirwa, W., & Niyonzima, F. N. (2025a). 6Ps-based instructional model: An innovative framework for supporting organic chemistry education through a multimedia-supported flipped classroom approach. *Discover Education*, *4*(1), 1–23. https://doi.org/https://doi.org/10.1007/s44217-025-00775-1

Nsabayezu, E., Habimana, O., Nzabalirwa, W., & Niyonzima, F. N. (2025b). Using multimedia-supported flipped classrooms approach to modernize organic chemistry instruction: exploring students' and teachers' challenges. *Discover Education*, *4*(1), 267.

Oben, A. I. (2021). Research instruments: A questionnaire and an interview guide used to investigate the implementation of higher education objectives and the attainment of Cameroon's Vision 2035. *European Journal of Education Studies*, *8*(7).

Owusu, F. K. (2020). *Using problem-based learning approach to improve the performance of science students in mole concept, a case study at Techiman Senior High School*. University of Education, Winneba.

Pal, D., & Patra, S. (2021). University students' perception of video-based learning in times of COVID-19: A TAM/TTF perspective. *International Journal of Human–Computer Interaction*, *37*(10), 903–921.

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.

Ramesh, A. P. V., Abd Rauf, R. A., & Fadzil, H. M. (2021). ISSUES IN TEACHING MOLE CONCEPTS FOR MEANINGFUL LEARNING. *Journal of Issue In Education*, *44*(1), 1–10.

Soltura, R. T. (2021). Designing context-based video instruction in enhancing the conceptual understanding of Grade XI students. *Indonesian Journal of Educational Research and Review*, *4*(3), 409–423.

Stadtländer, C. T.-H. (2009). Qualitative, quantitative, and mixed-methods research. *Microbe Magazine*, *4*(11), 485.

Staver, J. R., & Lumpe, A. T. (1995). Two investigations of students' understanding of the mole concept and its use in problem solving. *Journal of Research in Science Teaching*, *32*(2), 177–193.

Twagilimana, I., Perumal, J., Habimana, O., Dlamini, R., Ndayambaje, I., Emmanuel, O., Niyibizi, E., Makalela, L., Makda, F., & Ezechiel, N. (2026). Integrating ICT in Rwandan schools to enhance access proficiency and utilization. *Discover Education*, *5*(1), 80.

Velázquez-Marcano, A., Williamson, V. M., Ashkenazi, G., Tasker, R., & Williamson, K. C. (2004). The use of video demonstrations and particulate animation in general chemistry. *Journal of Science Education and Technology*, *13*(3), 315–323.

Wang, C., Chen, X., Yu, T., Liu, Y., & Jing, Y. (2024). Education reform and change driven by digital technology: A bibliometric study from a global perspective. *Humanities and Social Sciences Communications*, *11*(1), 256.

Wang, J., Tang, H., Kantor, T., Soltani, T., Popov, V., & Wang, X. (2024). Surgment: segmentation-enabled semantic search and creation of visual question and feedback to support video-based surgery learning. *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*, 1–18.

Woldemariam, D. Y., Ayele, H. S., Kedanemariam, D. A., Mengistie, S. M., & Beyene, B. B. (2024). Effects of technology-assisted chemistry instruction on students' achievement, attitude, and retention capacity: A systematic review. *Education and Information Technologies*, *29*(11), 13763–13785. https://doi.org/10.1007/s10639-023-12411-2

Yousef, A. M. F., Chatti, M. A., & Schroeder, U. (2014). The state of video-based learning: A review and future perspectives. *International Journal on Advances in Life Sciences*, *6*(3), 122–135.