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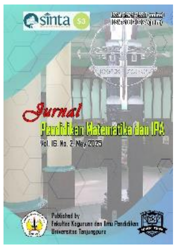

# DEVELOPMENT OF VIDEO-BASED STUDENT WORKSHEETS (LKM) USING GEMINI VEO 3 TO IMPROVE STUDENTS' INQUIRY SKILLS IN SCIENCE LEARNING

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***Abstract***

*21st-century science education demands mastery of inquiry skills as part of higher-order thinking. However, in learning about elements and compounds in an agricultural context, students often struggle to visualize abstract microscopic processes, resulting in low analytical ability. This study aims to develop a Generative AI Gemini Veo 3 video-based Student Worksheet to improve students' inquiry skills. The study employed a Research and Development (R&D) method using the 4D model (Define, Design, Develop, Disseminate) involving 94 eighth-grade students. Product validation by experts indicated high feasibility, with scores of 92% from material experts and 89% from media experts. The effectiveness test showed a significant improvement in students' inquiry skills, with an N-Gain value of 0.71 (high category), particularly in visual-based data analysis. These findings imply that integrating Generative AI-based video into learning materials can serve as an effective strategy to support inquiry-based learning and enhance students' understanding of abstract scientific concepts.*

***Keywords***: *Gemini Veo 3, Inquiry Skill, Digital LKM, 4D Model, Science Learning*

## INTRODUCTION

Natural Science Education in the 21st century requires a paradigm shift in learning, from what was originally oriented towards mastering content to developing higher-order thinking skills, especially inquiry skills [1]. Inquiry-based learning places students as active subjects in the scientific process, which involves the ability to formulate problems, formulate hypotheses, design and carry out investigations, analyze data, and draw conclusions based on empirical evidence [2].

However, the implementation of inquiry learning in schools still faces various obstacles. research conducted by several empirical studies in Indonesia and overseas suggested that students are not very well between investigative or inquiry skills, so

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continued to strengthen it. In Indonesia, students' science process skills in planning experiments and communicating findings are said to be at the low category at the elementary level [3]. In secondary level, we are trained on little practicum and independently designing/conducting investigations [4]. So students show weak abilities when it comes to proposing actions and results interpretation. Internationally, these same patterns exist where students show limited ability to perform core inquiry tasks like generating hypotheses and reflecting on the results of an investigation [5]. The findings indicate that students' inquiry skills are not well developed and suggest the need for other instructional methods. This condition shows that there is a gap between the demands of the curriculum and the reality of learning in the classroom, thus creating an urgency for the innovation of teaching materials that are able to visualize abstract science phenomena and facilitate the inquiry process in a more concrete, contextual, and interesting way for students.

In line with these challenges, the integration of Artificial Intelligence (AI) technology in the field of education is growing rapidly and has become a transformative global trend. Recent bibliometric studies show a significant increase in the number of publications related to the use of AI in science education, with a primary focus on personalizing learning, learning efficiency [6]. More specifically, the presence of Generative Artificial Intelligence (Gen AI) opens up new opportunities in the development of adaptive and contextual learning content. In contrast to conventional educational technology which is generally limited to static simulations or passive learning videos, Gen AI enables the production of teaching materials that are dynamic, flexible, and responsive to the needs of the curriculum and the characteristics of students [7]. This trend confirms that the use of AI is no longer just an option, but rather a strategic need to bridge the limitations of conventional teaching resources in facilitating complex inquiry skills.

Nonetheless, the huge potential of AI in education has not been fully offset by equitable and in-depth utilization in science learning practices. Most AI-based media research and development still focuses on the use of text-based chatbots, automated scoring systems, or learning data analysis, while the use of generative AI for science learning video production is still relatively limited [8]. On the other hand, teachers often face technical constraints and time constraints in producing high-quality learning videos that are able to accurately and systematically represent the scientific process. In fact, instructional videos have a crucial role in inquiry-based learning, especially for visualizing experiments, microscopic phenomena, as well as chemical and physical processes that are difficult or impossible to do directly in the classroom [9], [10]. This limited access to sophisticated yet easy-to-use visual media has implications for students' low ability to visualize abstract concepts, which further impacts the development of their inquiry skills [11].

To answer this gap, this research offers a solution through the development of video-based teaching

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materials by utilizing the latest video generative technology from Google DeepMind, namely Gemini Veo 3. This technology has advanced text-to-video capabilities, allowing educators to produce high-resolution learning videos (up to 1080p) that are capable of visualizing complex science concepts and experimental scenarios only through text commands (prompts) [12]. The use of Gemini Veo 3 as a pedagogical partner allows the presentation of visual representations that not only support students' conceptual understanding, but also increase affective engagement and learning motivation, which are particularly relevant at the inquiry stages such as observation, interpretation, and inference [13]. The novelty of this research lies in the specific integration of this cutting-edge generative video model into the syntax of inquiry learning, an approach that has been rarely explored in the science education literature until now.

Based on this description, the purpose of this research is to develop and test the feasibility of Gemini Veo 3 video-based Student Worksheets (MFIs) to improve students' inquiry skills in science learning. The videos designed in this study are structured to represent key phases of the inquiry process, including problem orientation through contextual scientific phenomena, guided hypothesis formulation, visualization of virtual experiments, and data interpretation activities. Specifically, the videos focus on science topics that are abstract and require visualization, such as changes in the state of matter and simple physical or natural phenomena, which are often difficult to observe directly in classroom settings. Through the integration of dynamic visualizations, simulated experiments, and guiding questions embedded in the worksheets, these videos are expected to facilitate students in formulating problems, designing investigations, and drawing evidence-based conclusions. Theoretically, this research is expected to enrich the Technological Pedagogical Content Knowledge (TPACK) framework by including video-based generative AI elements as a cognitive tool in science learning. Practically, the resulting product is expected to be an alternative solution for teachers in providing immersive, efficient, and technology-aligned learning media, so as to optimally stimulate students' curiosity, analytical skills, and investigative skills [14].

## METHOD

This study used a Research and Development (R&D) approach to develop and test the effectiveness of video-based LKM with Artificial Intelligence using Gemini Veo 3 in improving students' inquiry skills in science learning. The study was conducted at SMPN 2 Margoyo, with eighth grade students selected purposively based on the characteristics of science learning. The total sample size was 94 students divided into three classes. The development model used was Thiagarajan's 4D model, which includes the stages of Defining, Designing, Developing, and Disseminating.

In the Define stage, a needs analysis was conducted through observation, interviews, and initial testing to identify learning problems, student characteristics, and difficulties

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with abstract concepts. Furthermore, a gap analysis of inquiry skills was conducted based on five main indicators: observing, formulating problems, formulating hypotheses, analyzing data, and drawing conclusions. These were analyzed descriptively and quantitatively as the basis for product design.

The Design stage focused on designing a prototype inquiry-based learning material integrated with Generative AI video using Gemini Veo 3. The design included scenario development, storyboarding, LKM structure, and the integration of video-based prompt engineering to visualize abstract phenomena, along with visual design and learning time allocation.

In the Development stage, validation was conducted by three experts (materials, media, and language) using a Likert-scale questionnaire converted to percentages with a minimum eligibility criterion of 75%. Next, a small group trial was conducted in one class (n = 30 students) to measure the readability, understandability, and ease of use of the product, the results of which were used as the basis for formative revisions.

The Disseminate stage was conducted through a large-scale field trial in two classes (n = 64 students) using a quasi-experimental pretest–posttest control group design. The pretest instrument used true-false questions to identify initial misconceptions, while the posttest was based on AKM with various question formats to measure inquiry skills and HOTS. Product effectiveness was analyzed by comparing pre-test and post-test scores and calculated using the N-Gain index.

Data collection techniques included interviews, observations, questionnaires, and documentation. Data were analyzed qualitatively to describe user needs and responses, and quantitatively to assess the product's feasibility and effectiveness.

## RESULT AND DISCUSSION

### Define Stages

The definition stage begins with the analysis of the front end (Front-end analysis) which identifies the fundamental problem that students' low inquiry skills in elemental and compound materials are due to the inability of conventional teaching materials to visualize crucial abstract processes in agriculture, such as the reaction mechanism of ionization of NPK fertilizers and their diffusion into plant roots, which often triggers students' misconceptions in distinguishing nutrients and complex compounds [15]. Findings on the analysis of students (Learner Analysis) shows that even though students have good digital literacy, they experience cognitive difficulties in formulating logical hypotheses when only faced with textual MFIs without dynamic visual stimulus, so a cognitive bridge in the form of video media is needed [16]. Therefore, through task analysis (Task Analysis) and concept, it is stipulated that MFI development must be integrated with technology Generative AI Gemini Veo 3 which is able to produce realistic microscopic simulations to support inquiry syntax from observation to conclusion as a strategic solution to improve understanding of agricultural chemistry concepts as a whole [17], [18].

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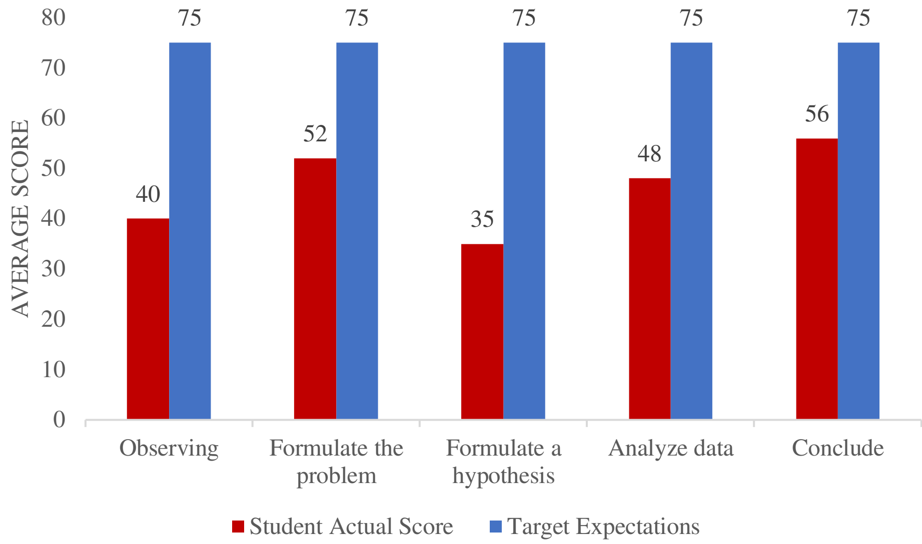


Figure 1. Student Inquiry Skills Gap Analysis

The gap analysis results were obtained from a preliminary diagnostic test based on five inquiry skill indicators, as described in the method section. To strengthen these findings, the researcher conducted a gap analysis of students' inquiry skills profiles by comparing actual achievements and expected ideal targets in the curriculum. The quantitative data obtained from the preliminary survey are visualized in Figure 1, which specifically highlights significant inconsistencies in the indicators of 'observing the phenomenon' and 'analyzing the data'.

Based on the gap analysis graph, data interpretation showed a sharp disparity between students' actual abilities and the curriculum targets, where the indicators 'Hypothesis' and 'Observing' recorded the lowest scores (35 and 40 on a scale of 100, respectively). The extreme achievement deficit in these two aspects confirms that the main cognitive obstacle of students lies in the inability to visualize abstract chemical reaction processes that occur on agricultural land, thus empirically validating the urgency of integrating Gemini Veo 3-based simulation videos into MFIs as a visual bridge solution to concretize these microscopic phenomena.

The low achievement of these two fundamental indicators indicates the absence of adequate visual media, thus validating the need for technological intervention as mapped in the solution matrix in Table 1.

### Design Stage

The design stage aims to produce a prototype of MFIs that are ready to be developed. At this stage, the researcher transforms the conceptual framework into a complete digital MFI's visual product. The MFI structure is designed to guide students through the syntax of inquiry with the help of visualizations from the Gemini Veo 3 video. The design of each LKM component is shown in Table 2.

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Table 1. Matrix of discovery stages define and specification of MFIS based on Gemini Veo 3

| Define Analysis Components | Specific Problem Findings (Agricultural Material) | Solution: MFI Feature Integration & AI Video |
|---|---|---|
| Learner Analysis | Students of the Alpha generation are passive when reading a long text on "The Chemical Properties of Soils". Motivation is low because the material is considered irrelevant. | Flipbook/Digital Format: MFIs are made interactive (similar to Heyzine) with *video hyperlinks*. Videos use *the cinematic style of AI to attract visual attention from the beginning of learning.* |
| Concept Analysis | Difficulty distinguishing the concept of Macroscopic (Yellow leaves) from Sub-microscopic (Lack of $Mg^{2+\text{ ions}}$). | Split-Screen Video Feature: Gemini Veo 3 videos are designed to display two screens at once: Left (Garden Conditions) and Right (Molecular Animation within the leaf network). |
| Task Analysis | CP requires students to analyze the impact of excess/deficiency of nutrients. Students are often *stuck* because there is no *real-time visual data.* | AI *Time-lapse* Simulation: The video shows an explanation of several nutrients as a theoretical foundation in working on MFIs. |
| Curriculum Analysis (*Front-end*) | Inquiry Skill *Demands: Students must be able to find problems (Problem Finding*) independently. | Open Problem Scenario: The intro video does not provide an answer, but rather shows anomalies (e.g., the administration of different reagents to test the nutrient content in the soil) to provoke students to write a problem formulation in MFIs. |
| Formulation of Objectives | Improve the ability to make scientific arguments based on evidence. | "Visual Evidence" Column: Within the MFI, a special column is added where students are required to include *a video timestamp* that supports their conclusions. |

Table 2. The design of each LKM

| **Design** | ***Screenshot*** | **Explanation** |
|---|---|---|
| Cover Page Design |  | Cover pages are designed to visually represent the context of the material. The depiction of the agricultural atmosphere with farmers watering plants and pictures of NPK fertilizers creates a fresh but scientific impression to attract the interest of Generation Alpha students [17], [18] |

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| Design | *Screenshot* | Explanation |
|---|---|---|
| Concept Map and Learning Goal Flow |  | Concept maps are designed to help students organize their knowledge of material structures in the context of agriculture. The placement of nutrients (N, P, K) along with their testing with multiple reagents and fertilizer compounds in the material hierarchy emphasizes the position of the chemical concept in real applications. Learning objectives are explicitly stated so that students understand the competency targets that must be achieved, especially the ability to associate elemental properties with plant nutrition [15]. |
| AI Video Integration |  | In the summary of the material, MFIs do not present long texts, but rather AI videos *Stuart T* with Gemini Veo 3. This video provides a real explanation and reduces abstract things related to elemental and compound materials. Problem formulation columns are provided to facilitate the syntax of the inquiry *Problem finding* directly after visual stimulation [16]. |
| AI-generated Image Visualization |  | On the work step, a picture of the result is displayed *Stuart T* with Gemini AI to visualize the stages of the activity clearly [19]. |

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| Design | *Screenshot* | Explanation |
|---|---|---|
| Evaluation Instruments |   | The evaluation instrument is arranged into two, namely *Pre-test* and *Post test*. *Pre-test* It is compiled using a model of true and false questions. For stages *Post test* It was prepared with a literacy and numeracy HOTS question model with 5 question forms including multiple-choice questions, PGK MCMA, PGK categories, matchmaking, and description. This question is designed with the AKM question model to improve skills *Inquiry Skills* with different cognitive levels [20]. |

In addition to the prototype design at this stage, the design of the proportion of time in one learning cycle using this MFI. The goal is to ensure that AI video integration does not dominate (passive) learning, but rather serves as a spark for student inquiry activity (active). Figure 2 shows that the design of MFIs is designed with the principle of Student-Centered. Despite using advanced technology (Gemini Veo 3), the video viewing duration (blue block) is designed to be short and dense, only dominant at the Orientation and Data Collection stages. In contrast, the largest portion is allocated to student activities (orange blocks), especially at the Data Analysis stage (12 minutes). This guarantees that the video serves as a scaffolding, not a substitute for the thought process.

## Develop Stage

The development phase aims to produce a Gemini Veo 3 video-based MFI final product that has been validated and revised based on expert input and limited trials. This stage consists of two main steps: expert validation (Expert Appraisal) and development trials (Developmental Testing) [21]. The following graph shows the recapitulation of the product feasibility percentage score based on the assessment of three experts (Material, Media, Language) and the results of student responses at the limited trial stage.

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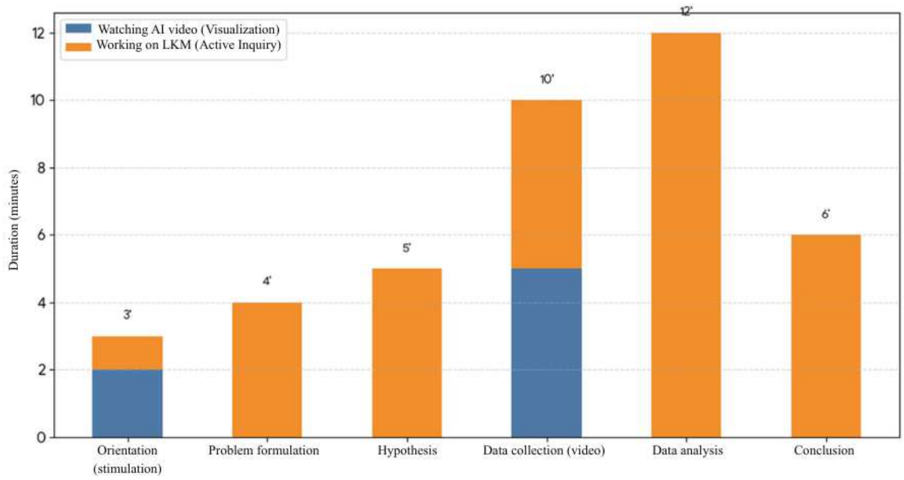


Figure 2. Design of Student Activity Distribution between Watching AI Videos and Working on MFIs

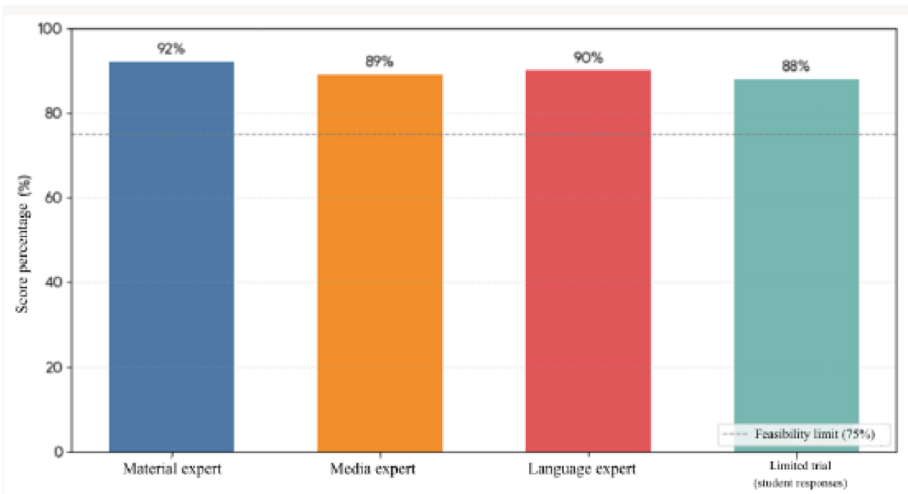


Figure 3. Results of expert validation and limited trial of video-based MFIs with Gemini Veo 3

Based on the graph above, the development results at the Develop stage show that the Gemini Veo 3 video-based MFI product is of excellent quality and feasible to implement. The Subject Expert's assessment obtained the highest score of 92%, which indicates that the integration of the concepts of agricultural elements and compounds with the syntax of the inquiry has been presented accurately and in-depth. Media Experts and Linguists gave ratings of 89% and 90%, respectively, confirming that the visual design of AI videos and the language readability of MFIs have met the feasibility standards of digital learning media. This consistency of quality is also reflected in the Limited Trial, where student responses reached 88%, which means that students feel greatly helped by video visualization in understanding abstract material. Overall, all

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assessment components are well above the feasibility limit (75%), so that the product is declared valid without major revisions and is ready to proceed to the dissemination stage (Disseminate).

**Stages of Dissemination**

The deployment phase aims to test the effectiveness of the Gemini Veo 3 video-based MFI product on an actual class scale through a One-Group Pretest Posttest design. The fundamental difference in this stage lies in the differentiation of evaluation instruments designed to comprehensively capture students' cognitive development, from understanding basic concepts to higher-level thinking skills (HOTSs).

**a. Initial Diagnostic Analysis (Pre-test)**

Before the treatment is given, students do a pre-test which is prepared using the True-False question model. This format was chosen to quickly diagnose students' fundamental misconceptions about elemental and compound matter in the context of agriculture. The pre-test results showed a low average score, which was 48.50. Analysis of question items revealed that 70% of students answered "True" to incorrect statements such as "Urea fertilizer is absorbed by the roots in the form of solid granules". This indicates that students do not have the correct microscopic model mentality and tend to understand agricultural phenomena only macroscopically (see fertilizer physics), without understanding the ionization process that actually occurs (Azizah et al., 2022).

**b. Final Implementation and Measurement (Post-test AKM Model)**

After the implementation of learning using MFIs integrated with Gemini Veo 3-based simulation videos, final measurements were carried out using post-test instruments based on the Minimum Competency Assessment (AKM). This instrument is designed to measure students' inquiry skills and science literacy through visual stimuli presented in the form of videos. Question items are arranged with the dominance of the L3 cognitive level (reasoning), which includes various forms of questions, namely multiple choice to measure the ability to recall concepts, multiple choice multiple answers that allow students to choose more than one correct answer, complex multiple choice in the form of true false or yes no categories to classify statements, matching questions to connect statements or visual representations with the right answer, as well as description questions that require students to formulate arguments, reason, and draw conclusions based on the inquiry process that has been carried out.

**c. Effectiveness Analysis (N-Gain)**

Based on figure 4, there is a significant difference between the profile of students' initial ability (pre-test) and final ability (post-test). During the pre-test with the True-False model questions, the lowest scores were found in the indicators "Formulating Hypotheses" (38) and "Data Analysis" (45). This confirms that without the help of the media, students tend to guess only the answer and have difficulty imagining abstract variables of soil chemical reactions.

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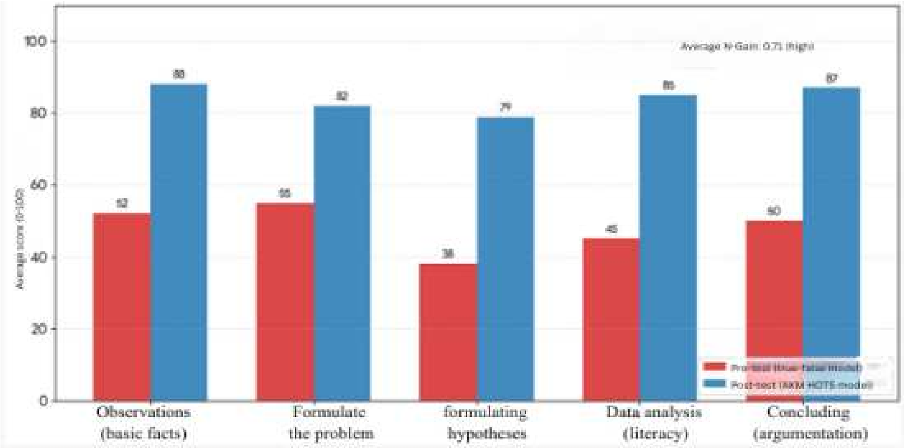


Figure 4. Improving Students' Inquiry Skill Profiles: Pre-Test and Post Test

However, after the intervention using Gemini Veo 3-based MFIs and evaluated using the AKM question, there was a drastic spike in scores on both indicators to 79 and 85. The highest improvement in the "Data Analysis" aspect (+40 points) showed that the successful simulation video functioned as concrete visual data that made it easier for students to answer complex literacy questions (PGK and Description). Overall, the average N-Gain of 0.71 (High Category) proves that this MFI is effective in transforming students' understanding from simply memorizing facts (basic level) to high-level reasoning skills (HOTS) [22]. These findings also align with research by Lawide et al., which asserts that interactive visual media can strengthen higher-order thinking skills [23]. Thus, generative videos in worksheets (LKM) function not only as visual aids but also as cognitive scaffolding that helps students think more systematically during the inquiry process.

## CONCLUSION

This research demonstrates that the development of a Generative AI Gemini Veo 3 video-based worksheet using a 4D model is valid and effective in improving students' inquiry skills in the topic of elements and compounds. Expert validation results indicated a high level of feasibility, while the effectiveness test demonstrated a significant increase with an N-Gain value of 0.71 (high category), particularly in the data analysis and hypothesis formulation indicators. These findings confirm that the integration of generative video can overcome the limitations of visualizing abstract concepts and function as cognitive scaffolding in inquiry learning.

This research still has limitations in the trial design, which did not fully utilize strict experimental controls and the limited scope of material on a specific topic. Therefore, future research is recommended to implement a more robust experimental design (e.g., a control group design) and test the effectiveness of this model on other

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abstract science materials to obtain broader generalizability of the findings.

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