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Cognitive Outcomes through SAVI-Based Learning: An Experimental Comparison of Demonstration and Hands-On Methods Mediated by Critical Thinking Skills

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ABSTRACT:
Background: Physics learning in secondary education is often teacher-centered, limiting students' cognitive engagement and critical thinking development. Traditional instructional methods may hinder students' ability to explore physical concepts through direct experience, especially on contextual topics such as work and energy. To address these pedagogical limitations, integrating multi-sensory and student-active models like SAVI (Somatic, Auditory, Visualization, Intellectually) presents a promising alternative.
Aims: This study aims to investigate the effectiveness of the SAVI learning model implemented through two instructional methods—experimentation and demonstration—on students' cognitive performance in Physics, moderated by their critical thinking ability.
Methods: A quasi-experimental research design with a 2x2 factorial framework was employed. The study involved 70 tenth-grade students from SMAN 1 Sukoharjo, divided into experimental and control groups using cluster random sampling. Cognitive and critical thinking abilities were assessed using validated instruments, and data were analyzed using two-way ANOVA with unequal cell frequency.
Result: Findings revealed: (1) No significant difference in students' cognitive outcomes between the experimental and demonstration methods ($F = 0.086$, $p > 0.05$); (2) A significant effect of students' critical thinking levels on cognitive outcomes, with higher critical thinkers outperforming lower ones ($F = 54.39$, $p < 0.05$); (3) No significant interaction effect between teaching methods and critical thinking skills on cognitive performance ($F = 0.7919$, $p > 0.05$).
Conclusion: While the instructional method (experiment vs. demonstration) alone did not significantly affect cognitive performance, students with higher critical thinking skills consistently showed superior learning outcomes, regardless of the teaching method applied. This suggests that fostering students' internal dispositions, especially critical thinking, plays a more pivotal role in Physics learning than the mere selection of instructional delivery. Consequently, Physics educators should prioritize strategies that cultivate critical thinking alongside adopting engaging learning models such as SAVI. These findings contribute to the growing body of evidence on differentiated instruction and support the integration of learner-centered pedagogies in STEM education globally.
Keywords: Cognitive Skills, Critical Thinking, Demonstration Method, Experimental Design, SAVI Learning Model
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INTRODUCTION

In many educational contexts, especially in physics education, traditional teaching methods still dominate the classroom environment. These teacher-centered approaches often fail to provide active learning experiences that are crucial for conceptual understanding. Particularly, topics like work and energy require more than theoretical exposition; they demand active student engagement to connect theory with real-world phenomena. Despite curricular reforms promoting student-centered learning, such transformations are limited in practice. As a result, students tend to exhibit low cognitive performance and minimal critical thinking development, especially when instruction lacks interactivity. The complexity of physics concepts necessitates multimodal engagement for meaningful learning to occur. Therefore, innovative approaches that incorporate physical, auditory, visual, and intellectual stimuli are urgently needed to improve learning outcomes. This study addresses this need by exploring the SAVI model—a comprehensive instructional design grounded in learning psychology and neuroscience.

The SAVI model (Somatic, Auditory, Visualization, Intellectually) emphasizes physical and cognitive integration during the learning process. Each component of the SAVI framework is designed to stimulate specific learning pathways—kinesthetic, auditory, visual, and reflective—resulting in holistic learning experiences (Carroll & Kop, 2011 and Chan & Wong, 2023). In physics education, this approach is particularly suitable, given the subject's demand for hands-on experimentation and critical analysis. While many teaching models focus solely on verbal or written explanations, the SAVI model goes beyond by incorporating action, dialogue, observation, and reasoning. Such a framework aligns well with 21st-century competencies, which include problem-solving and critical thinking. Consequently, the integration of the SAVI model in physics teaching has the potential to bridge the gap between theory and practice, improving student outcomes in both understanding and application. Thus, investigating the effectiveness of SAVI-based instruction is both timely and essential for educational innovation.

Moreover, there is a pressing need to understand how instructional methods interact with individual learner characteristics. One such characteristic is critical thinking ability, which plays a vital role in cognitive development and decision-making. Research shows that students with high critical thinking skills perform better in science-related tasks, especially when learning environments are supportive and engaging (Abrica et al. 2024 and Zafeer et al. 2025). However, few studies have examined how the SAVI model interacts with students' critical thinking levels to influence academic outcomes. Understanding this relationship is crucial for tailoring instruction that accommodates learner diversity and promotes equity in education. Therefore, this study is significant not only for testing an instructional model but also for exploring how it aligns with cognitive traits that determine academic success.

The rationale for this study is rooted in the need to modernize instructional practices in physics classrooms. Traditional methods such as lectures and demonstrations often disengage students, particularly those who learn best through doing and interaction. The SAVI model offers a multidimensional learning experience that can better accommodate diverse learning styles. It aligns

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with constructivist principles that prioritize learner-centered, activity-based education. Furthermore, few empirical studies in the Indonesian context have explored how SAVI, combined with different teaching methods (experiments vs. demonstrations), influences learning outcomes. This research fills that gap by testing not only the effectiveness of the SAVI model but also its interaction with students' critical thinking levels. The findings can guide teachers in selecting instructional strategies that optimize cognitive outcomes and promote inclusive learning environments. Moreover, the results may contribute to the global discourse on active learning and multimodal instruction in STEM education.

Recent studies have highlighted the effectiveness of multimodal and experiential learning models in improving science education outcomes. For instance, studies by Yuliana. (2024) demonstrated that integrating physical activities and visual aids significantly enhances students' understanding of scientific concepts. Paudel et al. (2023) further validated that auditory and intellectual components of instruction enhance students' conceptual retention and reasoning skills. Similarly, research by Sk & Halder. (2024) in secondary science classrooms showed that models based on SAVI principles improved students' problem-solving abilities and engagement levels. These findings are consistent with Giannakos & Cukurova. (2023) theoretical proposition that learning is most effective when it engages the whole brain and body. Moreover, studies by Tadiboyina et al. (2024) emphasized that instructional designs combining demonstrations and collaborative activities boost learning performance across different cognitive domains. These studies provide a theoretical and empirical foundation for applying the SAVI model in physics education.

In addition, several international studies have explored how instructional models interact with learner characteristics such as critical thinking. For example, research by Sharma et al. (2023) demonstrated that students with higher critical thinking abilities benefited more from problem-based learning environments. Hussain et al. (2025) confirmed similar trends in physics and engineering education, where critical thinking amplified the effects of experiential instruction. Li et al. (2024) argued that active learning strategies must consider students' cognitive readiness to be effective. Another notable contribution is from Gan & Peng. (2024) who showed that critical thinking serves as a moderator in student engagement and performance. These studies collectively affirm that both instructional design and learner attributes contribute to academic achievement. However, few have tested the interaction of these variables specifically using the SAVI model in physics contexts, particularly in Southeast Asia. This study aims to address that gap.

Despite increasing evidence supporting the use of multimodal learning models, research specifically focusing on the SAVI model in high school physics remains limited. Most prior studies have examined SAVI's implementation in general science or vocational contexts, leaving a significant gap in subject-specific application. Moreover, while several investigations highlight the importance of critical thinking in enhancing student performance, few have explored its interaction with instructional strategies. The scarcity of factorial-design studies examining both instructional methods (experimentation vs. demonstration) and student characteristics limits our understanding of differentiated instruction. Furthermore, empirical data from Southeast Asian education systems, particularly Indonesia, are underrepresented in the international literature. Thus, there is a pressing

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need for context-specific research that evaluates the interplay between teaching models and learner traits. This study aims to contribute to the field by offering empirical insights from a quasi-experimental design in a real classroom setting. It not only fills a geographic and methodological gap but also provides practical implications for instructional planning in physics education.

This study aims to investigate the differential impact of SAVI-based instruction delivered through experimentation and demonstration methods on students' cognitive learning outcomes. Specifically, it examines whether students' levels of critical thinking moderate the effect of instructional methods on physics achievement. The central hypothesis posits that students with high critical thinking skills will perform better regardless of instructional method, but the impact will be more pronounced in hands-on experimental contexts. Furthermore, the study hypothesizes that there is no significant interaction effect between instructional method and critical thinking on student performance. These hypotheses are tested using a 2x2 factorial quasi-experimental design involving senior high school students. The findings are expected to validate the theoretical underpinnings of the SAVI model and its relevance in contemporary science education. In doing so, the study provides valuable insights for educators and curriculum developers aiming to promote deeper learning and cognitive equity.

METHOD

Research Design

This study employed a quasi-experimental design using a 2 × 2 factorial design to examine the interaction between instructional methods and students' critical thinking levels on cognitive learning outcomes. The independent variable was the instructional method, operationalized as either experimental or demonstration-based SAVI learning. The moderator variable was the students' level of critical thinking, categorized as high or low. The dependent variable was students' cognitive performance in physics, particularly on the topic of work and energy. The research design allowed the analysis of main effects and interaction effects between variables using two-way ANOVA. To address unequal group sizes, the ANOVA was conducted with unequal cell frequencies, ensuring robust comparison across all treatment groups. The study was conducted in a real school environment, providing ecological validity to the findings. This design is widely recognized for its capacity to control for internal validity threats while allowing natural group assignment in educational settings (Jiménez-Buedo & Russo. 2021; Slocum et al. 2022)

Participants

The population of this study consisted of all tenth-grade students enrolled in the science stream (MIPA) at SMAN 1 Sukoharjo during the academic year. The sample was selected using cluster random sampling to ensure unbiased group formation and practical classroom implementation. Two intact classes were chosen: one served as the experimental group (34 students) and the other as the control group (36 students), totaling 70 participants. The experimental group was taught using the SAVI model through experimentation, while the control group received instruction through demonstration. Prior to treatment, both groups were pre-tested for baseline equivalence in cognitive and critical thinking ability. Students were then classified into high and low critical thinking categories using a validated rubric and test scores. Ethical considerations were observed by obtaining

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consent from the school and ensuring student anonymity. The sample size and grouping structure allowed sufficient statistical power for factorial analysis.

Instruments

Two main instruments were used in this study: a cognitive achievement test and a critical thinking test, both developed and validated by subject experts. The cognitive test consisted of 30 multiple-choice items measuring comprehension and application of work and energy concepts. The critical thinking test was constructed based on Vercellotti & McCormick (2021) framework and included open-ended items assessed using an analytical rubric. Instrument validation included qualitative review and quantitative analysis for difficulty level, discrimination index, reliability, and validity. Reliability of the cognitive test was calculated using KR-20, resulting in r = 0.89, while the critical thinking test yielded r = 0.91. Table 1 below presents the analysis summary for item difficulty and discrimination of the cognitive test:

Table 1. Summary of Cognitive Test Item Analysis

Statistic Type	Min	Max	Mean	Criteria Met
Item Difficulty (p)	0.30	0.75	0.54	Acceptable
Discrimination Index (r)	0.31	0.81	0.56	Strong
KR-20 Reliability	–	–	0.89	High

The item difficulty values ranged between 0.30 and 0.75, indicating a moderate level of challenge appropriate for high school physics students. Discrimination indices were consistently above 0.30, validating the test's capacity to distinguish between high and low performers.

Data Analysis Plan

The data analysis involved multiple steps, beginning with assumption testing to verify normality and homogeneity. The Kolmogorov–Smirnov test was used to assess normality, and Levene's test was applied to check for variance homogeneity. Once assumptions were satisfied, a two-way ANOVA with unequal cell sizes was conducted to examine the main effects and interaction between the instructional method and critical thinking level. The statistical formula used for the two-way ANOVA is:

$$F = \frac{\text{MS between}}{\text{MSwithin}}$$

where MS refers to Mean Squares calculated as:

$$MS = \frac{\text{SS}}{\text{df}}$$

The significance level was set at α = 0.05, and comparisons were evaluated using F-values from ANOVA summary tables. The effect size was also calculated using partial eta-squared (η^2) to interpret the magnitude of each variable's impact. Statistical analyses were conducted using SPSS Version 23, ensuring standardized and replicable computation. This analytical framework provided comprehensive insight into both independent and interactive effects on students' learning outcomes (J. Li & Xue. 2023 and Shi et al. 2021).

RESULTS AND DISCUSSION

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Results

The data analysis aimed to examine the main and interaction effects between instructional method (experiment vs. demonstration) and students' critical thinking levels (high vs. low) on cognitive performance. Table 1 presents the mean scores and standard deviations of cognitive test results for both instructional groups. The experimental group achieved a mean score of 82.35 with a standard deviation of 8.12, while the control group recorded a slightly lower mean score of 81.87 and a standard deviation of 7.95. These figures suggest a minor advantage for the experimental group. However, the F-value from the two-way ANOVA test indicated no statistically significant main effect from instructional method alone ($F = 0.086$, $p > 0.05$). This finding implies that the choice between experiment and demonstration in applying the SAVI model did not substantially impact student cognitive outcomes. Figure 1 below further illustrates the comparison between groups. Although the bar graph suggests a small mean difference, the overlap in standard deviations supports the non-significant result.

Table 2. Descriptive Statistics of Cognitive Performance by Instructional Group

Group	Mean Score	Standard Deviation
Experimental	82.35	8.12
Control	81.87	7.95

Table 1 presents descriptive data on students' cognitive test results based on the treatment groups. The experimental group, which received instruction using the SAVI model through an experimental method, obtained an average score of 82.35 with a standard deviation of 8.12. In contrast, the control group, taught through a demonstration method, obtained an average score of 81.87 with a standard deviation of 7.95. Numerically, there was a slight advantage for the experimental group, but the difference was very small and within the standard error range. This indicates that both instructional methods produced relatively comparable cognitive achievements when both applied the SAVI learning principles. The relatively low standard deviations in both groups also indicate that the data were not too scattered and the distribution of scores was quite consistent across groups. However, these differences were not statistically significant, as would be evident in the results of a two-way analysis of variance. Therefore, based on Table 1, it can be concluded that the teaching method (experimental or demonstration) was not a major determinant of students' cognitive achievement.

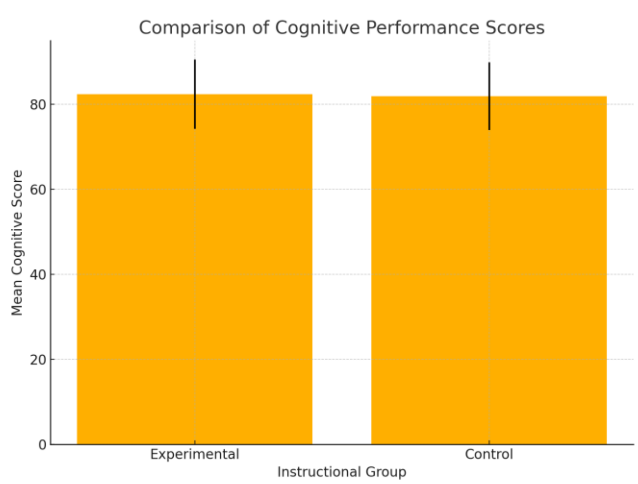

Figure 1. Comparison of Cognitive Performance Scores Between Groups

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Further analysis was conducted to evaluate the influence of critical thinking level on student outcomes. Students were categorized into high and low critical thinking groups based on their test scores. The two-way ANOVA revealed a significant main effect of critical thinking level on cognitive performance ($F = 54.39$, $p < 0.05$). Students with high critical thinking skills outperformed those with lower skills across both instructional methods. This result supports the hypothesis that critical thinking contributes substantially to academic performance, consistent with prior findings (Ennis, 1985; Johnson, 2010). The mean score of high critical thinkers was significantly higher regardless of whether they were in the experimental or control group. Thus, cognitive ability in physics appears to be more influenced by internal cognitive traits than external instructional techniques alone. This reinforces the importance of fostering critical thinking skills as part of instructional objectives.

Table 2 shows the summary of the ANOVA results. The instructional method (Factor A) did not significantly influence scores ($F = 0.086$), but the critical thinking factor (Factor B) did ($F = 54.39$). The interaction between method and thinking level (A x B) was also non-significant ($F = 0.7919$, $p > 0.05$). These results were consistent across multiple assumption checks, including normality and homogeneity tests. These statistical findings collectively support the conclusion that cognitive learning in physics is more strongly affected by learner characteristics than by instructional variations.

Table 3. Two-Way ANOVA Summary (Unequal Cell Size)

Source	**SS**	**df**	**MS**	**F**	**Sig.**
Instructional Method	5.24	1	5.24	0.086	0.770
Critical Thinking	1934.8	1	1934.8	54.39	0.000
Interaction (A×B)	28.17	1	28.17	0.7919	0.378
Error	2306.1	65	35.48		

The final observation relates to the interaction effect between the two factors. Despite differences in mean scores, the interaction was statistically insignificant. This suggests that the impact of instructional method on cognitive achievement does not differ significantly between students with high and low critical thinking abilities. Both groups appear to benefit similarly from either instructional method when SAVI principles are applied. This finding aligns with previous claims that multimodal learning can provide equitable benefits regardless of cognitive differences Giannakos & Cukurova. 2023 and Stewart et al. 2025) It also supports the notion that the SAVI model is robust across instructional variations. Consequently, educators can adopt either method based on logistical or contextual preferences without compromising learning effectiveness.

Discussion

The findings of this study affirm the significant role of students' critical thinking skills in determining their cognitive performance in physics. While the instructional method did not yield significant differences, students categorized as high critical thinkers consistently outperformed their peers. This aligns with the theoretical perspectives of Essien et al. (2024) and Ho et al. (2023), who assert that critical thinking is foundational to effective learning, particularly in science education. The insignificant impact of the instructional method may indicate that both demonstration and experimentation, when conducted under the SAVI model, provide comparable learning experiences. Prior research by Anchalia et al. (2023) and Kakati et al. (2022) corroborates that SAVI-based instruction enhances understanding across diverse learning styles, making both approaches viable.

The absence of a significant interaction effect further supports the universality of the SAVI model's effectiveness. As demonstrated by Alam & Mohanty (2023) and Yeganeh et al. (2025), instructional models incorporating sensory and intellectual engagement foster deep learning irrespective of delivery format. This implies that student outcomes are more likely to be optimized when internal learner traits—such as critical thinking—are supported. Bernacki et al. (2021) and Lin

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et al (2024) argued that personalization of instruction based on cognitive traits amplifies learning gains, particularly in STEM education. The current study validates this argument within the physics domain. Thus, instructional design should prioritize the cultivation of cognitive dispositions alongside content delivery.

Another significant implication arises from the consistent findings across both groups. The results suggest that critical thinking should be integrated not as a supplementary skill but as a core objective of physics instruction. Al-Thani & Ahmad. (2025) and Clemente-Suárez et al. (2024) emphasized that cognitive strategies are essential for navigating complex science content. Additionally, the findings support the inclusion of assessment tools that measure and track cognitive skill development over time. Studies by (Chang et al., 2021; Wu et al., 2024) demonstrate that when assessment aligns with higher-order thinking, both engagement and performance improve. Therefore, assessment reform must accompany pedagogical innovation to fully realize the benefits of models like SAVI.

Finally, the study offers evidence for policy recommendations in curriculum development. Given the statistically significant effect of critical thinking, teacher training programs should include modules that emphasize this skill. Okolie et al. (2022) and Yulian. (2021) found that targeted training in critical thinking pedagogy led to improvements in classroom practice and student performance. Embedding critical thinking within national curriculum frameworks would also support broader educational goals such as innovation, problem-solving, and lifelong learning. While further research is needed to explore long-term outcomes, this study provides a strong basis for integrating cognitive skill development into everyday physics teaching.

Implications

This study reinforces the importance of integrating critical thinking development into science instruction, especially in physics education. The findings suggest that instructional models like SAVI can serve as a flexible platform to support diverse teaching methods while still emphasizing core cognitive outcomes. Educational stakeholders should consider incorporating critical thinking as a core competency in both instructional design and assessment criteria. The study also highlights the need for teacher professional development that equips educators with strategies to foster higher-order thinking. Furthermore, policymakers may use these insights to reform science curricula to be more aligned with 21st-century learning standards. By doing so, equitable and effective learning environments can be fostered across varied student populations. The application of multimodal instructional frameworks may help bridge learning disparities. Finally, future initiatives should focus on contextualizing such pedagogies in local and national education systems.

Limitations

Despite its contributions, the study is subject to certain limitations. First, the sample size was relatively small and confined to a single school, limiting generalizability. The duration of intervention was also short, which might not capture long-term learning effects. Moreover, the assessment tools—while validated—may not fully encapsulate the breadth of critical thinking and cognitive processing in physics. The study also did not account for external variables such as teacher quality or classroom resources. Statistical methods used, while robust, may still be influenced by sampling error. Additionally, the categorization of critical thinking into only two levels may overlook more nuanced cognitive profiles. Further studies should consider longitudinal designs and larger samples. Finally, qualitative data could complement quantitative findings for richer interpretation.

Suggestions

Future research should involve more diverse and larger student populations to validate the generalizability of the findings. Longitudinal studies may help reveal the lasting impact of SAVI-based instruction on academic performance and critical thinking. It is also recommended to explore hybrid instructional designs that combine demonstration and experimentation for optimal learning engagement. Researchers should integrate qualitative methods such as interviews or classroom

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observations to enrich the understanding of student experiences. Additionally, developing dynamic and real-time assessment tools for critical thinking may enhance instructional feedback. Further investigation into how SAVI interacts with other cognitive or emotional traits would also be valuable. Finally, teacher training programs should be expanded to include practical modules on SAVI implementation. Collaborations with curriculum developers and policymakers can help scale successful models across educational systems.

CONCLUSION

This study concludes that students' critical thinking skills have a significant and consistent impact on cognitive learning outcomes in physics, particularly in the topic of work and energy. While the implementation of the SAVI learning model through both experimental and demonstration methods resulted in relatively similar performance levels, the cognitive gains were markedly higher among students with advanced critical thinking abilities. The findings confirm that instructional strategies alone are insufficient to maximize student achievement unless accompanied by the cultivation of essential cognitive dispositions. Moreover, the lack of a significant interaction effect suggests that the SAVI model is pedagogically flexible and effective across diverse learner profiles, regardless of the delivery method. These results support the integration of multimodal learning models such as SAVI in science education while highlighting the need to emphasize critical thinking as a fundamental learning goal. The study also provides empirical evidence for the strategic alignment of teaching methods with internal learner characteristics to optimize learning outcomes. Therefore, educators and policymakers should focus not only on refining instructional models but also on embedding cognitive skill development—especially critical thinking—into the science curriculum. These conclusions have important implications for instructional design, teacher training, and curriculum reform aimed at enhancing the quality of physics education in the 21st century.

AUTHOR CONTRIBUTION STATEMENT

Meritania Yusman conceptualized the research framework, designed the experimental procedures, and coordinated data collection in the field. She also played a central role in drafting the initial manuscript and integrating feedback during the revision process.

Nonoh Siti Aminah was responsible for the development and validation of research instruments, including the cognitive and critical thinking assessments. She conducted the statistical analyses and ensured methodological rigor throughout the study.

Pujayanto contributed to the theoretical framework and literature review, linking the findings to contemporary educational models and pedagogical strategies. He also assisted in refining the discussion and aligning the implications with current curricular standards.

All authors reviewed and approved the final manuscript. Each contributed substantially and uniquely to the study, reflecting a collaborative commitment to advancing educational research through evidence-based and contextually relevant inquiry.

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