10.22633/rpge.v29iesp4.20768

Revista on line de Política e Gestão Educacional
Online Journal of Policy and Educational Management

[1] University of Education, Hue University (HUEdU), Hue – Vietnam. Lecturer, Department of Chemistry Education.

CHARACTER-BASED CHEMISTRY ANIMATIONS FOR ENHANCING STUDENT INTEREST: DESIGN, IMPLEMENTATION, AND EVALUATION THROUGH MIXED METHODS

ANIMAÇÕES DE QUÍMICA BASEADAS EM PERSONAGENS PARA AUMENTAR O INTERESSE DOS ALUNOS: DESIGN, IMPLEMENTAÇÃO E AVALIAÇÃO POR MEIO DE MÉTODOS MISTOS

ANIMACIONES DE QUÍMICA BASADAS EN PERSONAJES PARA AUMENTAR EL INTERÉS DEL ESTUDIANTADO: DISEÑO, IMPLEMENTACIÓN Y EVALUACIÓN MEDIANTE MÉTODOS MIXTOS

Trang Nguyen Thi THUY[1]
ntttrang.hued@hueuni.edu.vn

How to reference this paper:

Thuy, T. N. T. (2025). Character-based chemistry animations for enhancing student interest: design, implementation, and evaluation through mixed methods. *Revista on line de Política e Gestão Educacional*, *29*(esp4), e025099. https://doi.org/10.22633/rpge.v29iesp4.20768

Submitted: 20/11/2025
Revisions required: 25/11/2025
Approved: 04/12/2025
Published: 20/12/2025

ABSTRACT: The decline in student interest in Chemistry poses challenges for science education, often linked to the subject's abstract and demanding nature. This study designed and evaluated character-based animated videos to foster engagement in Chemistry learning. Thirty animations were developed for seven units of the Vietnamese Grade 10 curriculum. Depending on learning objectives, each theme comprised one or more pairs of complementary videos following a dual structure: problem-posing videos introducing real-life contextual challenges and explanatory videos visualizing molecular-level processes. The research adopted a mixed-methods design involving 57 Chemistry teachers and 137 students in Vietnam. Quantitative data were analyzed using descriptive statistics and Kruskal–Wallis tests, while thematic analysis was applied to qualitative responses. Both teachers and students rated the videos highly for clarity, pedagogical value, and emotional appeal. Character-driven storytelling enhanced curiosity and sustained attention, while the dual-video design effectively supported inquiry-based learning.

KEYWORDS: Animated videos. Chemistry education. Educational technology. Instructional design. Situational interest.

RESUMO: *O declínio do interesse dos alunos pela Química representa um desafio para o ensino de ciências, frequentemente associado à natureza abstrata e exigente da disciplina. Este estudo concebeu e avaliou vídeos animados com personagens para promover o engajamento na aprendizagem de Química. Trinta animações foram desenvolvidas para sete unidades do currículo do 10º ano do ensino fundamental no Vietnã. Dependendo dos objetivos de aprendizagem, cada tema compreendia um ou mais pares de vídeos complementares, seguindo uma estrutura dupla: vídeos que apresentavam problemas contextualizados da vida real e vídeos explicativos que visualizavam processos em nível molecular. A pesquisa adotou uma metodologia mista, envolvendo 57 professores de Química e 137 alunos no Vietnã. Os dados quantitativos foram analisados por meio de estatística descritiva e testes de Kruskal-Wallis, enquanto a análise temática foi aplicada às respostas qualitativas. Tanto professores quanto alunos avaliaram os vídeos positivamente em termos de clareza, valor pedagógico e apelo emocional. A narrativa centrada nos personagens aumentou a curiosidade e sustentou a atenção, enquanto o design com dois vídeos apoiou efetivamente a aprendizagem baseada em investigação.*

PALAVRAS-CHAVE: *Vídeos animados. Ensino de química. Tecnologia educacional. Design instrucional. Interesse situacional.*

RESUMEN: *La disminución del interés del alumnado por la Química constituye un desafío para la enseñanza de las ciencias, frecuentemente asociado al carácter abstracto y exigente de la disciplina. Este estudio diseñó y evaluó videos animados con personajes para promover el compromiso en el aprendizaje de Química. Se desarrollaron treinta animaciones para siete unidades del currículo de 10.º grado de la educación básica en Vietnam. Según los objetivos de aprendizaje, cada tema incluía uno o más pares de videos complementarios, siguiendo una estructura doble: videos que presentaban problemas contextualizados de la vida real y videos explicativos que visualizaban procesos a nivel molecular. La investigación adoptó un enfoque mixto, envolvendo 57 docentes de Química y 137 estudiantes en Vietnam. Los datos cuantitativos se analizaron mediante estadística descriptiva y pruebas de Kruskal-Wallis, mientras que el análisis temático se aplicó a las respuestas cualitativas. Tanto docentes como estudiantes evaluaron positivamente los videos en términos de claridad, valor pedagógico y atractivo emocional. La narrativa centrada en los personajes incrementó la curiosidad y mantuvo la atención, mientras que el diseño de dos videos apoyó de manera efectiva el aprendizaje basado en la indagación.*

PALABRAS CLAVE: *Videos animados. Enseñanza de la química. Tecnología educativa. Diseño instruccional. Interés situacional.*

Article submitted to the similarity system

iThenticate

Editor: Prof. Dr. Sebastião de Souza Lemes
Deputy Executive Editor: Prof. Dr. José Anderson Santos Cruz.

INTRODUCTION

The decline in student interest in science subjects, particularly Chemistry, represents a global educational challenge. While science disciplines are fundamental to fostering critical thinking and problem-solving skills, many secondary school students perceive Chemistry as a dry, abstract, and cognitively demanding subject (Brunyé et al., 2008; Schiefele et al., 1983). This context is particularly pressing in Vietnam amidst ongoing educational reforms. The 2018 General Education Curriculum has transitioned Chemistry from a compulsory to an elective subject, placing greater pressure on educators to design engaging and relevant pedagogical approaches to sustain student interest. A national survey revealed that over 50% of Chemistry teachers observed negative student attitudes toward the subject, manifested as boredom and disengagement, which they attributed to an overloaded curriculum and uninspiring teaching methods (Hoa, 2015).

To address this issue, pedagogical innovation and the integration of educational technology are crucial. Animated videos have emerged as an effective tool for engaging students, especially in science subjects with complex, microscopic concepts. Mayer's cognitive theory of multimedia learning (Mayer, 2001, 2014) provides a solid theoretical foundation, emphasizing the importance of dual-channel processing (visual and auditory) and the reduction of extraneous cognitive load. Numerous empirical studies have demonstrated that well-designed animated videos can improve students' scientific reasoning, conceptual understanding, and academic achievement compared to traditional static materials (Arumugam & Nirmala, 2018; Yaseen, 2018).

This study proposes an innovative pedagogical model to enhance student interest through the use of animations featuring anthropomorphized chemical characters. These videos are created using a variety of accessible digital tools, including artificial intelligence (AI). Unlike content found on many popular educational platforms, our model is built on a unique two-step process: (1) Problem-Posing Animation to stimulate curiosity and critical thinking before a lesson, and (2) Explanatory Animation to provide solutions after students have had time to reflect. This approach is inspired by Problem-Based Learning and theories of interest development, such as the framework by Hidi and Renninger (2006), where situational interest is a key precursor to long-term individual interest.

However, a significant research gap exists in Vietnam. Most domestic studies on the use of animation in science education lack content specificity, fail to align with the 2018 curriculum, and often do not apply established theories of multimedia learning or interest development (Hùng & Linh, 2022; Minh & An, 2023). Furthermore, the absence of mixed-methods research (combining quantitative and qualitative data) has limited the empirical evidence regarding the impact of animation on both cognitive outcomes and affective engagement.

Therefore, the objective of this study is to develop and evaluate the effectiveness of Chemistry animations designed with a two-step model and featuring anthropomorphized characters. The specific research questions are:

How can anthropomorphized Chemistry animations be designed to align with both pedagogical principles and the new national curriculum's scientific content requirements?

How do students and teachers evaluate the appropriateness and appeal of these character-based Chemistry animations?

To what extent do these animations enhance students' situational interest in Chemistry learning?

This research not only provides a concrete solution for the Vietnamese educational context but also offers an innovative, replicable instructional design model with clear empirical evidence that can be referenced and applied to the teaching of STEM subjects in other countries.

Theoretical framework

This study is built upon a solid theoretical foundation that systematically integrates principles from multimedia learning, cognitive load theory, and interest development. The synthesis of these frameworks not only provides a rationale for our instructional design but also explains how our designed animations can foster student engagement and a deeper understanding of Chemistry. The following sections detail how each theory informed the design and evaluation of our educational animations.

Pedagogical potential of animation in chemistry education

In the context of advancing information and communication technologies, animated videos have become a powerful medium for enhancing situational interest and improving learning outcomes. In Chemistry—a discipline filled with abstract, microscopic concepts—animated videos are particularly useful for bridging the gap between observable phenomena and molecular-level processes (Chang & Quintana, 2006; Vermaat & Kramers-Pals, 2003; Yaseen, 2018). They promote multimodal learning by combining visuals, narration, and sound to stimulate multiple sensory channels (Barak et al., 2011), which aids in both comprehension and memory retention. Empirical studies have shown that well-designed animations can enhance students' scientific reasoning, improve conceptual understanding, and increase achievement when compared to traditional static materials (Arumugam & Nirmala, 2018; Demissie et al.,

10.22633/rpge.v29iesp4.20768

2011; Yusuf, 2017). When infused with narrative elements, emotional cues, and character-based storytelling, animations also boost learners' intrinsic motivation and interest (Barak et al., 2011; Bülbül & Kuzu, 2021). These qualities make animations especially effective for secondary school Chemistry, where engagement is often undermined by cognitive overload and abstract content.

Cognitive theory of multimedia learning and cognitive load theory

To address the cognitive challenges of learning abstract Chemistry concepts, our instructional design is grounded in the synergistic principles of Richard Mayer's Cognitive Theory of Multimedia Learning (Mayer, 2001, 2014) and John Sweller's Cognitive Load Theory (Sweller, 1998). Cognitive Theory of Multimedia Learning posits that the human mind processes information through separate visual and auditory channels, each with a limited capacity. Meaningful learning occurs when learners actively select, organize, and integrate information from both channels. Based on this, our animations combine dynamic visuals, narration, and text to maximize this dual-channel processing.

Cognitive Load Theory further informs our design by distinguishing between three types of cognitive load: intrinsic load (the inherent difficulty of the material), extraneous load (caused by poor instructional design), and germane load (the cognitive effort required for schema formation). Our animation design specifically aims to minimize extraneous load by avoiding distracting elements and redundant on-screen text, while also reducing intrinsic load by visually representing complex, abstract concepts through characters and narratives. This approach, which directly applies Mayer's personalization principle (using conversational agents and characters to make content more engaging), makes the content more accessible and allows students to focus on germane load—the essential

Problem-based learning and interest theory

This study proposes an innovative pedagogical model designed to foster critical thinking and sustained interest by leveraging the principles of Problem-Based Learning and Inquiry-Based Learning. The model uses a unique two-step animation process: a problem-posing animation to stimulate curiosity, followed by an explanatory animation to provide a solution. This approach is designed to activate a self-directed, inquiry-driven learning process.

This approach is consistent with the four-phase framework of interest development (Hidi & Renninger, 2006), where a triggered situational interest (sparked by the problem-posing video) can evolve into a more maintained situational interest (supported by the explanatory video and subsequent learning activities). This theoretical alignment provides a robust framework for assessing the animations' potential to influence students' motivation and learning behavior.

Multimodal assessment

To comprehensively capture the complex and context-dependent nature of student engagement, this study adopts a multi-method approach to evaluation, as recommended by contemporary theories of interest (Renninger & Hidi, 2011). While self-report instruments (e.g., Likert-scale questionnaires) are useful for gauging perceived engagement, they are susceptible to social desirability bias and may not capture spontaneous, in-the-moment responses (Paulhus, 1991). To address this limitation, our methodology adds a layer of objective data from facial expression analysis. This non-intrusive method provides a reliable measure of affective engagement, allowing us to identify expressions such as curiosity, enjoyment, and focused attention (D'Mello & Graesser, 2012; Ekman, 1978). By combining self-report and behavioral data, this study can capture the complex nature of student engagement with instructional media, thereby providing a more comprehensive and robust picture of their impact.

In summary, our study's design is not an isolated pedagogical experiment but is systematically informed by an integrated theoretical framework. We apply the principles of Cognitive Theory of Multimedia Learning and Cognitive Load Theory to create animated content that is both cognitively sound and visually engaging. We leverage Problem-Based Learning and Interest Theory to structure this content in a way that actively nurtures student curiosity and engagement. Finally, we employ a multimodal assessment approach to provide a rigorous, multi-layered evaluation of our animations' effectiveness. This robust theoretical foundation serves as the core justification for our methodology and provides a clear pathway for interpreting our findings.

METHODOLOGY

Animated video design

The animations were developed based on four core principles: (1) Pedagogical appropriateness, ensuring compatibility with teaching objectives and methods; (2) Scientific accuracy, maintaining the correctness of chemical concepts; (3) Cognitive suitability, presenting an optimal amount of information to avoid excessive cognitive load; and (4) Educational animation design criteria, which include clarity of content, visual presentation, and applicability in a classroom context.

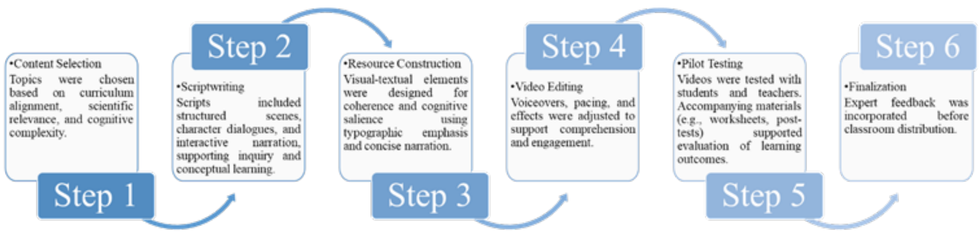
The videos were first systematically constructed based on the Vietnamese Grade 10 Chemistry Curriculum (Ministry of Education and Training, 2018), covering seven knowledge units and their required learning outcomes. Specifically, these units include Atomic Structure, The Periodic Table of Elements, Chemical Bonds, Redox Reactions, Chemical Energy, Reaction Rate, and Group VIIA Elements. Sub-topics requiring visual representation—due to their abstract, kinetic, or microscopic nature—were given priority. For example, for the topic of redox reactions, a core competency is for students to “identify redox reactions in daily life” and “describe the change in oxidation number.”

To enhance student engagement and facilitate the comprehension of abstract concepts, we adopted a character design principle where chemical elements and compounds are personified. This approach, inspired by Mayer’s personalization principle of Multimedia Learning Theory, gives each character a personality that reflects its chemical properties. For instance, the Zinc atom is personified as an active, friendly character who easily “gives away” its electrons, while the Copper ion is depicted as a shy character with a distinctive blue color. This design choice is intended to make the interactions between substances more relatable and memorable for students.

As illustrated in Figure 1, the animation video development process comprised six systematic stages, each ensuring pedagogical coherence and cognitive effectiveness.

Figure 1

Six-step Development Process of the Chemistry Animated Videos



Note. Prepared by the authors.

The primary tools used in the design and production process included Canva (for graphic and layout design), CapCut (for video editing and motion graphics), and various AI applications for voice synthesis and media processing. This approach allows educators with limited resources to create high-quality, customized educational content.

A total of 30 animations were developed, distributed across the seven knowledge units in the Grade 10 Chemistry curriculum. Each selected sub-topic features a pair of videos: a problem-posing video and an explanatory video. This dual structure integrates guided instruction with autonomous exploration, fostering inquiry-based learning. For example, a problem--posing video uses storytelling to pique curiosity, while its accompanying explanatory video

e-ISSN: 1519-9029
10.22633/rpge.v29iesp4.20768

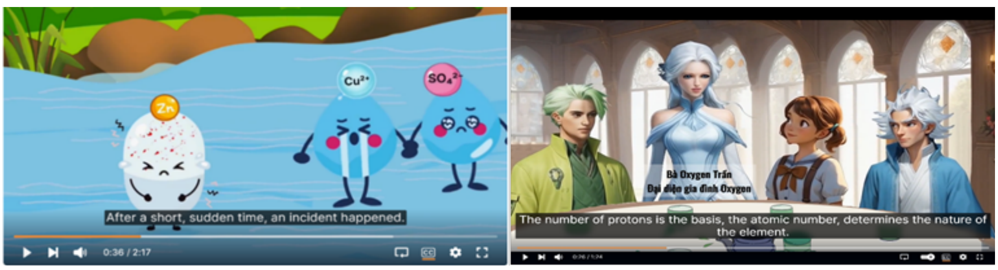
provides a detailed, molecular-level analysis. This design ensures a consistent pedagogical role across topics, with each concept being approached through both exploratory and explanatory modalities. The videos are partially published on the GanjingWorld platform (https://www.ganjingworld.com/s/bON8yNm9p9).

To illustrate our design and pedagogical approach, this section will analyze two examples from the developed animated videos. These examples demonstrate how we use storytelling and personified characters, supported by AI tools, to make complex chemical concepts understandable and age-appropriate for students.

Case Study 1: The Redox Reaction between Zinc and Copper (II) Sulfate. To illustrate our dual video structure, we analyze the video on the reaction between Zinc (Zn) and Copper (II) sulfate ($CuSO$). The animation link for this content is: https://www.ganjingworld.com/vi-VN/video/1hep772fbq26rejaal4oKiEOZ1q21c?playlist_id=1hep7c1o3va1UyUphcvPpEM16p0p. The first part, the Problem-Posing Animation, introduces a scenario where the character "Zinc" (Zn) is playing. Feeling hot, Zn jumps into a lake representing the Copper (II) sulfate ($CuSO_4$) solution. The lake is initially blue, and the copper (Cu^{2+}) and sulfate (SO_4^{2-}) ions are depicted as distinct characters. However, as Zn enters the lake, red spots begin to appear on its body (representing the deposition of copper), and the blue color of the water (representing the Cu^{2+} ions) gradually fades, making the Cu^{2+} and SO_4^{2-} characters appear sad and confused. The animation concludes with a question: "What is happening? Can you help explain what's going on?". This storytelling approach stimulates curiosity and prompts students to think critically about the underlying chemical changes before a formal explanation is provided. Following this problem-posing segment, the Explanatory Animation provides a detailed, step-by-step visual explanation of the redox reaction at the molecular level. It shows Zn atoms losing electrons to become Zn^{2+} ions, and Cu^{2+} ions accepting these electrons to become neutral Cu atoms, which then deposit on the surface of the Zn. Visual and auditory cues (narration) are synchronized to ensure students can easily follow the electron transfer process. Figure 2 illustrates an image from the animated video of Zn + $CuSO_4$.

Figures 2 and 3

Illustration of an animation design: The redox reaction between zinc and copper(ii) sulfate and The periodic table of elements



Note. Prepared by the authors.

10.22633/rpge.v29iesp4.20768

Case Study 2: The Periodic Table of Elements. To illustrate the use of AI in creating aesthetically pleasing, age-appropriate character and background visuals, we present a video on the Periodic Table of Elements. In this animation, a student named Anna wants to learn about the elemental cells and is led by the “Village Elder” to a town hall meeting. The “residents” of this town are the chemical elements. At the meeting, Anna listens to conversations between the elements, thereby grasping their properties and relationships in a lively manner. This approach helps to de-abstract the periodic table, transforming the elements into familiar, memorable characters, which in turn fosters student interest and understanding of fundamental chemical concepts. Figure 3 illustrates an image from the animated video of The Periodic Table of Elements.

Research Design

This study adopted a convergent mixed methods design (Creswell & Clark, 2017) to comprehensively evaluate the effectiveness, pedagogical value, and motivational impact of the developed animated chemistry videos. A total of 30 animations were developed to cover all seven major topics in the Grade 10 chemistry curriculum. The research was implemented in two concurrent phases:

Phase 1 – Teacher Evaluation: Participating teachers reviewed all 30 animations and completed an online questionnaire to assess the videos’ scientific accuracy, curricular relevance, and potential to support student learning. This phase focused on validating the pedagogical and scientific principles outlined in our methodology.

Phase 2 – Student Engagement Assessment: This phase was designed as a comparative pilot study to assess student motivation when learning with this method versus a traditional instructional approach. Students participated in lessons where a specific subset of animations, focusing on oxidation-reduction reactions and reaction rate, were incorporated.

Following these lessons, they completed surveys to measure their engagement, emotional response, and perceived novelty. To obtain a more objective, multimodal measure of affective engagement, a qualitative facial expression analysis was also conducted. This observational approach, grounded in the Facial Action Coding System (FACS) (Ekman, 1978), was included to provide an independent layer of data that captures spontaneous emotional responses, which may not be fully captured by self-report measures alone (Pekrun, 2006).

Both quantitative data (from Likert-scale survey items) and qualitative data (from open-ended responses and observation-based indicators) were collected concurrently. These data were triangulated to provide a multidimensional understanding of how the animated videos influence both the instructional process and students’ interest in chemistry learning (Buchholtz, 2019).

Data collection instrument

To comprehensively assess the pedagogical effectiveness, cognitive support, and motivational impact of the animated chemistry videos, two complementary instruments were developed based on established theoretical frameworks of instructional design (Gagne et al., 2005) and multimedia learning (Mayer, 2009): a teacher evaluation questionnaire and a student perception questionnaire. The content validity of these instruments was established through expert review and feedback from a pilot study involving two educational technology specialists, 50 chemistry teachers, and 150 students. The instruments' reliability was confirmed with high internal consistency, with Cronbach's alpha values of 0.97 for the teacher evaluation scale and 0.849 for the student perception scale (Cronbach, 1951).

Teacher Evaluation Questionnaire: A structured questionnaire was developed to evaluate the pedagogical quality and usability of the animated video from the perspective of in-service Chemistry teachers. The instrument consisted of two parts: (i) 12 Likert-scale items assessing three core dimensions — *scientific and curricular alignment* (S1 – Alignment with the secondary school Chemistry curriculum; S2 – Scientific accuracy; S3 – Relevance to real-life contexts; S4 – Clarity and engagement of the narrative), *visual and auditory quality* (V1 – Use of vivid and engaging visuals; V2 – Appropriate graphic design; V3 – Clarity of narration and sound; V4 – Use of visual effects to support teaching), and *perceived pedagogical value* (P1 – Ability to stimulate student interest; P2 – Support for student understanding; P3 – Encouragement of creative thinking; P4 – Usefulness for self-study and review); and (ii) three open-ended questions eliciting qualitative feedback on strengths, areas for improvement, and suggestions for classroom integration. All Likert-scale items were rated on a 5-point scale (1 = Strongly Disagree to 5 = Strongly Agree). The selection of these evaluation criteria aligns closely with Mayer's Twelve Principles of Multimedia Learning (Mayer, 2014), including the principles of coherence, modality, and personalization.

Specifically, the emphasis on scientific accuracy, contextual relevance, and clear narration corresponds to coherence and signaling principles, while vivid visuals and appropriate audio support the modality and multimedia principles. Moreover, the pedagogical value criteria reflect the learner-centered orientation of Mayer's framework, aiming to promote cognitive engagement and meaningful learning experiences. Additionally, the instrument incorporated insights from the Four-Phase Model of Interest Development (Hidi & Renninger, 2006), especially the triggered and maintained situational interest phases. This dual theoretical grounding ensured that both instructional effectiveness and the motivational potential of the animated videos were appropriately evaluated.

Student Perception Questionnaire: To examine students' affective and cognitive engagement with the animated video, a structured questionnaire was developed based on theories

10.22633/rpge.v29iesp4.20768

of situational interest (Hidi & Renninger, 2006) and multimedia learning (Mayer, 2001). The instrument comprised two parts: (i) six Likert-scale items evaluating three dimensions — *emotional engagement* (E1 – I felt curious when the teacher used an animated video; E2 – I prefer learning via animation rather than verbal explanation), *perceived novelty* (N1 – This was my first time watching an animated video in Chemistry class; N2 – The video provided a novel approach to the lesson), and *willingness to further participate* (W1 – I wanted to learn more after watching the animated video; W2 – I was interested in asking questions after watching the video); and (ii) one open-ended question asking students to compare the animated video with previous lesson introductions (e.g., teacher narration, games), aiming to elicit reflective feedback on interest and motivation. All Likert-scale items were rated on a 5-point scale (1 = Strongly Disagree to 5 = Strongly Agree).

Facial Expression Data Collection: To supplement self-reported data and provide an objective measure of students' in-the-moment emotional and cognitive engagement, a qualitative facial expression analysis was conducted. This involved a non-intrusive video recording of the classroom during the lesson, with cameras strategically placed to capture the faces of as many students as possible. This approach was implemented with the explicit consent of all students and the teacher, ensuring strict adherence to ethical research protocols and privacy protection. The video footage was then used to select specific, representative static images for analysis using the FACS. This method allowed for the objective identification and classification of specific facial muscle movements and emotional expressions (e.g., smiles, focused attention, curiosity), providing a rich, qualitative layer of data that validates and extends the findings from the self-report questionnaires.

Sample and data collection

This study's sample consisted of two distinct groups: secondary school chemistry teachers and secondary school students. A total of 57 in-service chemistry teachers from various regions across Vietnam participated in the study. These teachers were granted access to all 30 animated videos via a secure link and were asked to complete an online questionnaire. All 57 teachers provided complete responses to the Likert-scale items, while a subset responded to the open-ended questions: 38 for question 1, 28 for question 2, and 26 for question 3.

The student sample included 137 secondary school students from four different secondary schools in Hue City, Central Vietnam. These students participated in lessons where specific animations were incorporated. Data was collected via surveys after two distinct viewing periods: an initial viewing designed to spark curiosity before new content was introduced, and a subsequent viewing to reinforce and clarify understanding after an inquiry-based learning activity. All 137 students completed the Likert-scale items. To obtain an objective measure

10.22633/rpge.v29iesp4.20768

of engagement, the classroom sessions were also video-recorded with the explicit consent of all participants and the teacher, ensuring ethical compliance. This video footage was used to extract representative static images for a qualitative facial expression analysis, adding a behavioral data layer to the self-reported survey responses. The qualitative responses from a smaller, representative sample of 61 students from two of the four schools were selected for detailed analysis.

Data analysis

Data were analyzed using a combination of quantitative and qualitative techniques to provide a comprehensive understanding of the animations' impact.

For the quantitative data, descriptive statistics, including percentages, means (M), and standard deviations (SD), were used to summarize responses from all Likert-scale items. To compare perceptions and responses across different subgroups, the non-parametric Kruskal–Wallis H test was employed.

This method was chosen because data derived from Likert scales are ordinal and often do not meet the assumptions of parametric tests like ANOVA. The Kruskal-Wallis H test is a robust alternative well-suited for comparing independent groups with non-normally distributed data (Field, 2013; Siegel & Castellan, 1988). Specifically, this test was used to compare teacher perceptions across four experience-based groups and to compare student responses across the four participating schools.

The qualitative data, collected from open-ended responses, underwent thematic content analysis. This approach allowed us to systematically identify and interpret common themes, recurring patterns, and unique insights from both teachers and students. The analysis also included a report on the frequency of each emergent theme to highlight its prevalence within the qualitative feedback (Braun & Clarke, 2006).

A separate qualitative analysis was performed on the facial expression data. Using the FACS as a guide, specific emotional expressions and non-verbal cues were identified from the static images extracted from the classroom videos. This analysis focused on classifying expressions related to focused attention, curiosity, and enjoyment. The findings from this qualitative analysis were then triangulated with the quantitative survey data and the thematic analysis of open-ended responses to provide a rich, multi-layered understanding of student engagement.

10.22633/rpge.v29iesp4.20768

RESULTS

Teacher Evaluation of the Animated Videos

The evaluation results (see Table 1) indicate that the animated video—designed specifically for this study—was positively received by in-service Chemistry teachers in terms of both scientific soundness and pedagogical effectiveness. The highest ratings were found in the scientific alignment dimension (S1–S3), with mean scores ranging from 4.60 to 4.63 and over 66% of teachers selecting "Strongly Agree" for alignment with curriculum and scientific accuracy, confirming that the video successfully adhered to the national Chemistry curriculum and accurately conveyed core scientific concepts. This validation is particularly significant as it supports the central objective of the study: to develop scientifically robust and instructionally meaningful media. The highest overall score was recorded for "Relevance to real-life contexts" (S3, $M = 4.63$), suggesting that the integration of chemical concepts with practical applications was especially effective.

Strong ratings were also observed for pedagogical value, especially for stimulating student interest (P1, $M = 4.58$) and fostering creativity (P3, $M = 4.53$). However, the relatively lower mean score for "sound clarity" (V3, $M = 4.19$) and the corresponding lower percentage of "Strongly Agree" responses (40.4%) point to a technical shortcoming.

Table 1

Descriptive statistics and distribution of teacher responses to each evaluation item

Indicator	S1	S2	S3	S4	V1	V2	V3	V4	P1	P2	P3	P4
M	4,60	4,60	4,63	4,42	4,42	4,35	4.19	4,44	4,58	4,39	4,53	4,53
SD	0,70	0,70	0,70	0,92	0,75	0,74	0,85	0,68	0,70	0,73	0,76	0,80
% "Strongly agree"	66,7	66,7	70,2	61,4	52,6	45,6	40,4	49,1	64,9	47,4	63,2	66,7

Note. Elaborated by authors (2025). 5-point Likert scale: 1 = Strongly Disagree; 5 = Strongly Agree.

To explore how teaching experience influenced teacher evaluations, a Kruskal–Wallis H test was conducted across four groups: <5 years ($n = 17$), 5–<10 years ($n = 13$), 10–<15 years ($n = 11$), and ≥15 years ($n = 16$). Significant differences emerged in several items (see Table 2), notably C1, C2, and A1, with the 10–<15 year group reporting lower average scores (~4.0–4.1) and greater variability ($SD > 1.0$).

CC BY NC SA
10.22633/rpge.v29iesp4.20768

Table 2

Mean scores (SD) and Kruskal–Wallis p-values for video evaluation items by years of teaching experience

Group	S1	S2	S3	S4	V1	V2	V3	V4	P1	P2	P3	P4
<5 yrs	4,59 (0,51)	4,65 (0,49)	4,65 (0,49)	4,47 (0,72)	4,47 (0,62)	4,41 0,71)	4,35 (0,70)	4,53 (0,51)	4,65 (0,49)	4,53 (0,52)	4,59 (0,62)	4,59 (0,62)
5–<10 yrs	4,69 (0,48)	4,69 (0,48)	4,69 (0,48)	4,23 (1,24)	4,54 (0,52)	4,31 (0,48)	3,77 (0,83)	4,46 (0,52)	4,69 (0,48)	4,23 (0,60)	4,46 (0,66)	4,46 (0,78)
10–<15 yrs	4,09 (1,22)	4,00 (1,18)	4,18 (1,25)	4,00 (1,18)	3,91 (1,14)	4,00 (1,10)	3,82 (1,17)	3,91 (1,04)	4,00 (1,18)	4,00 (1,18)	4,09 (1,22)	4,09 (1,30)
≥15 yrs	4,88 (0,34)	4,88 (0,34)	4,88 (0,34)	4,81 (0,40)	4,63 (0,62)	4,56 (0,63)	4,63 (0,50)	4,69 (0,48)	4,81 (0,40)	4,63 (0,50)	4,81 (0,40)	4,81 (0,40)
p-value	0,085	0,032	.221	.120	.169	.312	0,017	0,054	0,068	.188	.182	.333

Note. Elaborated by authors (2025). * $p < .05$.

In contrast, teachers with ≥15 years of experience gave the highest and most consistent ratings (M = 4.63–4.88), particularly on scientific alignment and pedagogical value.

A thematic analysis of teachers' open-ended responses provided deeper insights into the animations' strengths and areas for improvement, effectively triangulating the quantitative findings.

Perceived Strengths of the Animations: A qualitative analysis of responses to the question 'What did you like most about the animated video we designed?' revealed that most comments (≈55%) praised the visual appeal, describing the videos as "lively," "cute," and "engaging." Additionally, a significant number of responses (≈47%) highlighted the video's ability to increase student motivation and interest. Other valued aspects included the clarity and conciseness (≈32%) and real-life relevance (≈26%) of the content.

Suggestions for Improvement: From the 28 teachers who offered suggestions, a thematic analysis revealed several areas for refinement that help to explain patterns in the Likert-scale evaluation. The most frequent concern (≈29%) related to audio quality, specifically narration clarity and pacing, as reflected in comments like "Voice tone needs to be more consistent" (T18) and "The speech is too fast" (T14). Visual aspects were also mentioned, with 21% of teachers suggesting enhancements to color vibrancy and scene transitions. Similarly, about 21% of responses pointed to the need for standardizing chemical nomenclature. Additional suggestions, though less frequent, included improving synchronization between voice and visuals and expanding content to diversify topics or increase interactivity.

Recommendations for Better Pedagogical Integration: In addition to rating and reviewing the animation, 26 out of 57 teachers responded to the open-ended question: "What recommendations do you have to enhance the teaching effectiveness of this animated video?" Analysis revealed three main directions. A portion of the teachers (≈23%) were already

10.22633/rpge.v29iesp4.20768

satisfied with the current format, affirming its alignment with core instructional goals and supporting the high ratings for Scientific accuracy (S2) and Instructional value (P2, M = 4.55). A number of suggestions (≈15%) emphasized the need to embed real-life scenarios or contextualized questions to enhance application. Other recommendations focused on improvements to narration, including using more standard accents and natural voice tones. Finally, requests to broaden content coverage (≈12%) for wider curricular integration point to opportunities for scaling the animation into a more flexible and adaptive learning tool. The findings from both the Likert ratings and thematic analysis offer a comprehensive understanding of how teachers evaluate the videos' design and instructional relevance. The suggestions provided highlight key areas—particularly narration quality, contextual integration, and content scope—for future development to enhance instructional usability and learner impact.

Student perceptions of the impact of animated videos on learning interest

Descriptive statistics revealed consistently high levels of student agreement across all six survey items (see Table 3), indicating strong engagement with the animated videos. Mean scores ranged from 4.10 (N1) to 4.54 (N2), with minimal standard deviations (0.697 to 0.954), suggesting a strong consensus among students. The most significant agreement was observed in items related to emotional engagement and the willingness to learn more. A notable 100% of students selected "Strongly Agree" for item W1 ("I wanted to learn more after watching the animated video"), while over 63% strongly agreed that the video sparked their curiosity (E2) and provided a novel learning experience (N2).

Table 3

Percentage distribution and descriptive statistics for student responses to items E1–W2 (n = 137)

Measure	E1	E2	N1	N2	W1	W2
M	4.460	4.401	4,095	4.540	4,474	4.350
SD	0,777	0,927	0,954	0,697	0,777	0,845
% Strongly Agree (5)	59,1	63,5	43,8	63,5	100,0	54,7

Note. Elaborated by authors (2025).

To further examine the impact of the animated videos on student engagement, this study compared responses from students at four different schools using the six questionnaire items representing emotional engagement (E1–E2), perceived novelty (N1–N2), and willingness to participate (W1–W2). Descriptive statistics and Kruskal–Wallis tests were conducted to assess group differences. The results are presented in Table 4.

Table 4

Comparison of mean scores (SD) and Kruskal–Wallis test results for items E1–W2 by school

Item	School 1	School 2	School 3	School 4	p-value
E1	4,395 (0,856)	3,880 (0,927)	4,719 (0,581)	4,667 (0,526)	.000***
E2	3,974 (1,174)	4.120 (1.130)	4,781 (0,553)	4,667 (0,477)	0,002**
N1	3,789 (1,069)	3,400 (0,866)	4,625 (0,660)	4,381 (0,731)	.000***
N2	4,526 (0,647)	4,080 (0,997)	4,781 (0,553)	4,643 (0,485)	.004**
W1	4,289 (0,835)	4.000 (1.041)	4,781 (0,553)	4,690 (0,468)	.000***
W2	4,237 (0,751)	3,520 (1,085)	4,688 (0,645)	4,690 (0,468)	.000***

Note. Elaborated by authors (2025). $p < .05$; ** $p < .01$; *** $p < .001$.

The analysis revealed statistically significant differences across schools for all six items ($p < .01$). Students from Schools 3 and 4 consistently reported the highest levels of engagement across all dimensions. For example, the mean score for E1 (“I felt curious when the teacher used an animated video”) was highest at School 3 ($M = 4.719$), while School 2 showed the lowest score ($M = 3.880$). This pattern was consistent for both perceived novelty and willingness to participate, indicating a strong group effect.

To complement the quantitative findings, open-ended responses were collected from 61 students across School 1 ($n = 36$) and School 2 ($n = 25$) in response to the question: “*Compared to previous ways of lesson introduction, did watching the animated video make you more engaged? Why or why not?*” Thematic analysis of these responses revealed six major themes, which generally corroborated the trends observed in the Likert-scale results.

The most frequent theme was increased interest due to novelty or variation, with students describing the animation as a refreshing change from typical lesson introductions. Students also reported that the video format helped improve focus and concentration, aligning with the high engagement scores in the emotional component (E1 and E2). One student explained, “It helped me concentrate on what I needed to do” (S6, School 2), and another noted, “The visual appeal helped me focus and learn better” (S30, School 1). Another recurring theme was the enhancement of understanding and visualization, with students stating that the animations made abstract concepts more concrete. For example, S5 from School 2 remarked, “It made the content easier to visualize and more engaging”, and S12 from School 1 added, “It helped me understand the lesson more clearly.” Some students mentioned that the animation stimulated their curiosity and motivation to learn, with statements such as “It sparked curiosity and made me want to learn more” (S10, School 2), and “It stimulated my curiosity” (S7, School 1). These responses reflect the construct of situational interest, which was central to the design of the questionnaire and theoretical framing of this study. Other themes, though less frequent, included the perception of animation as a blend of learning and entertainment, and its connection to real-life situations—both of which point to the affective and contextual relevance of animated content in science education. Notably, a few students from School 2 expressed neutral or indifferent attitudes, possibly reflecting individual differences in receptiveness or the school's comparatively lower baseline engagement, as reflected in the quantitative analysis.

Facial Expression Analysis: Qualitative Support for Learner Engagement: To provide objective and multimodal evidence of engagement, a qualitative facial expression analysis was conducted using static images from classroom observations. This analysis was guided by the FACS to identify emotional expressions, providing a layer of objective data that goes beyond self-reported measures. The analysis revealed a clear progression of emotional responses in students, moving from focused attention to genuine enjoyment.

- Stage 1: Initial Exposure to the Animation: At this early stage of viewing, the majority of students demonstrated high levels of visual attention and cognitive engagement. For instance, Student 1 (S1) exhibited a serious facial expression with a gaze fixed directly on the screen—indicative of focused attention, commonly associated with AU1+2 (inner and outer brow raiser). Other students, such as S4, S5, and S7, sat upright with attentive gazes, suggesting active reception and interest. Notably, Student 6 leaned forward with fixed eye contact and an intense expression—an archetypal marker of strong cognitive immersion. Student 9 demonstrated a facial expression of curiosity, with widened eyes directed upward—linked to AU5 (upper lid raiser)—suggesting heightened perceptual arousal and interest;
- Stage 2: Sustained Attention Phase: Despite the limited camera angle, most students appeared to sustain their level of attentiveness. S10 and S11 maintained serious facial expressions and a steady gaze toward the screen, indicative of continued focus. S12 was observed to lean forward slightly, an intentional action reflecting active engagement and increased visual access to the animation;
- Stage 3: Emotional Climax: At the moment when the video introduced humorous elements, student expressions changed markedly, revealing a distinct shift in emotional valence. Positive affect became increasingly observable across the class, with several students smiling or laughing softly—a combination of AU6 (cheek raiser) and AU12 (lip corner puller) indicative of genuine enjoyment. S1 transitioned from a slight smile to a broad, joyful smile, reflecting a progressive emotional response. S8, while partially covering their face, exhibited raised cheeks and squinted eyes, consistent with a Duchenne smile, which is widely accepted as a marker of

authentic emotional pleasure. This was particularly notable as S8 was previously identified as a typically less responsive student, yet the animation successfully elicited a spontaneous and positively valenced emotional reaction, underscoring its potential for engaging even less active learners.

Temporal Trajectory of Emotional Response: Across the three key timestamps, students' facial expressions gradually evolved from focused attention and curiosity to visible amusement and joy, suggesting a cumulative emotional impact.

DISCUSSION

Teacher evaluation of the animated videos

The findings from the teacher evaluations provide robust evidence for the pedagogical effectiveness of the animated videos. The high ratings for scientific alignment (S1–S3) confirm the videos' successful adherence to the national Chemistry curriculum and their accuracy in conveying core scientific concepts. The especially high score for "Relevance to real-life contexts" (S3) is consistent with research emphasizing that connecting abstract scientific knowledge to real-world contexts significantly enhances student engagement and learning transfer (De Jong, 2005).

Strong ratings on pedagogical value, particularly for stimulating student interest (P1) and fostering creativity (P3), suggest the animations have substantial potential to enhance student engagement. These results align with the principles of interest development (Hidi & Renninger, 2006) and multimedia learning (Hidi & Renninger, 2006; Mayer, 2014; Mayer, & Fiorella, 2014) and reinforce previous research that well-designed multimedia can significantly enhance comprehension and motivation (Barbara et al., 2016; Fyfield et al., 2022; Mayer, 2001).

The thematic analysis of qualitative feedback confirmed these strengths, with teachers praising the videos' visual appeal (≈55%) and ability to increase student motivation (≈47%). This aligns with the Cognitive Theory of Multimedia Learning (Mayer, 2014) and recent research on how emotionally designed animations can enhance intrinsic motivation (Mou, 2023; Teplá et al., 2022).

However, the quantitative results and qualitative feedback also highlighted a key area for improvement: sound clarity. The relatively low mean score for "sound clarity" (V3, M = 4.19) was corroborated by teacher comments (≈29%) pointing to inconsistent voice tone and pacing. This finding is consistent with research emphasizing that poor audio can increase extraneous cognitive load and impair learning (Moreno & Mayer, 2007), particularly when visual information is also present (Sweller, 1998). The feedback also provided specific recommendations, such as standardizing chemical nomenclature (≈21%) and improving synchronization between voice and visuals.

The analysis of differences by teaching experience revealed that while teachers with fewer than 10 years of experience and those with 10-15 years had more varied opinions, veteran teachers (≥15 years) consistently gave the highest ratings. This may reflect their accumulated pedagogical expertise and greater familiarity with the curriculum, as research has shown a strong correlation between years of teaching experience and a deeper understanding of curricular alignment and instructional methods (Morehead, 2005; Polikoff, 2013)

In conclusion, the findings affirm the strengths of the current design and provide actionable insights for refining both content and delivery. To enhance inclusivity and usability across teacher groups, future versions should improve audio quality, align more closely with standardized nomenclature, and enhance structural clarity, strategies shown to support science learning and engagement (Swain, 2012). The suggestions provided by teachers highlight key areas—particularly narration quality, contextual integration, and content scope—for future development to enhance instructional usability and learner impact, aligning with the need for adaptable media designs that can support broader curricular goals (Adam et al., 2021; Polikoff, 2013).

Student perceptions of the animated videos

The quantitative and qualitative findings provide strong evidence for the effectiveness of the animated videos in fostering student engagement and motivation. The high mean scores and low standard deviations across all survey items for student perception confirm that the videos successfully engaged a broad range of learners. The particularly strong endorsement of emotional engagement items (E1 and E2) and cognitive engagement items (W1 and W2) aligns with the situational interest framework (Hidi & Renninger, 2006) and multimedia learning theory (Mayer, 2014). This reinforces the notion that curiosity-triggering, novel, and emotionally engaging stimuli can significantly enhance attentional focus and sustained engagement. The motivational effect observed, especially the strong desire to continue learning, echoes previous international findings on the crucial role of curiosity in promoting exploratory behavior, deeper processing, and attention regulation (Hunaepi et al., 2024; Pekrun, 2006).

However, the analysis revealed a statistically significant variation in engagement levels across different schools. Students from Schools 3 and 4 consistently reported the highest levels of engagement, while School 2 showed the lowest. This finding is consistent with international studies on technology integration in education (Urquiza-Fuentes & Velázquez-Iturbide, 2013).

10.22633/rpge.v29iesp4.20768

The observed differences may be attributed to institutional characteristics and student demographics, as the lower engagement scores at School 2 could be linked to its shorter institutional history and a student population with a lower average academic performance. These findings align with prior research indicating that multimedia learning environments, while generally beneficial, do not produce uniform effects across all learner groups (Liew et al., 2017; Um et al, 2012), with effectiveness often mediated by factors such as learners' prior knowledge, institutional culture, and teacher training (Polikoff, 2013). Further post-hoc analysis (e.g., Dunn's test) would be necessary to identify the specific pairs of schools with statistically significant differences.

The thematic analysis of students' open-ended reflections provided rich qualitative support for the quantitative findings. The most frequent theme of novelty and variation directly corroborates the high Likert scores for perceived novelty (N2, M = 4.54), confirming that students saw the animation as an innovative instructional method that enhanced their situational interest. Similarly, comments on improved focus and concentration, enhanced understanding, and stimulated curiosity reinforce the cognitive and affective benefits suggested by the quantitative data.

Finally, the facial expression analysis served as a crucial qualitative triangulation, providing objective, in-the-moment evidence of student engagement that goes beyond self--reported measures. The clear progression from focused attention to genuine enjoyment, particularly when humorous elements were introduced, provides concrete support for the animation's ability to not only capture attention but also evoke positive emotional responses. This multimodal evidence aligns with prior literature indicating that affective experiences can enhance motivation and engagement (Mayer, 2014; Pekrun, 2006) and strengthens the claim that animated videos can foster comprehensive cognitive-affective engagement in chemistry classrooms.

Overall, the findings from the student questionnaires and facial analysis affirm the animated videos' strong potential to enhance learning interest and engagement, while also highlighting the importance of considering institutional and demographic factors that may influence their effectiveness.

CONCLUSION

This study aimed to address three core research questions: (1) how to design character-based animated Chemistry videos that align with pedagogical and scientific principles, (2) how teachers and students evaluate the appropriateness and appeal of these videos, and (3)

10.22633/rpge.v29iesp4.20768

to what extent the animations enhance students' situational interest in Chemistry learning. Drawing on the Vietnamese Grade 10 Chemistry curriculum, the study developed thirty educational animations across seven thematic units, each following a dual-format structure—problem-posing and explanatory videos—and grounded in four design principles: pedagogical alignment, scientific accuracy, cognitive appropriateness, and animation quality.

Teacher evaluations (*n* = 57) revealed strong endorsements for the videos' scientific alignment, pedagogical value, and relevance to real-life contexts, confirming the design's alignment with curriculum standards and instructional goals. Although minor technical issues such as voice clarity were noted, open-ended feedback highlighted the visual appeal, motivational effect, and clarity of content as key strengths. These findings affirm the value of involving educators in media evaluation and provide concrete directions for improvement and pedagogical integration.

Student feedback (*n* = 137) from four secondary schools further demonstrated the videos' positive impact on situational interest. Likert-scale responses showed consistently high scores across emotional engagement, perceived novelty, and willingness to learn. Statistically significant differences among schools suggested that contextual and institutional factors may mediate the effectiveness of multimedia.

Thematic analysis of student reflections reinforced these findings, with students highlighting increased curiosity, better focus, improved understanding, and a sense of novelty brought by the animations. This self-reported data was triangulated with a layer of behavioral data, where preliminary analysis of facial expressions from a subset of students revealed a high frequency of expressions associated with curiosity and focused attention, providing an objective measure of on-task engagement.

Together, the results provide empirical evidence that character-driven animated Chemistry videos, when thoughtfully designed, can serve as pedagogically sound and contextually appropriate tools to enhance engagement and interest in science learning. This study contributes to the growing body of research on educational animations and offers practical implications for their development, evaluation, and integration in secondary science education. Future research should extend the evaluation to include long-term learning outcomes, classroom implementation, and adaptive interactivity features to maximize instructional impact.

Despite its promising findings, this study is subject to several limitations that should be acknowledged. First, the current video set covers only seven topics within the Grade 10 Chemistry curriculum. Although teacher feedback indicated strong interest in broader curricular integration, expanding the video library to include additional content—such as atomic theory, organic chemistry, or environmental chemistry—could support more comprehensive and sustained instructional implementation. Second, while the videos were generally well-received, the current format offers limited interactivity. Incorporating elements such as embedded questions, branching narratives, or adaptive feedback mechanisms could further promote active engagement, formative assessment, and differentiated instruction.

These enhancements may be particularly beneficial for supporting diverse learners and fostering deeper inquiry. Third, while most videos met technical expectations, a few early versions received feedback regarding narration quality and audio clarity. These issues were subsequently addressed through targeted revisions, including enhanced voice recording and improved synchronization between audio and visuals. Nonetheless, the initial feedback underscores the importance of ensuring consistent technical quality across the entire video collection. Future development efforts should consider involving professional audio engineers and conducting early-stage user testing to enhance both cognitive and perceptual coherence.

Finally, while this article emphasizes affective engagement and perceived instructional value, it is one of several planned publications stemming from this research. The study's robust mixed-methods design, which included supplementary data from pre/post-tests and behavioral observations via facial expression analysis, provides a multi-layered understanding of learning impact. It is therefore recommended that future publications and research adopt a more holistic evaluation framework that triangulates affective, cognitive, and behavioral indicators. Broader investigations across diverse classroom contexts, student populations, and instructional approaches will also be essential to assess the generalizability and scalability of character-based Chemistry animations as a pedagogical tool.

Recommendations

Based on the findings from both teacher and student evaluations, several key recommendations can be made for refining the animated video and guiding future research. First, to address the technical shortcomings identified by teachers and to reduce cognitive load for learners, the audio quality must be optimized. This includes improving narration clarity, standardizing pacing, and using more natural voice tones. Second, to enhance pedagogical usability and align with teachers' suggestions, the content should be expanded to cover a wider range of topics and include more contextualized, real-life scenarios.

This will help students see the practical relevance of chemical concepts, thereby boosting their motivation and engagement. Third, the next iterations of these educational animations should strategically integrate interactive elements that allow learners to manipulate variables or explore concepts, moving beyond passive viewing. Finally, based on the success of the humor-related emotional peak observed in the facial analysis, future designs should

10.22633/rpge.v29iesp4.20768

continue to incorporate engaging and emotionally resonant elements to sustain learner interest and foster a positive learning environment.

Limitations

This study has several limitations that should be addressed in future research. While the facial expression analysis provided valuable qualitative data, it was limited to a small sample and static images, thus lacking a comprehensive, longitudinal view of student engagement. Future studies could employ more advanced observational methods or eye-tracking technology to capture a more complete picture of cognitive and affective responses.

Additionally, the absence of a post-hoc analysis for the school-wise comparison limits the ability to identify specific pairs of schools with statistically significant differences. Addressing these limitations will strengthen the generalizability and academic rigor of future research on animated educational media.

10.22633/rpge.v29iesp4.20768

REFERENCES

Adam, M., Chase, R. P., & McMahon, S. A. (2021). Design preferences for global scale: A mixed-methods study of "glocalization" of an animated, video-based health communication intervention. *BMC Public Health*, *21*, 1–12. https://doi.org/10.1186/s12889-021-11043-w

Arumugam, S., & Nirmala, N. (2018). Science animation and students' attitudes. In *Encyclopedia of Information Science and Technology* (4th ed., pp. 2599–2615). IGI Global. https://doi.org/10.4018/978-1-5225-2255-3.ch227

Barak, M., Ashkar, T., & Dori, Y. J. (2011). Learning science via animated movies: Its effect on students' thinking and motivation. *Computers & Education*, *56*(3), 839–846. https://doi.org/10.1016/j.compedu.2010.10.025

Barbara, F., Kramer, E., & Kim, J. A. (2016). Split-attention and coherence principles in multimedia instruction can rescue performance for learners with lower working memory capacity. *Applied Cognitive Psychology*, *30*(5), 691–699. https://doi.org/10.1002/acp.3244

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brunyé, T. T., Taylor, H. A., & Rapp, D. N. (2008). Repetition and dual coding in procedural multimedia presentations. *Applied Cognitive Psychology*, *22*(7), 877–895. https://doi.org/10.1002/acp.1396

Buchholtz, N. (2019). Planning and conducting mixed methods studies in mathematics educational research. In G. Kaiser & N. Presmeg (Eds.), *Compendium for early career researchers in mathematics education* (pp. 91–112). Springer. https://doi.org/10.1007/978-3-030-15636-7_6

Bülbül, A., & Kuzu, A. (2021). Emotional design of educational animations: Effects on emotion, learning, motivation and interest. *Participatory Educational Research*, *8*(3), 344–355. https://doi.org/10.17275/PER.21.69.8.3

Chang, H., & Quintana, C. (2006). Student-generated animations: Supporting middle school students' visualization, interpretation and reasoning of chemical phenomena. In *Proceedings of the International Conference of the Learning Sciences* (pp. 71–77).

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research* (3rd ed.). Sage Publications.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*(3), 297–334. https://doi.org/10.1007/BF02310555

D'Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. *Learning and Instruction*, *22*(1), 145–157. https://doi.org/10.1016/j.learninstruc.2011.10.001

De Jong, T. (2005). The guided discovery learning principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 215–229). Cambridge University Press.

Demissie, T., Ochonogo, C. E., & Engida, T. (2011). Pedagogy-based-technology and chemistry students' performance in higher institutions: A case of Debre Berhan University. *US-China Education Review*, *5*, 602–611.

Ekman, P., & Friesen, W. V. (1978). *Facial action coding system* (FACS) [Database record]. Consulting Psychologists Press. https://doi.org/10.1037/t27734-000

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th ed.). Sage Publications.

Fyfield, M., Henderson, M., & Phillips, M. (2022). Improving instructional video design: A systematic review. *Australasian Journal of Educational Technology*, *38*(3), 150–178. https://doi.org/10.14742/ajet.7296

Gagné, R. M., Wager, W. W., Golas, K. C., & Keller, J. M. (2005). *Principles of instructional design* (5th ed.). Wadsworth Publishing.

Hidi, S., & Renninger, A. (2006). The four-phase model of interest development. *Educational Psychologist*, *41*(4), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Hoa, Đ. T. H. (2015). Students' attitude towards chemistry from the perspective of chemistry teachers. *HCMUE Journal of Science*, *6*(72), 32–39.

Hunaepi, H., Suma, I. K., & Subagia, I. W. (2024). Curiosity in science learning: A systematic literature review. *International Journal of Essential Competencies in Education*, *3*(1). https://doi.org/10.36312/ijece.v3i1.1918

Hùng, N. Q., & Linh, H. M. (2022). Integrating stories and mathematical games in teaching mathematics for 3rd and 4th grade. *Dong Thap University Journal of Science*, *11*(4), 41–50. https://doi.org/10.52714/DTHU.11.4.2022.965

Liew, T. W., Zin, N. A. M., & Sahari, N. (2017). Exploring the affective, motivational and cognitive effects of pedagogical agent enthusiasm in a multimedia learning environment. *Human-Centric Computing and Information Sciences*, *7*(9), 1–21. https://doi.org/10.1186/s13673-017-0089-2

Mayer, R. E. (2001). *Multimedia learning*. Cambridge University Press. https://doi.org/10.1017/CBO9781139164603

Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). Cambridge University Press.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In *The Cambridge handbook of multimedia learning* (2nd ed., pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005

Mayer, R. E., & Fiorella, L. (2014). Principles for reducing extraneous processing in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 279–315). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.015

Minh, T. H., & An, P. H. T. (2023). Principles and procedures for designing animated films to support teaching natural sciences grade 9. *Vietnam Journal of Education*, *23*(7), 178–184.

Ministry of Education and Training. (2018). T*he 2018 Vietnam general education curriculum in chemistry*.

Morehead, P. (2005). The continuing challenges of technology integration for teachers. *Essays in Education*, *15*(1). https://openriver.winona.edu/eie/vol15/iss1/10

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, *19*(3), 309–326. https://doi.org/10.1007/s10648-007-9047-2

Mou, T.-Y. (2023). Science learning with designed animation... *International Journal of Educational Research Open*, *4*, 100246. https://doi.org/10.1016/j.ijedro.2023.100246

Paulhus, D. L. (1991). Measurement and control of response bias. In J. P. Robinson et al. (Eds.), *Measures of personality and social psychological attitudes* (pp. 17–59). Academic Press. https://doi.org/10.1016/B978-0-12-590241-0.50006-X

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review*, *18*(4), 315–341. https://doi.org/10.1007/s10648-006-9029-9

Polikoff, M. S. (2013). Teacher education, experience, and the practice of aligned instruction. *Journal of Teacher Education*, *64*(3), 212–225. https://doi.org/10.1177/0022487112472908

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist*, *46*(3), 168–184. https://doi.org/10.1080/00461520.2011.587723

Schiefele, H., Krapp, A., Prenzel, M., Heiland, A., & Kasten, H. (1983). Principles of an educational theory of interest. In *Proceedings of the ISSBD*.

Siegel, S., & Castellan, N. J. (1988). *Nonparametric statistics for the behavioral sciences* (2nd ed.). McGraw-Hill.

Swain, K. T. (2012). *Meaningful use of animation and simulation in the science classroom* [Master's thesis]. http://digitalcommons.brockport.edu/ehd_theses/143

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251–296. https://doi.org/10.1023/A:1022193728205

Teplá, M., Teplý, P., & Smejkal, P. (2022). Influence of 3D models and animations on students in natural subjects. *International Journal of STEM Education*, *9*(1), 1–20. https://doi.org/10.1186/s40594-022-00382-8

Um, E. R., Plass, J. L., Hayward, E. O., & Homer, B. D. (2012). Emotional design in multimedia learning. *Journal of Educational Psychology*, *104*(2), 485–498. https://doi.org/10.1037/a0026609

Urquiza-Fuentes, J., & Velázquez-Iturbide, J. (2013). Toward the effective use of educational program animations: The roles of student engagement and topic complexity. *Computers & Education*, *67*, 178–192. https://doi.org/10.1016/j.compedu.2013.02.013

Vermaat, H., & Kramers-Pals, H. (2003). The use of animations in chemical education. In *AECT Conference Proceedings*.

Yaseen, Z. (2018). Using student-generated animations: The challenge of dynamic chemical models in states of matter and the invisibility of the particles. *Chemistry Education Research and Practice*, *19*(4), 1166–1185. https://doi.org/10.1039/C8RP00109F

Yusuf, Y. (2017). Learning chemistry by ICT (virtual animation) at Maumere High School, East Nusa Tenggara. *Journal of Education, Teaching and Learning*, *2*(1), 1–7. https://doi.org/10.26737/jetl.v2i1.138

10.22633/rpge.v29iesp4.20768

CRediT Author Statement

Acknowledgements: We extend our sincere gratitude to the educational experts, chemistry teachers nationwide, and students from four secondary schools in Hue City. Their invaluable contributions to the questionnaire design, video feedback, and active participation were essential to the success of this study.
Funding: This research was supported by Hue University (Grant No. DHH2024-03-192).
Conflicts of interest: The author declares that there are no conflicts of interest regarding the publication of this paper.
Ethical approval: All procedures performed in this study involving human participants complied with ethical standards for educational research. Although the analysis was based on static images from classroom observations, none of these images have been published in this paper. This decision was made to adhere to research ethics principles and to protect the privacy of the student participants. The study was conducted with the approval and consent of the participating schools and individuals.
Data and material availability: The datasets and materials generated and analyzed during the current study are available from the corresponding author upon reasonable request.
Authors' contributions: The author was responsible for all aspects of this study, including conceptualization, methodology, data analysis, and manuscript preparation.

Processing and editing: Editora Ibero-Americana de Educação

Proofreading, formatting, normalization and translation