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Enhancing Elementary Students' Understanding of the Solar System through Smart TV and Solar Scope Integration: A Classroom Action Research Study

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ABSTRACT

This study was motivated by students' low conceptual understanding and learning outcomes in the Solar System topic within Integrated Science and Social Studies (IPAS) learning at SDN 101 Bungo. The predominance of conventional teaching methods and the limited use of interactive media made it difficult for students to comprehend abstract scientific concepts. Therefore, this study aimed to improve students' learning outcomes and classroom engagement through the implementation of Smart TV-based learning media integrated with the Solar Scope system. This research employed a Classroom Action Research design based on the Kemmis and McTaggart model, which consisted of two cycles involving planning, action, observation, and reflection. The participants were 25 sixth-grade students. Data were collected through achievement tests, classroom observations, and documentation and were analyzed using both quantitative and qualitative approaches. The findings revealed a substantial improvement in students' academic achievement and learning activities. The average score increased from 65 in the pre-action stage to 70 in Cycle I and reached 85 in Cycle II. Similarly, the percentage of students achieving learning mastery improved from 52% to 60% and finally to 92%. Students also demonstrated higher levels of participation, interaction, collaboration, and motivation during the learning process. These findings indicate that the integration of Smart TV and Solar Scope provides meaningful visual experiences that facilitate students' understanding of abstract concepts and promote more student-centered learning. Consequently, this instructional innovation can serve as an effective alternative for enhancing elementary science education in the digital era.

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INTRODUCTION

Science and Social Studies (IPAS) education in elementary schools has increasingly become a central concern in contemporary educational reform because it provides the foundation for scientific literacy, environmental awareness, and critical thinking skills. Despite rapid technological development and substantial investment in digital infrastructure, the quality of science learning outcomes among elementary students remains uneven across many educational settings. This paradox has attracted considerable attention from researchers and policymakers, particularly in countries that are implementing technology-oriented curricula. International large-scale assessments continue to indicate that many students experience difficulties in understanding scientific concepts that require abstract reasoning and spatial imagination. In Indonesia, this challenge becomes more apparent in topics such as astronomy and the solar system, where students are expected to understand phenomena that cannot be directly observed in everyday life. At the same time, the Independent Curriculum emphasizes inquiry, scientific reasoning, and active participation, requiring schools to transform traditional instructional practices into more meaningful learning experiences. Consequently, the gap between curricular expectations and classroom realities has become an urgent issue that deserves systematic investigation. Understanding how technology can support conceptual learning in elementary science classrooms is therefore both an educational necessity and a practical challenge.

One of the most persistent problems in science instruction concerns students' limited ability to comprehend abstract concepts through conventional teaching methods. In many elementary classrooms, learning activities are still dominated by lectures, textbook explanations, and static illustrations that provide little opportunity for students to explore scientific phenomena independently. Such approaches often encourage memorization rather than conceptual understanding, particularly when students are introduced to complex topics involving motion, scale, and spatial relationships. The solar system is a clear example of this challenge because students must mentally construct representations of planetary orbits, rotational movements, and interactions among celestial bodies. Previous studies have shown that the absence of appropriate visual support frequently leads to misconceptions and fragmented knowledge structures (Heinonen et al., 2023; Morris, 2025). Preliminary observations conducted in Grade VI at SDN 101 Bungo revealed similar conditions, where students demonstrated low engagement and unsatisfactory academic performance in learning about the solar system. The average achievement score remained below the expected standard, while classroom participation was limited to a small number of students. These findings indicate that traditional instructional practices alone are insufficient to facilitate meaningful learning in science education.

The urgency of addressing this issue has become more significant in the era of digital transformation, where educational systems are increasingly expected to integrate technology into everyday teaching practices. The Indonesian Independent Curriculum explicitly encourages teachers to create student-centered learning environments that promote critical thinking, creativity, collaboration, and communication. Achieving these competencies requires instructional strategies capable of connecting scientific theories with authentic learning experiences. At the same time, technological advancements have expanded access to various digital tools that can potentially enrich classroom instruction. Nevertheless, educational technology does not automatically improve learning outcomes when it is implemented without appropriate pedagogical planning. Several scholars have emphasized that the effectiveness of digital media depends on how instructional content, learner characteristics, and classroom interactions are aligned within a coherent learning design (Abuhassna et al., 2024; Hidayati & Slamet, 2025; Rathnasekara et al., 2025). Therefore, the challenge is not merely to introduce technology into schools but to identify instructional models that effectively utilize technology to support conceptual understanding. Investigating innovative learning media has consequently become an important agenda in science education research.

From a theoretical perspective, the integration of digital media into science learning can be explained through several influential educational frameworks. The Cognitive Theory of Multimedia Learning proposes that students learn more effectively when information is delivered through coordinated visual and verbal channels rather than through text alone (Mayer, 2024). According to this theory, meaningful learning occurs when learners actively select, organize, and integrate information into coherent mental representations. Complementing this perspective, Cognitive Load Theory argues that instructional materials should minimize unnecessary cognitive demands and optimize the limited capacity of working memory (Sortwell et al., 2026; Sweller, 2020). In the context of solar system learning, students often experience excessive cognitive load because they must imagine complex astronomical phenomena that cannot be directly observed. Interactive visualizations can reduce this burden by transforming abstract information into concrete and dynamic representations. Furthermore, constructivist perspectives developed by Piaget and Vygotsky emphasize that knowledge is constructed through social interaction, exploration, and reflective thinking. These theoretical foundations suggest that science learning environments should provide opportunities for students to observe, discuss, and interpret phenomena collaboratively. Consequently, technology-enhanced instruction has strong theoretical potential to improve both learning outcomes and classroom engagement.

Recent educational research has consistently highlighted the positive contribution of multimedia technologies to science learning. Noetel et al., (2022) demonstrated that multimedia learning environments facilitate conceptual understanding by integrating visual, textual, and auditory elements within a single instructional system. Similarly, Jaramillo-Mediavilla et al., (2024) found that interactive multimedia supports students' engagement and motivation in elementary education by providing more attractive and participatory learning experiences. Research conducted by Manurung (2020) further showed that multimedia integrated with problem-based learning enhances students' scientific reasoning and problem-solving abilities. In a broader context, interactive multimedia has become one of the most effective approaches for improving learning quality across various educational levels. Abdulrahaman et al. (2020) also emphasized that digital media plays a strategic role in modern educational transformation by encouraging learner autonomy and interaction. International studies have reached similar conclusions, indicating that simulation-based learning environments contribute positively to students' comprehension of abstract scientific concepts (Pang et al., 2025; Wen et al., 2020). Collectively, these findings confirm the growing importance of multimedia technologies in contemporary education. However, the diversity of technological platforms and instructional contexts means that important questions remain unanswered.

Existing literature reveals several dominant trends that characterize current research on multimedia-based learning. First, most studies have focused on general forms of multimedia, such as educational videos, animations, mobile applications, and web-based platforms, rather than on specific classroom technologies. Second, previous investigations have predominantly measured cognitive achievement while paying less attention to students' learning activities, participation, and interaction during the instructional process (Yong & Peng, 2025). Third, Moreover, earlier studies often treated technology merely as a supplementary instructional tool without examining how digital media can be systematically integrated into student-centered pedagogical practices. Although the benefits of multimedia have been widely acknowledged, the mechanisms through which particular technologies support conceptual understanding in authentic classroom settings have not been sufficiently explored. Consequently, the educational value of many technological innovations remains context-dependent and requires further empirical verification. These limitations suggest that the current body of knowledge is still fragmented and incomplete.

Another important limitation concerns the scarcity of studies investigating the pedagogical potential of Smart TVs combined with astronomy simulation systems in elementary science education. Smart TVs possess unique characteristics because they function not only as display devices but also as interactive platforms capable of integrating multiple forms of digital content within classroom activities. When connected with simulation applications such as Solar Scope, Smart TVs allow students to observe planetary movements, orbital trajectories, and astronomical phenomena through dynamic three-dimensional visualizations. Despite these advantages, empirical research examining this combination remains extremely limited, particularly in Indonesian elementary schools. Most previous studies have focused on multimedia effectiveness in general and have not specifically addressed how Smart TV-based learning environments influence students' conceptual understanding and classroom engagement. Furthermore, little attention has been given to the role of iterative instructional improvement through classroom action research designs. As a result, evidence regarding the effectiveness of integrating Smart TV technology, simulation media, and student-centered learning strategies is still insufficient. This gap highlights the need for contextual research that bridges technological innovation and pedagogical practice.

The novelty of the present study lies in three interconnected aspects. First, this research integrates Smart TV technology with the Solar Scope simulation system to facilitate the learning of the solar system, an area that has received limited scholarly attention in elementary education. Second, unlike previous studies that primarily focused on learning achievement, this study simultaneously examines students' learning outcomes and classroom activities as complementary indicators of instructional effectiveness. Third, the research employs a classroom action research approach, enabling continuous refinement of teaching practices through cycles of planning, implementation, observation, and reflection. This design allows researchers to investigate not only whether technology works, but also how instructional improvements contribute to meaningful learning experiences. By combining technological innovation with pedagogical intervention, the study seeks to provide a more comprehensive understanding of multimedia-based science instruction. Therefore, this research addresses an important gap in the literature and contributes to ongoing discussions about technology integration in elementary education. The findings are expected to enrich both theoretical and practical perspectives on digital learning innovation.

Based on these considerations, the present study aims to examine the effectiveness of Smart TV-based learning media integrated with the Solar Scope system in improving students' learning outcomes and learning activities in science and social studies instruction on the solar system topic in Grade VI of SDN 101 Bungo. Specifically, the study investigates how interactive digital visualization influences students' conceptual understanding, participation, and engagement throughout the learning process. Theoretically, this research contributes to the development of multimedia learning studies by extending the application of Cognitive Theory of Multimedia Learning and Cognitive Load Theory within elementary science education contexts. Practically, the findings are expected to provide teachers with evidence-based strategies for designing technology-supported instruction that is interactive, collaborative, and aligned with the principles of the Independent Curriculum. In addition, the study offers insights for schools and policymakers regarding the effective utilization of digital infrastructure to support quality learning. More broadly, the research contributes to the ongoing effort to develop educational practices that are responsive to the demands of the digital era and the competencies required in the twenty-first century. Ultimately, this study aspires to demonstrate that technology can become a meaningful pedagogical instrument when integrated with appropriate instructional strategies and learner-centered approaches.

METHOD

Research Design

This study adopted a Classroom Action Research (CAR) design supported by quantitative and qualitative data to investigate the effectiveness of Smart TV-based learning media integrated with the Solar Scope system in improving students' learning outcomes and learning activities in science and social studies (IPAS) instruction. Classroom Action Research was considered the most appropriate approach because the primary objective of the study was not merely to describe a phenomenon but to improve classroom practices through systematic interventions. The research followed the cyclical framework proposed by Kemmis and McTaggart, which consists of four

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interconnected stages: planning, action, observation, and reflection. Quantitative data were employed to examine changes in students' academic achievement, whereas qualitative evidence was used to explore students' participation, interaction, and engagement during the learning process. Combining these forms of evidence enabled a comprehensive evaluation of the instructional intervention and provided a deeper understanding of how technology-supported learning influenced classroom dynamics.

Research Setting and Duration

The research was conducted at SDN 101 Bungo, Jambi Province, Indonesia, during the second semester of the 2025 academic year. The study took place in Grade VI classrooms within the context of IPAS instruction on the topic of the solar system. This setting was selected following preliminary observations indicating that students experienced considerable difficulties in understanding astronomical concepts and exhibited low levels of participation during classroom activities. The intervention was implemented over approximately six weeks and consisted of two action cycles. Each cycle included lesson preparation, classroom implementation, observation, evaluation, and reflection. The classroom was equipped with Smart TV facilities, allowing the Solar Scope application to be integrated into the learning process.

Participants

The participants were twenty-five students enrolled in Class VIA, consisting of thirteen boys and twelve girls aged between eleven and twelve years. Purposive sampling was employed because the selected class demonstrated relatively low achievement in science learning and encountered persistent difficulties in understanding the solar system. Students were included in the study if they actively attended classroom activities and completed all assessment procedures during both cycles. Students who did not participate consistently throughout the intervention period were excluded from the analysis. The selection of participants was based on pedagogical considerations and the need to improve learning quality within the classroom where the instructional problem had been identified.

Research Instruments

Data were collected through achievement tests, classroom observations, and documentation. Learning achievement tests were administered at the end of each cycle to assess students' understanding of the solar system. The test items covered several indicators, including the identification of planetary characteristics, the explanation of Earth's rotation and revolution, the interpretation of orbital movements, and the analysis of relationships among celestial bodies. Classroom observations were conducted using structured observation sheets designed to record students' attention, participation, collaboration, questioning behavior, and presentation skills during instructional activities. In addition, supporting documents, including lesson plans, students' worksheets, photographs, and field notes, were collected to strengthen the interpretation of the findings. All instruments were developed based on the learning outcomes specified in Phase C of the Independent Curriculum and on previous studies concerning multimedia learning and science education.

Instrument Trustworthiness

To ensure the appropriateness of the instruments, content validation was conducted through expert review involving specialists in elementary education and science instruction, as well as an experienced classroom teacher. The experts evaluated the instruments in terms of clarity, relevance, and alignment with the intended learning objectives. Revisions were subsequently made based on their suggestions before the instruments were implemented in the classroom. To improve the consistency of observational data, observations were conducted collaboratively with a classroom observer using the same assessment criteria and observation guidelines. The use of multiple data sources, including tests, observations, and documentation, also contributed to methodological triangulation and strengthened the credibility of the findings.

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Data Collection Procedure

The study was carried out in two action cycles, each consisting of planning, implementation, observation, and reflection stages. During the planning phase, the researchers prepared lesson plans, students' worksheets, learning materials, observation sheets, and assessment instruments integrated with Smart TV media and the Solar Scope application. In the implementation phase, the teacher introduced the solar system topic through interactive simulations displayed on the Smart TV. Students observed planetary movements, discussed scientific phenomena in small groups, completed learning tasks, and presented their findings to the class. Throughout the instructional activities, classroom observations and field notes were used to document students' responses and participation. At the end of each cycle, students completed an achievement test to measure their conceptual understanding. The reflection stage involved analyzing the strengths and weaknesses of the instructional process and identifying aspects that required improvement in the subsequent cycle. Based on the reflections from Cycle I, several modifications were introduced in Cycle II, including more structured worksheets, improved time management, heterogeneous grouping, and additional opportunities for collaborative inquiry.

Data Analysis

The data were analyzed using descriptive quantitative techniques and qualitative procedures. Quantitative analysis was conducted to determine changes in students' learning outcomes across the research cycles. The mean score of the class was calculated using the formula:

$$\bar{X} = \frac{\sum X}{N}$$

where $\bar{X}$ (mean score of the class), $\sum X$ (total score obtained by all students), and N (total number of students). To determine the percentage of learning mastery, the following formula was applied:

$$P = \frac{n}{N} \times 100\%$$

where P (percentage of students achieving mastery), n (number of students who achieved the minimum mastery criterion/KKM) and N (total number of students). The improvement in learning outcomes between cycles was measured using the percentage increase formula:

$$I = \frac{X_2 - X_1}{X_1} \times 100\%$$

where I (percentage increase in learning outcomes), X_1 (mean score in the previous cycle) and X_2 (mean score in the subsequent cycle). The intervention was considered successful when the average class score reached at least 80 and when a minimum of 85% of students achieved the predetermined mastery criterion.

Qualitative data derived from classroom observations, field notes, and documentation were analyzed using the interactive model developed by Thompson Burdine et al. (2021), which involves three interrelated stages: data reduction, data display, and conclusion drawing. Observation records were systematically coded according to several indicators, including students' attention, participation, collaboration, interaction, and confidence during classroom activities. Finally, quantitative and qualitative findings were interpreted collectively to provide a comprehensive understanding of the effectiveness of Smart TV-based learning media integrated with the Solar Scope system in improving students' learning outcomes and classroom engagement.

RESULTS AND DISCUSSION

Baseline Classroom Conditions

Prior to the intervention, classroom observations and diagnostic assessments were conducted to identify students' initial understanding of the solar system and to examine the instructional practices implemented in Grade VIA at SDN 101 Bungo. The observations revealed that classroom instruction relied predominantly on lectures, textbook explanations, and static illustrations. Although these approaches enabled teachers to deliver factual information efficiently, they provided limited opportunities for students to explore scientific concepts independently. This instructional pattern became particularly problematic in the context of solar system learning because students were expected to understand abstract phenomena involving planetary motion, orbital trajectories, and spatial relationships that cannot be directly observed in everyday life.

The results of the preliminary assessment confirmed these challenges. Students achieved an average score of 65, while only 52% met the Minimum Mastery Criterion (KKM). Classroom participation was also relatively low, with most students assuming passive roles during instructional activities. Questioning behavior, collaborative discussion, and scientific reasoning were rarely observed. Several students struggled to explain the differences between rotation and revolution, while others experienced difficulties in identifying the characteristics and relative positions of planets. These findings indicate that the instructional methods employed before the intervention were insufficient to support meaningful conceptual understanding and active participation.

Results of Classroom Action Research

The intervention was implemented in two consecutive cycles using Smart TV-based learning media integrated with the Solar Scope system. The quantitative findings obtained during each phase of the study are summarized in Table 1.

Table 1. Development of Students' Learning Outcomes Across Research Cycles

Indicators	Pre-Action	Cycle I	Cycle II
Mean score	65	70	85
Learning mastery (%)	52	60	92
Students achieving mastery (n)	13	15	23
Students not achieving mastery (n)	12	10	2

Table 1 demonstrates a consistent improvement in students' academic achievement throughout the intervention. The average score increased from 65 in the preliminary stage to 70 in Cycle I and reached 85 in Cycle II.

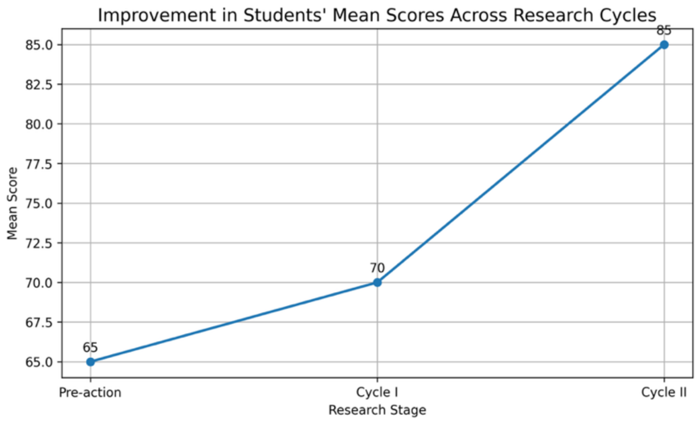

Figure 1. Improvement in Students' Mean Scores Across Research Cycles.

Likewise, the percentage of students achieving mastery increased from 52% in the pre-action stage to 60% in Cycle I and finally reached 92% in Cycle II.

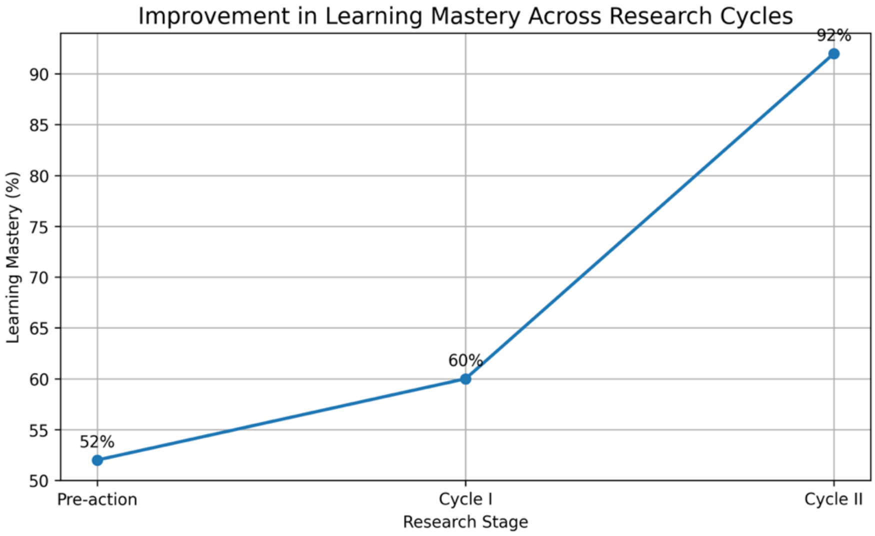

Figure 2. Improvement in Students' Learning Mastery Across Research Cycles.

The implementation of Cycle I focused primarily on introducing Smart TV and Solar Scope as instructional media. Through three-dimensional simulations, students were able to observe planetary movements, orbital paths, and astronomical events that had previously been presented only through verbal explanations. The classroom atmosphere became noticeably more dynamic, and students demonstrated greater curiosity toward the learning materials. Nevertheless, the improvement observed during this stage remained limited. Reflection sessions conducted after Cycle I revealed several factors that constrained the effectiveness of the intervention, including insufficient time allocation for discussion, students' unfamiliarity with simulation-based learning, and the limited capacity of existing worksheets to guide inquiry activities.

Based on these reflections, several pedagogical modifications were introduced in Cycle II. Learning worksheets were redesigned to encourage observation and analytical thinking, classroom management strategies were refined, and students were organized into heterogeneous groups to strengthen peer collaboration. Furthermore, the role of the teacher shifted from information provider to facilitator, allowing students to interact more actively with the simulation and construct their understanding through discussion and exploration. These changes substantially improved the quality of classroom interaction and contributed to the significant gains observed in the second cycle.

Changes in Students' Learning Activities

The improvement in academic performance was accompanied by noticeable changes in students' learning behaviors. During the initial stage, classroom activities were largely characterized by passive listening and limited interaction. By the end of Cycle II, however, students demonstrated greater confidence in expressing opinions, asking questions, and presenting their observations. Group discussions became more balanced, with students exchanging ideas and jointly interpreting the visual information displayed through the Solar Scope simulation.

Observational data further showed that students became increasingly engaged in inquiry-based activities. Rather than merely memorizing scientific facts, they actively explored the relationships among planetary characteristics, orbital motion, and astronomical phenomena. Students also exhibited stronger collaborative skills, particularly when working in heterogeneous groups. These findings suggest that the integration of Smart TV and Solar Scope not only improved learning outcomes but also transformed the classroom into a more interactive and student-centered learning environment.

Despite these positive developments, the intervention did not eliminate all learning difficulties. At the end of Cycle II, two students still failed to achieve the expected mastery criterion. Classroom observations suggested that differences in prior knowledge, learning pace, and confidence influenced students' responses to the instructional innovation. This finding highlights an important consideration: technological integration alone cannot fully accommodate individual differences among learners. Consequently, future instructional practices should incorporate additional forms of support, such as differentiated learning strategies and individualized guidance, to ensure that all students benefit equally from technology-enhanced instruction.

The findings of this study provide empirical evidence that integrating Smart TV technology with the Solar Scope system can significantly improve students' learning outcomes and classroom engagement in elementary science education. The increase in average scores from 65 in the preliminary stage to 85 in Cycle II, accompanied by the rise in learning mastery from 52% to 92%, indicates that interactive digital visualization contributes meaningfully to students' understanding of abstract scientific concepts. More importantly, the intervention altered the nature of classroom interactions by encouraging inquiry, collaboration, and active participation.

The present findings support Mayer's Cognitive Theory of Multimedia Learning, which argues that students learn more effectively when information is presented through complementary visual and verbal channels (Mayer, 2024). In this study, Smart TV and Solar Scope enabled students to observe planetary motion while simultaneously listening to explanations and engaging in discussions. The combination of these instructional elements facilitated the development of coherent mental models and reduced students' dependence on rote memorization. Unlike conventional instruction, which relied heavily on static images and teacher explanations, the digital simulation offered dynamic representations that made scientific concepts more accessible.

The results also align with Cognitive Load Theory (Sweller, 2020), particularly regarding the reduction of extraneous cognitive load. Prior to the intervention, students had to imagine complex astronomical phenomena without adequate visual support, which imposed substantial cognitive demands. Through interactive simulations, abstract concepts were transformed into observable representations, allowing students to allocate greater cognitive resources to conceptual understanding rather than to mental visualization. The substantial gains recorded in Cycle II suggest that reducing unnecessary cognitive burden can significantly enhance learning effectiveness in elementary science classrooms.

The improvement in students' participation further reflects the principles of constructivist learning proposed by Piaget and Vygotsky. Knowledge acquisition in this study did not occur through passive reception of information but through active engagement with scientific phenomena, peer interaction, and collaborative inquiry. Students observed simulations, discussed their interpretations, tested ideas, and collectively formulated explanations. Such learning experiences are consistent with the view that conceptual understanding develops through social interaction and meaningful engagement with the learning environment.

From a motivational perspective, the findings can also be interpreted using Keller's ARCS model, which emphasizes the roles of attention, relevance, confidence, and satisfaction in learning. The visual and interactive characteristics of Solar Scope successfully captured students' attention and increased the perceived relevance of the instructional content. Opportunities to explore simulations and communicate findings enhanced students' confidence, while successful completion of learning tasks generated satisfaction and encouraged further engagement. The combination of these motivational dimensions contributed to the more active classroom participation observed in Cycle II.

The findings of this study are broadly consistent with previous research demonstrating the effectiveness of multimedia learning environments in science education (Abdulrahaman et al., 2020; Jaramillo-Mediavilla et al., 2024; Manurung, 2020; Noetel et al., 2022). However, the present study extends existing knowledge in several important ways. Most previous studies focused on multimedia applications in general, whereas this research specifically examined the integration of Smart TV technology with an astronomy simulation platform within an elementary classroom context. Moreover, earlier investigations often concentrated exclusively on cognitive achievement, while the present study simultaneously explored changes in students' learning activities and classroom interaction. The use of a classroom action research framework also enabled continuous refinement of instructional practices through iterative cycles of reflection and improvement.

Nevertheless, several limitations should be acknowledged. The study was conducted in a single classroom involving a relatively small number of participants, which limits the generalizability of the findings. In addition, the intervention focused exclusively on the solar system topic and did not examine whether similar effects would emerge in other areas of science learning. Technical constraints, including differences in students' digital readiness and the availability of technological infrastructure, also influenced the implementation process. Future studies may address these limitations by involving larger samples, comparing different forms of digital media, and investigating the long-term impact of simulation-based learning on students' scientific literacy.

Overall, the integration of Smart TV and Solar Scope demonstrates considerable potential as an instructional innovation in elementary science education. The findings suggest that technology becomes pedagogically meaningful when combined with well-structured learning activities, collaborative inquiry, and reflective teaching practices. Rather than functioning solely as a presentation tool, Smart TV-based simulation can facilitate conceptual understanding, strengthen classroom interaction, and support the development of twenty-first-century competencies expected in the implementation of the Independent Curriculum.

CONCLUSIONS

The findings of this classroom action research demonstrate that the integration of Smart TV-based learning media with the Solar Scope system effectively enhanced students' learning outcomes and classroom engagement in Grade VI IPAS instruction at SDN 101 Bungo. The intervention led to a substantial improvement in students' academic performance, as indicated by the increase in the mean score from 65 in the preliminary stage to 85 in Cycle II, while the percentage of students achieving the Minimum Mastery Criterion rose from 52% to 92%. Beyond cognitive achievement, the use of interactive simulations encouraged greater participation, collaboration, and scientific inquiry, transforming the learning process from a predominantly teacher-centered approach into a more student-centered environment. These findings suggest that digital visualization can facilitate students' understanding of abstract scientific concepts when supported by appropriate pedagogical strategies and reflective teaching practices. Despite the study's limited scope, the results highlight the potential of Smart TV and Solar Scope as innovative instructional tools for elementary science education and provide practical implications for the implementation of technology-enhanced learning within the Independent Curriculum.

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