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Development of Intertextual Learning Videos on the Concept of Exothermic and Endothermic Processes

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***Abstract*:. :** *Learning the concepts of exothermic and endothermic processes remains challenging due to their abstract nature and the difficulty of connecting macroscopic, submicroscopic, and symbolic representations. This study aims to develop an intertextual-based learning video on exothermic and endothermic processes that is feasible in terms of content, pedagogy, and media aspects. The study used a Research and Development (R&D) approach based on the Borg and Gall model, limited to five stages: reseacrh and informating collecting, planning, develop preliminary form of product, preliminary field testing (review), and main product revision. Validation was done by experts in content, pedagogy, and media experts using assessment instruments based on the evaluated aspects. The review results indicate that the developed video meets the eligibility criteria after revisions based on expert feedback. The video integrates macroscopic, submicroscopic, and symbolic representations through the Predict–Observe–Explain (POE) model, supported by learning and multimedia principles. Therefore, the intertextual-based learning video is suitable as a learning medium to support students' conceptual understanding of exothermic and endothermic processes.*

***Keywords*:** *Learning videos; intertextual; multiple representations; exothermic processes; endothermic processes*

INTRODUCTION

Chemistry is a branch of natural science that studies the structure, composition, properties, changes in matter, and the energy that accompanies these changes (Brown et al., 2021). Chemistry is a branch of science that encompasses many interrelated terms and abstract concepts, some of which are related to other sciences (Syahri & Ahmad Maulana Ardi, 2016). Chemistry learning begins with simple concepts that then serve as the foundation for building more complex concepts (Lumadya, 2024). Chemistry learning requires a conceptual relationship between macroscopic (chemical process phenomena), submicroscopic (molecular), and symbolic representations (Johnston, 1982 in Treagust et al., 2003).

The abstract nature of chemistry makes it difficult for students to understand

concepts, particularly in connecting macroscopic, submicroscopic, and symbolic representations (Iswara et al., 2020; Irfandi et al., 2022). This difficulty is influenced by teacher-centered learning, which has not optimally facilitated the interconnection of the three representations (Salsabila & Nurjayadi, 2019; Laila et al., 2022). Therefore, understanding chemical concepts requires not only mastery of facts and concepts but also the ability to connect macroscopic, submicroscopic, and symbolic representations in an integrated manner (Sakti et al., 2020).

Thermochemistry is an essential concept and a challenging topic in chemistry learning due to its abstract nature and the need to connect energy changes at the particle level with macroscopic phenomena and everyday life (Donasari & Silabun, 2021; Yuliana & Sholichah, 2021; Abdjul et al., 2026; Naila & Nasution, 2026). One thermochemistry topic, namely exothermic and endothermic processes, requires students to understand macroscopic aspects such as temperature changes observed during reactions and submicroscopic aspects involving energy in the form of heat release or absorption at the particle level (Dewi et al., 2018).

Various studies show that students still experience misconceptions about the concept of exothermic and endothermic processes, such as difficulty distinguishing between exothermic and endothermic reactions and the accompanying energy signs (Irfandi et al., 2022; Rahmi & Azra, 2023; Rosyidah et al., 2024). Students also assume that endothermic reactions cause the ambient temperature to increase after the system is mixed, while exothermic reactions cause the ambient temperature to decrease (Rosyidah et al., 2024). These misconceptions often cause students to incorrectly classify examples of exothermic and endothermic events in everyday life (Zakiyah & Widodo, 2019; Sihaloho et al., 2021; Rokhim et al., 2023; Suleman et al., 2023; Hidayat et al., 2024). Misconceptions about the concept of exothermic and endothermic processes are influenced by learning that is still dominated by lecture methods so that students tend to memorize concepts without understanding the relationship between macroscopic, submicroscopic, and symbolic representations (Tua et al., 2020; Rokhim et al., 2023).

Students' limited understanding of exothermic and endothermic concepts is influenced by learning that has not fully integrated macroscopic, submicroscopic, and symbolic representations, so students have difficulty connecting concepts to real phenomena (Bait dkk., 2018 dalam Sihaloho et al., 2021). Therefore, the application of multiple representations (chemistry triplets) is important because it can help students understand abstract chemical concepts and reduce misconceptions in thermochemistry material (Sihaloho et al., 2021; Yuliana & Sholichah, 2021).

One way to address these issues is through the development of learning media (Indarta et al., 2022). Learning media can enhance learning outcomes (Rilanty & Juwitaningsih, 2020). One type of learning media is video. Learning videos can visualize abstract chemical concepts through a combination of images, sound, animation, and text, thereby increasing motivation, conceptual understanding, learning outcomes, and supporting independent learning (Asih et al., 2018; Komalasari, 2020;Parlindungan et al., 2020; Mutmainnah et al., 2021). However, analysis of learning videos on exothermic and endothermic processes shows that the videos still focus on verbal and symbolic

presentations, do not fully integrate macroscopic, submicroscopic, and symbolic representations, and do not optimally apply pedagogical aspects and multimedia principles.

One effort to address misconceptions about exothermic and endothermic processes is through the development of learning media oriented towards multiple chemical representations capable of visualizing abstract chemical concepts (Yuliana & Sholichah, 2021; Akbar & Djakariah, 2025). Learning media can enhance learning outcomes (Rilanty & Juwitaningsih, 2020). One such media is learning videos, which are able to visualize abstract concepts, thereby increasing students' understanding and motivation to learn (Asih et al., 2018). Therefore, intertextual-based learning videos have the potential to help students integrate macroscopic, submicroscopic, and symbolic representations, thereby enabling them to build a more comprehensive understanding of concepts (Kartika Sari & Nada, 2022; Hanif As'ad & Hartanti, 2024).

Various studies have developed various efforts to reduce misconceptions in thermochemistry material, such as the application of Problem-Based Learning (PBL), Predict–Observe–Explain (POE) strategies, practicums, multiple representation-based learning, remedial learning, and diagnostic instruments. However, the results of the analysis of existing learning videos on the concept of exothermic and endothermic processes show that each video has advantages and disadvantages in terms of content, pedagogy, and media. From the content aspect, the videos have not fully integrated macroscopic, submicroscopic, and symbolic representations as a whole. From the pedagogical aspect, learning is still dominated by direct explanations, thus not facilitating students to build concepts. Meanwhile, from the media aspect, the application of Mayer's multimedia principles is not optimal. Therefore, it is necessary to develop learning videos that integrate content, pedagogy, and media aspects in one learning product.

Based on these gaps, this study offers a novelty in the form of developing an intertextual-based learning video that integrates content, pedagogy, and media aspects into one learning product. From a content perspective, the video is designed by systematically connecting macroscopic, submicroscopic, and symbolic representations. From a pedagogical perspective, the video applies the Predict–Observe–Explain (POE) model based on constructivism theory and taking into account learning principles. From a media perspective, the video is developed based on Mayer's multimedia principles. The integration of these three aspects is the main characteristic that distinguishes this study from previous studies.

Based on the description, this study aims to develop an intertextual-based learning video on the concept of exothermic and endothermic processes, describe the characteristics of the developed learning video, and describe the results of a review of the content, pedagogy, and media aspects as a basis for product improvement.

METHOD

Research Design

This study used the Research and Development (R&D) method to develop an intertextual-based learning video on the concept of exothermic and endothermic processes. The development model refers to

Borg & Gall (2003), which is limited to five stages: (1) reseacrh and informating collecting, (2) planning, (3) develop preliminary form of product, (4) preliminary field testing, and (5) main product revision. This is because it matches the goal of the research, which is to produce a product that has gone through a review and revision process based on input from experts.

Development Stages

The research and information gathering stage includes analysis of learning outcomes, formulation of learning objectives and concept labels, multiple representation analysis, misconception analysis, and review of existing learning videos as a basis for determining product specifications. The planning stage includes determining multiple representations based on the analysis results, as well as script and storyboard development. The development of a preliminary form of the product stage involves creating a learning video that integrates macroscopic, submicroscopic, and symbolic representations, constructivism theory and learning principles, and Mayer's multimedia principles. Next, in the preliminary field testing stage, the product is reviewed by content, pedagogy, and media experts using a review sheet. The main product revision stage involves revising the video based on expert input until the final product is achieved.

Research Participants

The research participants consisted of four reviewers: three content and pedagogy experts and one instructional media expert. All reviewers provided input on content, pedagogy, and media aspects as a basis for product improvements.

Research Instrument

The research instrument consists of a review sheet containing assessment indicators for content, pedagogy, and media aspects, as well as a comments and suggestions section to obtain input on the product being developed.

Data Analysis Techniques

The research data is made up of qualitative information that comes from experts looking at the data, simplifying it, showing it clearly, and then drawing final thoughts based on what they found.

RESULTS ANALYZE

Characteristics of Intertextual-Based Learning Videos Developed

The development of intertextual-based learning videos began with an analysis of Learning Outcomes (CP), the formulation of Learning Objective Flows (ATP) and concept labels, an analysis of multiple representations from the General Chemistry textbook, an analysis of misconceptions, and an analysis of existing videos. The analysis revealed that the material on exothermic and endothermic processes is characterized by abstract concepts and the potential to give rise to misconceptions, particularly in connecting phenomena observed macroscopically with processes occurring at the submicroscopic level and symbolic representations. Therefore, the entire analysis results serve as the basis for determining the characteristics and specifications of the instructional video being developed.

The developed instructional video incorporates characteristics consistent with those defined by Riyana (2007): message clarity, a stand-alone nature, user-friendliness, accurate representation of content, effective visual presentation, high-resolution quality, and suitability for both individual and group (class) use. The implementation of these

characteristics in the developed product is presented in Table 1.

Table 1. presents the characteristics of video according to Riyana

Characteristics	Implementation in Instructional Videos
Clarity of Message	The video systematically presents the concepts of systems and surroundings, the law of conservation of energy, exothermic processes, and endothermic processes by connecting macroscopic, submicroscopic, and symbolic representations, making abstract concepts easier to understand.
Stand-alone	Each video includes learning objectives, contextual phenomena, Predict-Observe-Explain (POE) activities, concept explanations, multiple representation visualizations, and summaries, making it suitable for use without other learning media.
User-Friendly	The video uses communicative language, coherent presentation, clear narrative, and simple visuals for easy understanding by students.
Representativeness of Content	The material is structured based on the results of analyses of CP, ATP, concept labels, multiple representations, misconceptions, and existing videos, ensuring alignment with scientific concepts and learning needs.
Visualization with media	Video integrates experimental footage, particle animations, illustrations, energy diagrams, reaction equations, text, and narration to connect macroscopic, submicroscopic, and symbolic representations.
High resolution	Videos are developed with high-quality images and audio so that information can be clearly observed.
Individual and class	Videos can be used as a self-study medium or by teachers in classroom instruction.

The development of intertextual-based learning videos on the concepts of exothermic and endothermic processes was divided into four distinct videos. This division was adjusted according to the learning objectives and concept labels derived from the Learning Outcomes (CP). The four videos are: systems and surroundings, the law of conservation of energy, exothermic processes, and endothermic processes.

All four videos share a similar presentation structure: an introduction, main body, and conclusion. The main body applies the Predict–Observe–Explain (POE) model to facilitate students' concept development through predicting, observing phenomena, and explaining the results of their observations by connecting macroscopic, submicroscopic, and symbolic representations. The differences between the videos lie in the concept labels, contextual phenomena, experiments, and representations presented according to their respective learning objectives. The characteristics of each video are presented in Table 2.

Table 2. Characteristics of each video

Video	Focus Concept	Characteristics Video
Video 1: Systems and Surroundings	The concepts of systems, surroundings, system boundaries, and types of systems.	The video begins with a contextual phenomenon that encourages students to predict changes in mass and temperature. It continues with experimental observations, then connects macroscopic phenomena with submicroscopic visualizations and symbolic representations through the POE stages.
Video 2: The Law of Conservation of Energy	The concept of the law of conservation of energy as the basis for energy changes in chemical reactions.	The video uses the phenomenon of a space shuttle launch to help students understand the changes in energy forms before relating them to energy changes in chemical reactions through macroscopic, submicroscopic, and symbolic representations.

Video	Focus Concept	Characteristics Video
Video 3: Exothermic Processes	Energy release in exothermic processes.	This video presents exothermic reaction experiments, animations of bond release and formation at the particle level, energy diagrams, and reaction equations to explain the relationship between temperature changes and energy transfer.
Video 4: Endothermic Processes	Energy absorption in endothermic processes.	This video presents endothermic reaction experiments, animations of bond release and formation at the particle level, energy diagrams, and reaction equations to explain the relationship between temperature changes and energy transfer.

Analysis of Content Review Results

The review results indicate that the intertextual-based learning video meets the content requirements, including content accuracy, the presence of multiple representations, and the linking of multiple representations. However, the reviewer provided several suggestions for improving the presentation of concepts to better align with chemistry literature and the linking of multiple representations. All of these suggestions were incorporated through a revision process, resulting in a more refined final product. A summary of the review results is presented in Table 3.

Table 3. Summary of Content Aspect Review Results

Video	Reviewer Comments	Product Revision
Systems and surroundings	Submicroscopic and symbolic representations need clarification.	Added visualization of H_2O molecules and reaction equations.
Law of conservation of energy	The wording of the law of conservation of energy needs to be aligned with the General Chemistry textbook.	Adjusted the law of conservation of energy.
Exothermic processes	The summary emphasizes the concept of exothermic processes and does not revisit the law of conservation of energy.	The summary focuses on the characteristics of exothermic processes.
Endothermic processes	The submicroscopic representation is adapted to the actual conditions of the reaction.	The submicroscopic representation was improved by adding CH_3COOH molecules and representing $NaHCO_3$ in ionic form, consistent with the reaction conditions occurring in solution.

Figure 1. Comparison of the appearance of the learning video before and after revision based on the results of the content aspect review.

Before Revision



(a) System and surroundings

After Revision



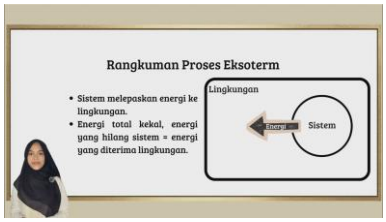
(b) System and surroundings



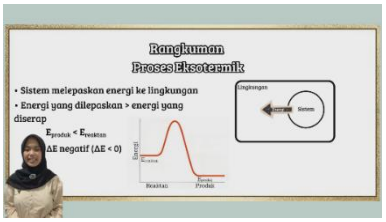
(c) Law of conservation of energy



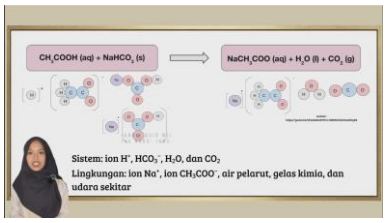
(d) Law of conservation of energy



(e) Exothermic process



(f) Exothermic process



(g) Endothermic Process



(h) Endothermic Process

Figure 1 shows several improvements made based on reviewer input on content aspects. The content review indicated that revisions were necessary to improve conceptual accuracy and clarify the connections between macroscopic, submicroscopic, and symbolic representations. Regarding the concepts of "system" and "surroundings", the addition of H_2O molecular visualizations and reaction equations aimed to clarify the relationship between observed phenomena and processes at the particulate level. For the law of conservation of energy, the wording was adjusted to align with general chemistry literature and prevent misconceptions regarding energy changes. Meanwhile, the summary for the concept of exothermic processes was modified to allow students to focus on the characteristics of these processes without repeating the previously discussed law of conservation of energy.

Revisions to the submicroscopic representation of the reaction between CH_3COOH and $NaHCO_3$ were also required to align the visualization with actual reaction conditions in solution. Acetic acid is a weak acid that exists primarily in molecular form, whereas dissolved $NaHCO_3$ is represented as Na^+ and HCO_3^- ions. Therefore, the visualization needed to depict the presence of CH_3COOH molecules and the relevant ions, rather than portraying all substances as intact molecules or using particle forms inconsistent with solution conditions. These adjustments are crucial because students often struggle to link macroscopic representations with submicroscopic processes (Iswara et al., 2020; Irfandi et al., 2022). Furthermore, inaccurate representations risk reinforcing misconceptions, as students might construct an understanding based on particle models that do not correspond to the observed chemical phenomena. Thus, intertextual-

based learning videos about the concepts of exothermic processes and endothermic processes are declared in accordance with the content aspect criteria, with notes for improvement.

Analysis of Pedagogical Review Results

The review results indicate that the intertextual-based learning video meets the pedagogical criteria, including cognitive, constructivist, and misconception criteria. For the cognitive criteria, the reviewer stated that the material structure was in accordance with the Learning Outcomes and Learning Objective Flow, with a sequence of concepts from systems and surroundings, the law of conservation of energy, exothermic processes, to endothermic processes. The reviewer also recommended that the video on the law of conservation of energy be shortened to make the material more effective.

For the constructivist criteria, the video was deemed to have effectively implemented the "Position for Exploration" (POE) model in facilitating students' conceptual understanding. The POE implementation also supported the principle of learning through a process from factual to conceptual knowledge and from concrete phenomena to abstract understanding. Several improvements were made, including refining the apperception in the endothermic process video by linking the new material to the previously studied concept of exothermic reactions, thereby enabling students to leverage their prior knowledge to grasp more complex concepts. Questions in the prediction phase were revised to focus on anticipated observational outcomes, while questions in the observation and conclusion phases were added to guide students in analyzing experimental results, comparing observations with initial predictions, and formulating conclusions based on evidence. These improvements support a constructivist learning process that involves the interaction between prior knowledge and new information (Sugrah, 2019).

Furthermore, the narrative regarding the direction of energy transfer within the system-and-surroundings framework was revised to prevent misconceptions about the relationship between temperature changes and energy transfer. In the presented experiment, energy transfer from the system to the surroundings was the dominant process. This distinction must be explicitly explained so that students do not mistakenly conclude that reactions involve only energy transfer from the system to the surroundings; energy can also transfer from the surroundings into the system—a concept addressed in the context of exothermic and endothermic processes. Additionally, explicit clarification is necessary to ensure students do not assume that exothermic processes always cause the temperature of the surroundings to drop, or that endothermic processes always cause it to rise. Misconceptions regarding the relationship between the type of process and changes in the temperature of the surroundings have been documented by Rosyidah et al. (2024). Therefore, the explanation of the direction of energy transfer must be linked to the specific system and surroundings being observed, rather than being associated solely with temperature changes in isolation. A summary of the results of the pedagogical aspect review is presented in Table 4.

Table 4. Summary of Pedagogical Aspect Review Results

Criteria	Reviewer Comments	Product Revisions
Cognitive	The sequence of the material is consistent with CP and ATP, but the video on the law of conservation of energy needs to be shortened.	Simplify the explanation without reducing the substance of the material.
Constructivism	The POE stages facilitated knowledge construction, but the apperception, prediction, observation, and conclusion stages need refinement.	Revise the apperception to connect exothermic and endothermic processes, revise the prediction questions to focus on observational results, add prompting questions to the observation stage, and add questions to the conclusion section.
Misconceptions	The explanation of the direction of energy transfer in the system and surroundings concept has the potential to lead to misconceptions.	Improve the narrative regarding the direction of energy transfer according to the context of the experiment.

Based on the results of the pedagogical aspect review, the intertextual-based learning video on the concept of exothermic and endothermic processes was declared to be in accordance with the pedagogical aspect criteria related to constructivism theory and learning principles with several improvements according to the reviewer's suggestions.

Analysis of Media Review Results

The review results indicate that the intertextual-based learning video meets the media aspects based on Mayer's multimedia principles and video presentation. All assessment indicators received a "Yes" rating, thus declaring the video suitable for use as an intertextual-based learning medium. The reviewer assessed that the video applied multimedia principles, such as coherence, signaling, spatial and temporal proximity, segmentation, modality, multimedia, and personalization. Furthermore, the visual quality, text readability, use of narration, color selection, and video duration were deemed to support effective material delivery. Therefore, the video was deemed suitable for use as a learning medium after improvements were made based on the reviewer's input.

Although all indicators met the eligibility criteria, the reviewer noted that every decision in media development, such as determining duration, material presentation structure, and learning strategies, should be based on previous research, a needs assessment, and a review of relevant literature. The topic of exothermic and endothermic processes is abstract in nature and requires connecting macroscopic, submicroscopic, and symbolic representations. Consequently, the video duration was determined by considering the time needed to present phenomena, experiments, particle visualizations, chemical equations, and learning activities without compromising the clarity of the material. A structure comprising an introduction, core activities, and a conclusion was selected to ensure a systematic learning flow, while the POE strategy was employed to engage students in predicting, observing, and explaining phenomena. The integration of verbal and visual elements also draws upon

Mayer's (2009) multimedia learning principles, which emphasize the importance of processing verbal and visual information in an integrated manner.

Regarding duration, the four developed instructional videos last 11 minutes 30 seconds for the topic of systems and surroundings, 11 minutes 13 seconds for the law of conservation of energy, 10 minutes 36 seconds for exothermic processes, and 10 minutes 20 seconds for endothermic processes. These durations were determined by considering the complexity of the material and the need to present phenomena, conceptual visualizations, and learning activities in a coherent sequence. Although instructional videos lasting less than 10 minutes are generally considered more effective for maintaining student attention, complex material may require a longer duration to ensure that explanations and conceptual visualizations are conveyed adequately. Hukom (2025) states that longer videos can enhance student understanding of complex material when supplemented with interactive and visual elements. Thus, the video durations in this study were not determined solely by a specific time limit but were tailored to the scope of the material and a presentation strategy that integrates phenomena, chemical representations, and the Predict, Observe, Explain (POE) stages. Overall, the reviewer stated that the intertextual-based learning video on the concept of exothermic and endothermic processes has very good potential to be used as a learning medium.

DISCUSSION

This research produced four intertextual-based learning videos developed through the integration of content, pedagogy, and media aspects. The integration of these three aspects is the product's main characteristic, distinguishing it from existing learning videos. Not only does the video present concepts scientifically, it is also designed to help students build connections between macroscopic, submicroscopic, and symbolic representations through the POE learning model, which supports learning principles, and multimedia presentation consistent with Mayer's theory. Thus, the video functions not only as a medium for conveying information but also as a medium that facilitates students' knowledge construction.

The results of the study indicate that the developed intertextual-based learning videos meet the content, pedagogy, and media aspects after undergoing a review and revision process. The integration of these three aspects is the product's main characteristic, distinguishing it from existing learning videos. Most learning videos on thermochemistry generally focus solely on conveying concepts through symbolic representations or visualizations of macroscopic phenomena, whereas this study systematically integrates macroscopic, submicroscopic, and symbolic representations in each video. This approach allows students to understand the relationship between observed phenomena, processes occurring at the particle level, and their scientific representations, making learning more meaningful. This finding aligns with Treagust et al. (2003) and Wu (2003) who stated that the interconnectedness of these three representations is a crucial component in building conceptual understanding in chemistry learning.

In terms of content, the review results indicate that the presentation of concepts in the video aligns with scientific concepts after

revisions based on reviewer input. Revisions were made to the presentation of submicroscopic representations, the explanation of the law of conservation of energy, the adjustment of summaries, and the relationship between macroscopic, submicroscopic, and symbolic representations. These improvements demonstrate that the expert validation process plays a crucial role in ensuring the accuracy of concepts presented in learning media. Conceptual accuracy is a fundamental aspect of chemistry learning because errors in conceptual presentation have the potential to lead to misconceptions that are difficult to correct in subsequent learning stages. The results of this study align with those of Indarta et al. (2022) and Rokhim et al. (2023), which state that misconceptions in thermochemistry are generally caused by suboptimal connections between chemical representations during the learning process. Therefore, improving the representations in the learning videos in this study is expected to help students build a more comprehensive conceptual understanding and reduce the potential for misconceptions. In terms of pedagogy, the learning video was developed based on constructivism theory through the application of the POE (Predict, Observe, Explain) model, which provides opportunities for students to build concepts gradually through predicting, observing phenomena, and explaining the results of observations.

visual quality, text readability, narrative clarity, color selection, and video duration were deemed to align with the characteristics of good learning media. These findings demonstrate that the video development took multimedia principles into account, allowing information to be presented more systematically and easily understood by students. These research findings support

The review results showed that improving apperception and questions at the predict, observe, and explain stages strengthened students' knowledge construction process. Apperception connecting exothermic and endothermic processes helped students connect prior knowledge with new concepts, while questions at the predict stage focused on observation results provided students with the opportunity to express predictions based on their existing knowledge before obtaining scientific explanations. Furthermore, questions at the observe and explain stages encouraged students to analyze experimental results, compare them with initial predictions, and draw conclusions based on the evidence obtained. These findings align with constructivism theory, which states that knowledge is actively constructed through learning experiences and interactions between prior knowledge and new information (Sugrah, 2019). Thus, the developed learning video not only functions as a medium for conveying information but also as a medium that facilitates student-centered learning.

Regarding the media aspect, the review results indicated that the instructional video met Mayer's multimedia principles and was therefore deemed suitable for use as a learning medium. The reviewer assessed that the integration of text, images, animation, experimental videos, and narration supported effective material delivery. Furthermore, the

Mayer (2009) Cognitive Theory of Multimedia Learning, which states that learning is more effective when visual and verbal information are presented in an integrated manner, thereby reducing students' cognitive load. These findings also align with research by Khairani et al. (2019), which demonstrated that the use of instructional videos positively impacts student learning

outcomes, and research by Jennah (2020), which states that instructional videos can improve learning quality through more engaging and easily understood presentations.

These research findings also contribute to the development of chemistry learning media. Previous studies have generally focused on developing learning media or improving student learning outcomes. This study integrates three main aspects—content, pedagogy, and media—into a single intertextual learning video. This integration is novel in this research because it produces a learning video that not only presents chemical concepts scientifically but is also designed based on constructivist theory through the Predict, Observe, Explain (POE) model and applies Mayer's multimedia principles. Furthermore, the video was developed by systematically connecting macroscopic, submicroscopic, and symbolic representations, helping students understand the concepts of exothermic and endothermic processes more comprehensively. Therefore, the developed learning video has the potential to become an alternative learning medium that supports more meaningful chemistry learn

Table 5. Comparison of the developed product with previous thermochemistry learning media

Research	Content Aspect	Pedagogical Aspect	Media Aspect
Donasari and Silaban (2021)	Focuses on thermochemistry material; details regarding the integration of macroscopic, submicroscopic, and symbolic representations are not specified in the reviewed article information.	Specific instructional approaches are not detailed in the available abstract.	Suitability is evaluated based on content, presentation, language, and graphic design aspects. The media was tested on 30 students, and learning outcomes were reported.
Yuliana and Sholichah (2021)	Uses an intertextual approach based on multiple representations for thermochemistry material. Details regarding the scope of concepts per representation are not specified in the available abstract.	Focused on developing students' chemical literacy; specific learning models or stages are not detailed in the abstract.	The product is a module developed through the development stage and assessed for validity, covering aspects such as being self-instructional, self-contained, stand-alone, adaptive, and user-friendly.
Tua et al. (2020)	Focuses on thermochemistry instruction; the use of multiple representations is not detailed in the reviewed article information.	Compares instruction using the PBL and Discovery Learning models with Macromedia Flash.	It utilizes Macromedia Flash as the medium, while examining learning outcomes, classroom interaction, and motivation.
This study	Connects macroscopic, submicroscopic, and symbolic representations in the presentation of thermochemistry concepts.	Integrates the Predict, Observe, Explain (POE) stages through activities involving prediction, observation of phenomena or experiments, and explanation.	The product is a video featuring conceptual visualization and expert review regarding content, pedagogy, and media aspects, including multimedia design principles.

Based on Table 5, previous studies have developed thermochemistry learning media in the form of Android applications, multiple-representation-based modules, and

Macromedia Flash media used in conjunction with specific learning models. This study developed a product consisting of four instructional videos that specifically link macroscopic, submicroscopic, and symbolic representations while integrating the POE (Predict-Observe-Explain) stages. Thus, the product's contribution lies in combining video media, the interlinking of chemical multiple representations, and POE learning stages into a video series covering the concepts of systems and surroundings, the law of conservation of energy, and exothermic and endothermic processes. This comparison highlights differences in focus and product characteristics, but it is not intended to imply that these elements have never been utilized in other studies.

This study has limitations because product development only reached the main product revision stage, so the video's effectiveness in improving conceptual understanding and reducing misconceptions has not been tested on students. Therefore, further research needs to continue the development stage with broader field trials to empirically demonstrate the product's effectiveness.

CONCLUSION

This study produced four intertextuality-based instructional videos covering the concepts of systems and surroundings, the law of conservation of energy, and exothermic and endothermic processes. The videos were developed by integrating macroscopic, submicroscopic, and symbolic representations using the Predict–Observe–Explain (POE) model and Mayer's multimedia principles. Review results indicate that the product met the criteria for content, pedagogy, and media aspects following revisions based on expert feedback.

Theoretically, this study provides insights into integrating multiple representations, constructivist learning models, and multimedia principles in the development of chemistry instructional videos. Practically, the developed product serves as an alternative instructional medium to assist teachers in presenting concepts regarding exothermic and endothermic processes and to help students connect observed phenomena with explanations at the particulate and symbolic levels.

A limitation of this study is that product development concluded at the main product revision stage and did not include field trials to measure effectiveness regarding conceptual understanding or the reduction of student misconceptions. Therefore, future research should conduct broader trials to determine the videos' effectiveness and applicability in the learning process.

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