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The Effect Of Virtual Reality In Electronic Worksheets With Discovery Learning On Improving Critical Thinking Skills Of Junior High School Students

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Abstract: One of the important skills in the 21st century is critical thinking skills, as educational objectives focus on development to face the challenges of the world of education. This study aims to analyze the impact of using virtual reality in electronic worksheets with discovery learning on critical thinking skills of junior high school students. This research is an experimental research with a quantitative approach using Quasi-Experiment. The research design used Nonequivalent Control Group Design with two sample classes totaling 32 experimental and 32 control class students. Data collection on the level of critical thinking skills is seen from the results of pretest and posttest essays of 6 items on solar system material on 6 aspects of critical thinking skills i.e. analysis, evaluation, interpretation, inference, explanation, and metacognition. Data analysis was carried out Independent Sample T-Test test and effect size test. The results of this study indicate that there are differences in the critical thinking skills of junior high school students who use virtual reality in electronic worksheets with discovery learning and the use of virtual reality in electronic worksheets with discovery learning on students' critical thinking skills has a very strong influence..

Keywords: Critical Thinking Skills, Discovery Learning, Electronic Worksheets, Virtual Reality

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1. Introduction

For students, 21st-century learning calls for them to be active, self-assured, and flexible in the formation of critical 6C skills (Critical Thinking, Creativity, Collaboration, Communication, Computational thinking, Compassion) (Inganah et al., 2023). Of these abilities, critical thinking is also considered fundamental to resolve challenging learning problems in the 21st century. Critical thought allows students to interpret, analyze and evaluate information, generate solutions, solve problems, form logical conclusions (Setiawan et al., 2022; Pahrijal et al., 2023). This has led us to the importance of developing critical thinking in the present science education. However, large international assessments suggest that Indonesian students' advanced thinking skills are still at a relatively low level.

Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) carried out by the OECD in 2015 and 2022, show that Indonesian students continue to perform at a level below the international average on questions of reasoning and analysis (OECD, 2022; Pusmendik, 2022). The evidence from empirical studies shows that students of junior high school level critical thinking skills in Indonesia are found to generally be low-medium skills (Putri et al., 2024). The implication of this finding is that students' learning outcomes usually seem to result from shallow understanding rather than deep conceptual understanding which is the basis of critical thinking (Lumban Gaol et al., 2022; Nggolaon et al., 2024). Many research have also found instruction to be one of the most important reasons and reasons students have a low level of critical thinking.

According to Suryaningrum and Fiana (2024), using reasoning is a struggle; students often have trouble applying reasoning in analysis of problems, evaluation of information, and justification of their answers. Similarly, Rani et al. (2024) emphasize that learning approaches, instructional models, and the limited use of appropriate learning media all affect students' critical thinking development. The research on scientific learning brings to light the necessity for environments that encourage inquiry and critical thinking processes that help students actively engage with their learning across subject areas, particularly in their science learning experiences. Science education is one of the more promising pedagogical methods to enhance critical thinking as it focuses on scientific knowledge, evidence-based thinking and active experience with natural phenomena.

According to Ritonga et al. (2020), science research grounded in science processes and experiential observation in learning from scientific learning encourages the student to build analytical and evaluation thinking ability. This corresponds with the constructivist theory of learning, which suggests that learners actively construct knowledge through interaction with their environment and others, rather than passively receiving information (Piaget, 1972; Vygotsky, 1978; Bruner, 1966). When students are immersed in authentic problem-solving and exploration of concepts, they are more inclined to cultivate higher order thinking, such as critical thinking. However, the effectiveness of science learning in promoting critical thinking is closely related to the content style and media utilized at the student level. Such complex, physical topics as solar system pose specific challenges for students, as they require a large spatial dimension and there are very limited opportunities for students to observe directly. Hafizah et al. (2023) state, abstract concepts need to be supported in instruction (e.g. visualization of relationship and construction of an accurate mental model). While solar system issues are able to assist students with their knowledge of planets, satellites, and astronomical events, many times they are taught in a theoretical and written-based format, hence limiting a student's critical input and conceptual involvement (Ningrum et al., 2024). This gap highlights the need for learning media which encourages exploration, visualization and inquiry. One way in which instruction has been found to be effective in promoting critical thinking is the electronic learner worksheet (e-worksheet). Electronic worksheets can help students structure the thought through the problem, and encourage student participation, as well as reflection. The research has verified that e-worksheets are a pragmatic and effective way to train up on how to think critically, especially since they allow learners to focus on enquiry and problem solving (Fenanda, 2024) and have relatively more positive effects compared to traditional worksheets. Although they are beneficial, electronic worksheets have been implemented in science learning to a lesser extent, and they are rarely linked with suitable learning models.

Discovery learning is a structured method of learning that correlates well with electronic worksheets while developing critical thinking skills. Since they do not have direct instruction, discovery learning aims to encourage students to actively explore, identify patterns, and construct concepts through investigation (Mukaramah et al., 2020; Jamallika et al., 2024). Within the constructivist model, the student is seen as an active knowledge creator in this way, developing autonomy and deep knowledge. Findings show that academic electronic worksheets with discoveries are real, practical, and can be useful to improve the learning and critical thinking skills of students (Fitri et al., 2023; Subakti et al., 2021). However, the use of discovery-learning-based electronic worksheets has been under-researched, particularly for abstract science topics. Recent growth in educational technology offers more venues for reinforcing discovery-based learning with the inclusion of virtual reality (VR). Virtual reality is a 3D immersive technology that enables individuals a chance to experience the same or similar virtual settings that they would encounter in real life (Muzaki, 2024; Tulangow et al., 2024). VR has proven to offer interactive and immersive experience, which also fosters engagement and concept awareness for students (Azizah et al., 2024; Oktarizka & Abidin, 2024).

From this perspective, VR offers learners tangible experiences and chances for reflective observations. In experiential learning theory, VR represents a crucial stage in the experiential learning cycle. VR in addition to engagement can influence learning via specific cognitive mechanisms. Immersive VR environments encourage metacognitive regulation by letting learners monitor spatial relationships in real time and can adjust mental models of situations on the fly, test hypotheses, or even test hypotheses. An interactive (embodied) VR framework aids inferential reasoning, enabling learners to experience relationships between things (e.g., planetary motion and spatial magnitude in the solar system). Furthermore, if efficiently designed, VR can also decrease extraneous cognitive load by providing intricate data in visual

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package and increase germane cognitive load that will facilitate schema construction and analytical reasoning, as proposed by cognitive load theory. The merging of electronic worksheets, discovery learning, and a virtual reality environment demonstrates that this is more than a technology innovation, but that it is an empirical approach to teaching. Incorporating constructivist tenets as well as experiential learning processes and cognitive load strategies in VR-supported electronic worksheets allows meaningful learning environments enabling students to engage in inquiry, reflection and problem solving. These kinds of environments are particularly well attuned to science instruction on abstract areas such as the solar system and are highly impactful for developing students' critical thinking skills.

Research on the use of virtual reality in electronic worksheets with discovery learning described above shows very good results. Electronic worksheets with discovery learning that combine an active learning approach that encourages exploration and discovery of concepts with virtual reality technology are thought to be able to create an interactive and immersive learning environment. However, its use in learning to find out its effect on aspects of critical thinking skills such as evaluation, analysis, interpretation, inference, explanation, and metacognition has never been done. This is what drives this research, by analyzing the impact of using virtual reality in electronic worksheets with discovery learning on the critical thinking skills of junior high school students on solar system material.

2. Method

This study uses a quantitative approach to determine the causal relationship in this study using Quasi Experiments The research design that will be used in this study is a Nonequivalent Control Group Design, which is part of Quasi Experiments, using pretest instruments before treatment and post-test after treatment to determine the level of critical thinking skills of students. This type of design requires two sample classes, namely the experimental class and the control class.

Table 1. Research Design Nonequivalent Control Group Design (Amaliya & Anas, 2024)

Group	Pretest	Treatment	Posttest
Experimental class	X_1	A	Y_2
Control class	X_3	B	Y_4

Description:
X_1: Experimental class pretest
Y_2: Experimental class posttest
A: Experimental class treatment
B: Control class treatment
X_3: Pretest of control class
Y_4: Posttest of control class

This research was conducted at SMP Negeri 4 Magelang. The population that will be the focus of this study is the entire class VII odd semester of the 2024/2025 school year, consisting of classes VIIA, VII B, VII C, VII D, VIIE, and VII F with a total population of 192 students. In this study, the sampling technique used Cluster Random Sampling where random sampling of a very broad object and selected class VII A with a total of 32 students as an experimental class and class VII B with a total of 32 students as a control class.

Data Collection Techniques and Tools

Data collection techniques are carried out with test techniques, namely in the form of pretest and posttest questions with essay-shaped questions with as many as 6 items to measure students' critical thinking skills that have been analyzed for validity, reliability, and difficulty level. Each question chosen represents 6 aspects of critical thinking skills, namely evaluation, analysis, interpretation, inference, explanation, and metacognition. The test was given to grade IX students who had learned solar system material and the results were analyzed to assess the effectiveness of the critical thinking skills test instrument. Collection techniques with non-test techniques using the learning implementation observation sheet to determine the implementation of learning in the classroom by the learning steps.

Data Analysis Technique

The data analysis technique was obtained from the pretest and posttest test results of critical thinking skills after the use of virtual reality in electronic worksheets with a discovery learning model in learning. The data obtained were then analyzed using the help of IBM SPSS version 23. The data obtained were carried out Independent Sample T-Test and an effect size test. However, the prerequisite tests that must be met before conducting the independent sample t-test and effect size test are the normality prerequisite test and the homogeneity prerequisite test. This study used the Shapiro-Wilk normality test because the sample data used in the control class and experimental class were less than 50 samples. The homogeneity test in this study used the Levene Test.

The Independent Sample T-test test in this study was used to determine the difference in critical thinking skills of experimental class students and control class students with the hypothesis that if Sig (2-tailed) > $\propto$ (0.05), it means that there is no significant difference in the results of students' critical thinking skills between the experimental class and the control class, but if Sig. (2-tailed) < $\propto$ (0.05), then it means that there is a significant difference in the results of students' critical thinking skills between the experimental class and the control class.

The effect size test in this study shows the magnitude of the difference obtained after treatment. In this study, the effect size test aims to determine how much influence the use of virtual reality in electronic worksheets with a discovery learning model has on the critical thinking skills of junior high school students on solar system material. This study's effect size measurement method uses Cohen's method, which looks at the average difference by looking at the standard deviation value. The interpretation criteria for the larger effect size according to Cohen means an obvious difference

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Table 2. Cohen's Effect Size Method Interpretation Criteria (Baidowi et al, 2024)

Cohen's value	Description
d > 0,8	Very high
0,5 < d ≤ 0,8	High
0,2 < d ≤ 0,5	Medium

3. Result and Discussion

The results of critical thinking skills obtained were analyzed using SPSS version 23 to test normality and homogeneity, then analyzed using hypothesis testing in the form of Independent Sample T-Test test and effect size test. The results of critical thinking skills in class VII SMP Negeri 4 Magelang both experimental and control classes can be seen in table 7.

Data on the results of critical thinking skills that have been tested can be seen in Table 3. Based on table 3, the normality test results of the pretest and posttest results of both experimental and control classes have a significance level greater than 0.05, which means that the data is normally distributed. The homogeneity test in this study used the Levene Test which can be seen in table 4. Based on table 4, the homogeneity test results obtained Sig. 0.061 the results of the homogeneity test on the critical thinking skills posttest data show a significance value greater than 0.05, meaning that the data is homogeneous.

Critical thinking skills data that have met the requirements of normality test and homogeneity test, then hypothesis testing can be done. The results of the hypothesis test analysis with the Independent Sample T Test and Effect Size Test can be seen in table 5 and table 6. The Independent Sample T-Test test in this study is the posttest value data from the experimental class and control class. The results of the Independent Sample T-Test Test obtained Sig. (2-tailed) of 0.000, the value is below the significance level of 0.05. These results show that the use of virtual reality in electronic worksheets with discovery learning on critical thinking skills of junior high school students shows a significant difference. The results of the effect size test in this study use Cohen's method, which looks at the average difference by looking at the standard deviation value. The effect size test results obtained a value of 1.23 which when interpreted in the effect size criteria based on Cohen's is included in the very high category.

Table 3. Test of Normality

Group	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest experimental class	0,958	32	0,245
Posttest experimental class	0,950	32	0,143
Pretest control class	0,956	32	0,211
Posttest control class	0,945	32	0,102

Table 4. Test of Homogeneity of Variance

		Levene Statistic	Df1	Df2	Sig.
Critical thinking skills score	Based on Mean	2.525	3	124	0,061
	Based on Median	2,212	3	124	0,090
	Based on Median and with adjusted df	2,212	3	121,184	0,090
	Based on trimmed mean	2,437	3	124	0,068

Table 5. Independent Sample T Test

	t-test for Equality of Means						
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Equal variances assumed	-4,909	62	0,000	-11,344	2,311	-15,963	-6,725
Equal variances not assumed	-4,909	58,682	0,000	-11,344	2,311	-15,968	-6,720

Table 6. Effect Size Test

Critical Thinking Skills	Effect Size Value	Description
Posttest Score Experimental Class and Control Class	1,23	Very high

The findings of this study reveal a statistically significant difference in students' critical thinking skills between the experimental and control groups following the implementation of virtual reality–supported electronic worksheets within a discovery learning framework. A summary of the descriptive statistics for the pretest and posttest scores is provided in Table 7.

Table 7. Average Results of Pretest and Posttest Critical Thinking Skills

	Experimental class		Control class	
	Pretest	Posttest	Pretest	Posttest
Sampel	32	32	32	32
Max score	54	92	63	83
Min score	17	46	17	42
Average	33.75	74.28	34.44	62.94

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N gain	0.63 (medium)	0.43 (medium)

As presented in Table 7, both the experimental and control groups exhibited comparable pretest mean scores, indicating similar baseline levels of critical thinking skills prior to the intervention. Following the instructional treatment, the experimental group achieved a markedly higher posttest mean score than the control group. The normalized gain analysis further demonstrates that students in the experimental group attained a higher learning gain (g = 0.63) compared to those in the control group (g = 0.43), reflecting a more substantial improvement in critical thinking skills among students who engaged with virtual reality–supported electronic worksheets within a discovery learning framework.

Beyond between-group comparisons, within-group analysis revealed a clear and consistent improvement in critical thinking skills from pretest to posttest in the experimental group. This finding suggests that the observed differences are not merely attributable to intergroup variation, but rather reflect meaningful learning progression resulting from the instructional intervention.

To obtain a more nuanced understanding of students' critical thinking development, the analysis was further disaggregated across six core dimensions of critical thinking: analysis, evaluation, interpretation, inference, explanation, and metacognition. The mean scores for each dimension in both groups are summarized in Table 8.

Table 8. Average Value of Critical Thinking Skills Aspects

Aspect	Experimental class				Control class			
	Pretest		*Posttest*		*Pretest*		*Posttest*	
	Average	Percentage (%)	Average	Percentage (%)	Average	Percentage (%)	Average	Percentage (%)
Analysis	2	50	3,25	81,25	2,281	57,03	2,906	72,66
Evaluation	1,156	28,91	2,813	70,31	1,219	30,47	2,438	60,94
Interpretation	1,344	33,59	2,906	72,66	1,031	25,78	2,75	68,75
Inference	1,563	39,06	3,219	80,47	1,719	42,97	2,5	62,50
Explanation	1,125	28,13	2,781	69,53	1,469	36,72	2,406	60,16
Metacognition	0,875	21,88	2,813	70,31	0,531	13,28	2,219	55,47

Overall, the experimental group demonstrated greater gains across all six dimensions of critical thinking compared to the control group. The most pronounced improvement in the experimental group was observed in the metacognitive dimension, followed by inference and evaluation, indicating that the intervention was particularly effective in fostering higher-order reflective and reasoning processes. In contrast, gains in the interpretation dimension were relatively comparable between the two groups, suggesting that certain components of critical thinking may be less responsive to the intervention or may require additional instructional scaffolding to achieve more substantial improvement.

The results of the analysis on each aspect of critical thinking skills based on table 8, show that the aspect of critical thinking skills that experienced the highest increase was in the sixth aspect, namely the metacognition aspect in the experimental class. The lowest increase in the aspect of critical thinking skills occurred in the first aspect, namely the analysis aspect in the control class. The robust metacognitive benefit points to how learning design facilitated students’ ability to plan, monitor, and evaluate their cognition on their own. Perhaps the improvement was also due to intentional introduction of discovery learning phases in the electronic worksheets, which encouraged reflective decision-making in the exploration and generalization stages, along with immersive feedback provided by virtual reality. In this regard, they are compatible with metacognitive paradigms, which argue that cognitive awareness and the ability to regulate one’s own learning arises not from learning passively through encounter with content but through being strategically directed towards it (Flavell, 1979; Schraw & Dennison, 1994). In line with this, past research has shown Immersive and inquiry-oriented learning environments have been proven effective in developing metacognitive regulation skills. A reflection-based approach in game-based learning fosters self-awareness and enhances students’ ability to regulate their learning strategies (Cantoia, 2023). Similarly, the Project-Based Learning model with phased guidance and real-time feedback significantly improves engineering students’ monitoring and evaluation abilities (Ghazali et al., 2025)

The difference in critical thinking skills of learners who use virtual reality in electronic worksheets with discovery learning is also very visible during learning. Learners are more active in exploring learning concepts independently and interactively. During learning activities, experimental class students showed a higher level of involvement, as seen from the way they asked more critical questions, connected concepts logically, and were able to conclude more systematically. While the control class tends to rely on the information provided without further exploration.

The very high effect size value based on table 6, also indicates that there is a difference in the average critical thinking skills between the control class and the experimental class using virtual reality in electronic worksheets with discovery learning is practically significant. In addition, the high effectiveness also indicates that the use of virtual reality in electronic worksheets with discovery learning can strengthen students' critical thinking skills, especially in the aspects of analysis, evaluation, interpretation, inference, explanation, and metacognition obtained during learning.

The findings of this study demonstrate that integrating virtual reality (VR) into discovery learning–based electronic worksheets does more than enhance learning outcomes; it fundamentally reconfigures how students engage in critical thinking processes. Rather than attributing improvements in critical thinking to technological novelty alone, the results indicate that these gains emerge from the synergistic interaction between immersive visualization, structured inquiry phases, and learner-centered pedagogical design. This interactional perspective challenges deterministic

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views of educational technology and reinforces the primacy of instructional alignment in technology-enhanced learning environments.

The pronounced improvement in the analysis component of critical thinking reflects students' enhanced capacity to organize information, identify patterns, and distinguish relevant from irrelevant data. Unlike conventional instruction—where abstract representations often limit analytical engagement—the VR-supported discovery learning environment enabled students to directly observe phenomena, explore relationships dynamically, and iteratively test ideas. Importantly, this finding contrasts with prior studies reporting marginal analytical gains when VR functioned primarily as a visualization aid without inquiry scaffolding. The present results suggest that discovery learning phases embedded in electronic worksheets are pivotal in transforming perceptual richness into analytical reasoning, underscoring that pedagogical structure, rather than immersive media per se, drives higher-order cognitive engagement.

Similarly, the observed gains in the evaluation aspect indicate that students developed stronger abilities to assess arguments, weigh evidence, and make informed judgments. While much of the existing literature emphasizes VR's motivational and engagement-related benefits, comparatively little attention has been given to its role in fostering evaluative judgment. The present findings address this gap by showing that when VR experiences are integrated with guided questioning and evidence-based tasks, students are encouraged to critically interrogate information rather than accept it unreflectively. This insight helps explain why earlier VR-based studies—despite reporting high engagement—did not consistently yield improvements in evaluative thinking.

In contrast, the relatively moderate gains in interpretation warrant closer examination. Although students demonstrated improved abilities to interpret data, textual explanations, and visual representations, the smaller increase compared to other critical thinking dimensions suggests that immersive environments alone may be insufficient to fully support interpretative reasoning. This finding aligns with cautionary perspectives in the literature that warn against assuming that rich visual representations automatically foster deep conceptual understanding. Interpretation appears to require explicit instructional prompts that guide learners to connect visual experiences with underlying concepts and broader explanatory frameworks.

Conversely, the substantial improvement in inference highlights VR's potential to support logical conclusion drawing when embedded within active inquiry processes. The immersive affordances of VR likely contributed to this outcome by rendering abstract phenomena—such as spatial relationships in the solar system—more concrete and cognitively accessible. Extending prior research, this study demonstrates that VR can meaningfully support inferential reasoning when learners are actively engaged in hypothesis formulation, evidence examination, and conclusion construction, rather than positioned as passive observers of simulations.

The gains observed in the explanation component further indicate that students became more proficient in articulating reasoning and justifying conclusions. This improvement can be attributed to the structured learning sequence inherent in discovery learning–based electronic worksheets, which required students to externalize their thinking through explanatory responses rather than brief factual answers. Notably, some earlier studies have reported that technology-enhanced instruction improves conceptual understanding without correspondingly enhancing students' ability to communicate reasoning. The present findings challenge this assumption, suggesting that explanation skills can be deliberately cultivated when instructional design systematically prompts learners to verbalize and reflect upon their reasoning processes.

One of the most pedagogically significant outcomes of this study is the improvement in metacognitive skills. Students' increased ability to reflect on problem-solving strategies and evaluate their own thinking indicates that the learning environment supported metacognitive regulation. While many prior studies have concentrated on cognitive performance indicators, metacognitive development has remained relatively underexplored. The findings here suggest that discovery-oriented VR environments can foster metacognitive awareness by encouraging learners to plan, monitor, and evaluate their learning, rather than merely complete prescribed tasks.

From a pedagogical standpoint, these results underscore that VR should not be conceptualized as a standalone instructional solution. Its effectiveness in promoting critical thinking is contingent upon its integration within a coherent learning model that foregrounds inquiry, reflection, and reasoning. Psychologically, the immersive and interactive characteristics of VR appear to reduce cognitive barriers associated with abstract content, enabling learners to allocate cognitive resources to higher-order thinking rather than basic comprehension. However, this benefit is highly dependent on careful instructional design to avoid cognitive overload and superficial engagement.

Despite its contributions, this study has limitations. The findings are context-specific, focusing on a single subject area and educational level, and do not address the long-term retention or transferability of critical thinking skills. Future research should examine how VR-supported electronic worksheets function across diverse scientific domains, learner profiles, and instructional contexts, as well as investigate the sustainability of cognitive and metacognitive gains over time.

Overall, this study contributes to the literature by demonstrating that the integration of VR, electronic worksheets, and discovery learning offers more than incremental improvement. It presents a pedagogically grounded approach that supports multiple dimensions of critical thinking—analysis, evaluation, interpretation, inference, explanation, and metacognition—and highlights the necessity of moving beyond technology adoption toward intentional instructional design that aligns technological affordances with cognitive and pedagogical objectives.

4. Conclusion

Based on the results of the analysis, this study concludes that integrating virtual reality (VR) into electronic worksheets grounded in discovery learning leads to a significant improvement in junior high school students' critical thinking skills. The

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Independent Samples *t*-test revealed a statistically significant difference between the experimental and control groups (Sig. (2-tailed) = 0.000), while the effect size value of 1.23 indicates a very strong effect according to Cohen's criteria. These results suggest that VR-supported electronic worksheets are highly effective in fostering higher-order thinking skills when implemented within a well-structured discovery learning framework.

Nevertheless, several limitations should be explicitly acknowledged. First, the sample size was relatively limited and drawn from a specific educational context, which may constrain the generalizability of the findings to broader student populations or diverse school settings. Second, the use of virtual reality may have introduced a novelty effect, whereby students' increased engagement and motivation were influenced, at least in part, by the newness of the technology rather than by enduring cognitive benefits. In addition, teacher-related factors—such as variations in instructional style or differing levels of familiarity with VR-based learning environments—may have affected both the implementation process and students' learning experiences.

Furthermore, this study focused on a single science topic and employed a relatively short intervention period, limiting the extent to which conclusions can be drawn regarding the long-term impact of VR-supported electronic worksheets on the development of critical thinking skills. The study also did not account for differences in students' prior technological experience or individual learning preferences, which may serve as moderating variables influencing the effectiveness of VR-based instruction.

Despite these limitations, the findings offer meaningful insights into the pedagogical potential of integrating virtual reality with electronic worksheets and discovery learning. Future research is encouraged to involve larger and more diverse samples, systematically control for novelty and teacher effects, and adopt longitudinal research designs to examine the sustainability of critical thinking gains across multiple science topics and varied educational contexts.

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