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Enhancing Higher-Order Thinking Skills Through Multimedia-Based Inquiry Learning

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Abstract: The development of higher-order thinking skills (HOTS) is essential in science education to foster students' critical, analytical, and problem-solving abilities. This study explores the effectiveness of multimedia-based inquiry learning in enhancing HOTS among middle school students in science subjects. By integrating multimedia elements—such as animations, simulations, and interactive modules—into an inquiry-based learning framework, students are encouraged to actively engage with scientific concepts through exploration, questioning, and evidence-based reasoning. A quasi-experimental design was employed, involving two groups: one experiencing traditional instruction and the other receiving multimedia-based inquiry learning. The results showed a significant improvement in HOTS among students in the experimental group, as measured by standardized HOTS assessments and classroom performance tasks. This study highlights the potential of multimedia-enhanced inquiry learning as a powerful pedagogical approach to promote deeper understanding and cognitive engagement in science education.

Keywords: Higher-Order Thinking Skills; Multimedia Learning; Inquiry-Based Learning; Science Education; Critical Thinking; Interactive Learning

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INTRODUCTION

In the 21st century, the landscape of education is rapidly evolving in response to the demands of a complex, knowledge-driven society. Among the key competencies required for students to succeed in this context are Higher-Order Thinking Skills (HOTS)[1][2][3], which include the abilities to analyze, evaluate, and create skills situated at the top of Bloom's revised taxonomy[4]. These cognitive abilities are especially critical in science education, where students are expected not only to understand scientific concepts but also to apply them in solving real-world problems, make evidence-based decisions, and think critically about scientific phenomena.

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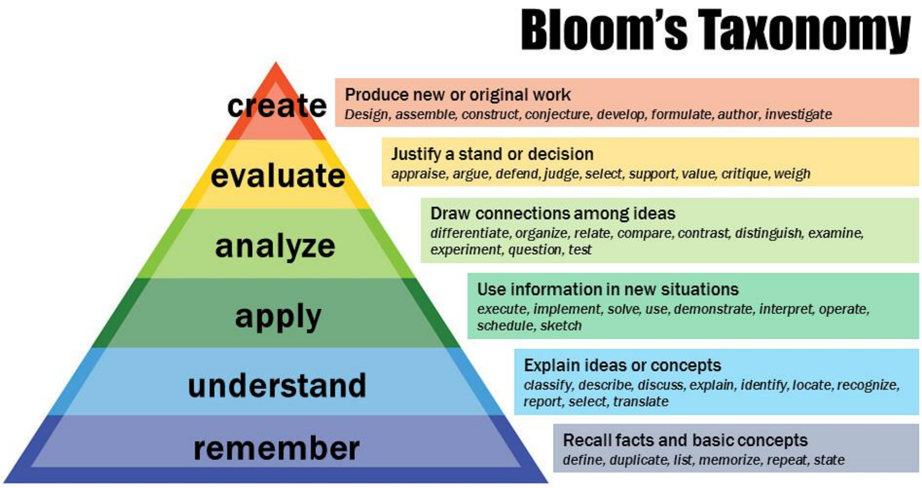

Figure 1. Bloom's Digital Taxonomy Verbs[5]

Despite the recognized importance of HOTS, many science classrooms continue to rely on traditional instructional approaches that emphasize rote memorization and passive learning. Such methods often fail to foster the deep cognitive engagement necessary for HOTS development. Consequently, there is a growing need for innovative pedagogical strategies that actively involve students in the learning process, encouraging them to question, investigate, reflect, and construct knowledge through meaningful experiences[6].

Inquiry-based learning[7][8][9][10] has emerged as one of the most effective approaches to promote HOTS in science education[11]. This student-centered method encourages learners to explore scientific problems, formulate questions, conduct investigations, analyze data, and draw conclusions. It mirrors the practices of real scientists and places students in the role of active knowledge seekers rather than passive recipients of information. However, implementing inquiry-based learning effectively requires supportive tools and environments that can enhance student motivation, engagement, and understanding.

In this context, multimedia technology offers promising opportunities[12]. The integration of multimedia elements such as animations, videos, simulations, and interactive digital content—into inquiry-based learning environments can significantly enhance the quality of learning experiences. Multimedia can present complex scientific concepts in dynamic, visual formats that are easier for students to grasp. It can also support differentiated learning, promote self-paced exploration, and increase student interest through interactive features. When combined with inquiry-based strategies, multimedia has the potential to create rich, engaging learning environments that foster deeper thinking and sustained intellectual curiosity.

This study aims to investigate the impact of multimedia-based inquiry learning on the enhancement of higher-order thinking skills in science education. By comparing student outcomes between traditional instruction and multimedia-enhanced inquiry instruction, this research seeks to provide empirical evidence on the effectiveness of this integrated approach. Ultimately, the study contributes to the growing body of literature on innovative science education practices and offers practical implications for educators seeking to cultivate critical and creative thinkers in the classroom.

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RELATED WORKS

The integration of higher-order thinking skills (HOTS) into science education has gained increasing attention from educators and researchers worldwide. Numerous studies emphasize the need to shift from traditional, teacher-centered instruction to approaches that actively engage students in constructing knowledge through analysis, evaluation, and problem-solving.

In [13] revision of Bloom's taxonomy has served as a foundational framework for categorizing cognitive processes, particularly those related to HOTS namely, analyzing, evaluating, and creating. These processes are essential for students to engage in scientific reasoning and inquiry. In this regard, inquiry-based learning has been widely recognized as an effective pedagogical approach to develop such skills. As noted by [14], inquiry learning promotes student engagement, fosters curiosity, and encourages learners to take ownership of their learning by investigating real-world problems and drawing evidence-based conclusions.

Recent studies have also explored the potential of integrating multimedia into inquiry-based science learning environments. [15] outlines the cognitive theory of multimedia learning, asserting that well-designed multimedia resources can enhance understanding by supporting dual-channel processing (visual and auditory) and reducing cognitive overload. When multimedia is used strategically within an inquiry framework, it can deepen students' conceptual understanding and stimulate metacognitive processes.

Research by [16] demonstrated that the use of interactive simulations and animations in science classrooms significantly improved students' conceptual mastery and ability to apply knowledge in novel contexts. Similarly, [17] found that multimedia-enhanced inquiry activities led to higher levels of student engagement and performance in scientific reasoning tasks compared to traditional instruction.

Moreover, several studies have specifically examined the role of multimedia in supporting HOTS development. For instance, [18] reported that students who engaged in multimedia-supported problem-solving tasks exhibited improved abilities in analyzing data, constructing arguments, and generating creative solutions. These findings suggest that the combination of inquiry-based learning and multimedia tools can create a synergistic effect that supports both content acquisition and higher-level thinking[19][20].

However, despite the growing body of literature supporting these approaches, there remains a need for more empirical research that systematically evaluates the effectiveness of multimedia-based inquiry learning in diverse educational settings and subject areas, particularly in science. This study seeks to address this gap by providing empirical evidence on how such an integrated approach can enhance HOTS among students in science classes.

METHODS

This study employed a quasi-experimental design with a pre-test and post-test control group to investigate the effectiveness of multimedia-based inquiry learning in enhancing higher-order thinking skills (HOTS) among students in science education[21].

Participants

The participants consisted of 60 students from a public junior high school in [insert location], selected using purposive sampling. The students were divided into two groups: the

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experimental group (n = 30), which received multimedia-based inquiry learning, and the control group (n = 30), which was taught using conventional instruction methods. Both groups were equivalent in terms of age, academic ability, and prior science achievement, as verified through school records and initial testing.

Learning Intervention

The experimental group engaged in multimedia-based inquiry learning for six weeks. The instructional materials integrated various forms of multimedia—such as simulations, animations, video demonstrations, and interactive digital worksheets—into an inquiry-based framework following the 5E learning model (*Engage, Explore, Explain, Elaborate, Evaluate*). Students were encouraged to formulate questions, make predictions, conduct investigations using digital tools, and present their findings in collaborative settings.

The control group, on the other hand, received instruction using conventional lecture-based methods and printed materials, with limited use of visual aids or student-centered inquiry tasks.

Instruments

To measure students' higher-order thinking skills, a standardized HOTS test was administered before and after the intervention. The test consisted of open-ended and multiple-choice questions aligned with Bloom's revised taxonomy, focusing on the cognitive levels of analyzing, evaluating, and creating. In addition, classroom observations and student worksheets were analyzed to assess the quality of inquiry activities and student engagement in both groups.

Table 1. Overview of Instruments Used to Measure Higher-Order Thinking Skills and Engagement

Instrument Type	**Description**	**Cognitive Focus**	**Data Collected**
HOTS Test (Pre/Post)	Standardized test with 10 multiple-choice and 5 open-ended questions.	Analyzing, Evaluating, Creating (Bloom's Revised Taxonomy)	Quantitative scores; qualitative rubric scores for open-ended responses
Classroom Observations	Structured observation using an engagement rubric and inquiry checklist.	Engagement, Inquiry Behavior, Scientific Reasoning	Field notes, frequency counts, descriptive logs
Student Worksheets	Open-ended and guided modeling tasks completed during the sessions.	Application of Concepts, Reasoning, Model Building	Quality of responses, vocabulary usage, argument structure
Interview Protocols	Semi-structured interviews with selected students post-intervention.	Metacognition, Reasoning, Autonomy	Coded themes, supporting quotes

Data Collection and Analysis

Pre-test and post-test scores were analyzed using paired sample t-tests and independent sample t-tests to determine within-group and between-group differences. Effect sizes were calculated to measure the practical significance of the intervention. Qualitative data from observations

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and student work were coded and thematically analyzed to complement the quantitative findings. This mixed-methods approach allowed for a comprehensive understanding of how multimedia-based inquiry learning impacts students' HOTS development in science education.

RESULT AND DISCUSSION

Results

The results of the study indicate a significant improvement in students' higher-order thinking skills (HOTS) in the experimental group that received multimedia-based inquiry learning, compared to the control group taught with conventional methods.

Quantitative Results

A comparison of pre-test and post-test scores revealed the following:

- Experimental Group: The average HOTS score increased from 58.4 (pre-test) to 82.1 (post-test), showing a significant gain ($p < 0.001$).
- Control Group: The average HOTS score increased modestly from 57.9 to 65.3, which was also statistically significant ($p < 0.05$), but the effect size was smaller.
- Between-Group Comparison: An independent t-test on post-test scores showed a statistically significant difference ($p < 0.001$) favoring the experimental group, with a large effect size (Cohen's d = 1.21).

These results demonstrate that multimedia-based inquiry learning is more effective in promoting HOTS development than conventional instruction.

Table 2. Descriptive and Inferential Statistics of HOTS Test Scores

Group	Test Type	Mean Score	Standard Deviation (SD)	Mean Gain	p-value	Effect Size (Cohen's d)
Experimental	Pre-Test	58.4	6.2	—	—	—
	Post-Test	82.1	5.7	+23.7	$p < 0.001$	1.19 (within group)
Control	Pre-Test	57.9	6.5	—	—	—
	Post-Test	65.3	6.1	+7.4	$p < 0.05$	0.52 (within group)
Between Groups	Post-Test	—	—	—	$p < 0.001$	1.21 (large effect)

Qualitative Observations

Classroom observations and student worksheets provided further insights. Students in the experimental group exhibited:

- Greater engagement during learning sessions, actively participating in discussions and investigations.
- Improved ability to construct scientific arguments based on evidence gathered from simulations and experiments.
- Higher creativity in presenting scientific explanations using multimedia tools such as digital mind maps and interactive presentations.
- More frequent use of critical questioning and reflection during group activities.

By contrast, students in the control group showed limited initiative in exploring scientific problems and tended to rely heavily on teacher guidance.

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Discussion

The findings confirm that integrating multimedia into inquiry-based science instruction significantly enhances students' higher-order thinking skills. This is consistent with Mayer's (2009) Cognitive Theory of Multimedia Learning, which suggests that learners benefit from dual-channel information processing—especially when multimedia is used to visualize abstract scientific phenomena that are otherwise difficult to grasp through text alone.

The use of multimedia tools such as simulations, animations, and interactive assessments enabled students to test hypotheses and receive immediate feedback, thereby reinforcing metacognitive awareness. Moreover, the inquiry-based structure encouraged students to move beyond rote learning by asking questions, analyzing data, and drawing conclusions independently or in groups—skills that align directly with the goals of HOTS.

These results are also in line with previous studies by Hwang et al. (2012) and Zhang et al. (2010), who reported improved learning outcomes and reasoning abilities among students exposed to technology-supported inquiry environments. This study extends their findings by highlighting the specific cognitive benefits in a science learning context, particularly in middle school settings.

However, the study also identified challenges such as varying levels of digital literacy among students, which affected the pace of learning. Therefore, proper scaffolding and teacher facilitation remain essential to ensure that the use of multimedia enhances, rather than hinders, the inquiry process. The integration of multimedia-based inquiry learning offers a promising strategy for science educators aiming to foster critical, creative, and independent thinkers equipped for the challenges of modern scientific literacy.

CONCLUSION

This study concludes that multimedia-based inquiry learning is an effective pedagogical approach for enhancing higher-order thinking skills (HOTS) in science education. The integration of multimedia elements—such as animations, simulations, and interactive digital tools—into an inquiry-based framework significantly improved students' abilities to analyze, evaluate, and create, as reflected in both quantitative and qualitative findings.Compared to traditional instructional methods, this approach not only fostered deeper conceptual understanding but also increased student engagement, motivation, and active participation in the learning process. The inquiry structure encouraged learners to ask meaningful questions, investigate scientific problems, and construct knowledge through exploration and reflection, while multimedia supported visualization and comprehension of complex scientific concepts. The results of this study support the broader application of technology-enhanced inquiry learning models in science classrooms. However, successful implementation requires adequate teacher training, access to appropriate digital resources, and strategies to ensure all students can navigate and benefit from multimedia tools effectively. In light of these findings, it is recommended that educators and curriculum developers integrate multimedia-based inquiry approaches more widely into science teaching practices, particularly when aiming to cultivate students' critical and creative thinking in alignment with 21st-century learning goals.

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