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The Effectiveness of Stellarium as an Interactive Digital Medium to Enhance Vocational High School Students' Understanding of Earth and Space Science

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Abstract: This study investigates the effectiveness of Stellarium, an interactive digital planetarium software, in improving vocational high school students' understanding of Earth and space science concepts. The research employed a one-group pre-test post-test design with 10 tenth-grade students from SMK Hamong Putera Pakem, Yogyakarta, Indonesia. Data were collected using cognitive tests (10 multiple-choice items), a student response questionnaire (10 Likert-scale items), and an observation sheet (11 indicators). The results showed a significant increase in students' scores from pre-test to post-test, with an average N-Gain score categorized as medium. Observation data revealed that students actively participated, collaborated effectively, and demonstrated conceptual understanding of rotation, revolution, lunar phases, and eclipses. Furthermore, student responses were overwhelmingly positive, with more than 80% agreeing that Stellarium made learning more engaging, motivating, and enjoyable. These findings highlight the potential of Stellarium as a technology-enhanced learning tool to facilitate abstract scientific concepts, foster active learning, and support the digital transformation of vocational education. The study contributes to the growing literature on immersive and interactive learning environments and provides practical insights for science teachers in vocational schools.

Keywords: Stellarium, Interactive digital media, Earth and space science, Vocational education, Technology-enhanced learning.

Introduction

The rapid development of digital technology has reshaped educational practices across the globe, positioning technology-enhanced learning (TEL) as a central component of 21st-century education (Dewi et al., 2021; OECD, 2019). In science education, digital tools are increasingly utilized to address persistent learning challenges, particularly those related to abstract and complex concepts (Becker & Park, 2011; Liu et al., 2020). Earth and space science is one such domain where students often experience conceptual difficulties due to the spatial and temporal nature of astronomical phenomena (Duit & Gropengießer, 2015; Treagust & Duit, 2008).

Topics such as Earth's rotation and revolution, lunar phases, and eclipses require learners to mentally visualize three-dimensional motion over time. Conventional instructional approaches relying on textbooks and static images frequently fail to support this level of abstraction, resulting in misconceptions that persist even after instruction (Duit & Gropengießer, 2015). Prior research has shown that students often confuse rotation with

revolution or misinterpret the causes of lunar phases, indicating a need for more effective instructional strategies (Treagust & Duit, 2008).

These challenges are particularly pronounced in vocational high schools (Sekolah Menengah Kejuruan/SMK) in Indonesia. Vocational education prioritizes practical skills and employability (Wulandari & Wibowo, 2019), leading many students to perceive general science subjects as less relevant to their future careers (Hidayati & Kusumawardhani, 2020). Consequently, motivation and engagement in science learning tend to be lower compared to vocational subjects (Keller, 2010). However, scientific literacy and digital competence remain essential foundations for adapting to technological advancements in modern industries (OECD, 2019; UNESCO, 2017).

One promising approach to addressing these challenges is the integration of interactive digital media that enable visualization and active exploration (Becker & Park, 2011; Liu et al., 2020). Digital simulations allow learners to observe phenomena that cannot be directly experienced, thereby supporting deeper conceptual understanding (Nordin & Faiz, 2020; Tsai & Lin, 2019). Stellarium, an open-source digital planetarium software, offers real-time simulations of the night sky and allows users to manipulate time, location, and perspective (Stellarium.org, 2025). Through these features, abstract astronomical concepts become observable and interactive (Wibisono et al., 2020).

Grounded in constructivist learning theory and the principles of technology-enhanced learning (Dewi et al.,2021), this study explores the effectiveness of Stellarium in teaching Earth and space science concepts to vocational high school students. The study aims to examine (1) the extent to which Stellarium improves students' conceptual understanding, (2) students' engagement and participation during learning activities, and (3) students' perceptions of Stellarium as a digital learning medium.

Theoretical Background

Constructivist learning theory posits that learners actively construct knowledge through interaction with their environment rather than passively receiving information (Duit & Gropengießer, 2015). In science education, this implies that meaningful learning occurs when students engage with phenomena, test ideas, and reconcile new information with prior knowledge. Conceptual change theory further emphasizes the importance of confronting misconceptions through experiences that challenge students' existing mental models (Treagust & Duit, 2008).

Visualization plays a crucial role in facilitating conceptual change, particularly for abstract scientific concepts (Nordin & Faiz, 2020). Simulation-based learning environments provide dynamic representations that support learners in forming accurate mental models (Becker & Park, 2011). Research on simulation-based learning consistently reports positive effects on students' conceptual understanding and engagement (Liu et al., 2020).

Technology-enhanced learning integrates digital tools to support not only cognitive outcomes but also motivation, collaboration, and digital literacy (Dewi et al., 2021). In vocational education, TEL serves a dual function: enhancing subject-matter understanding while simultaneously developing digital competencies relevant to the workplace (Wulandari & Wibowo, 2019). Open-source tools such as Stellarium are especially valuable in vocational contexts due to their accessibility and low cost, making them suitable for schools with limited resources (Stellarium.org, 2025; Wibisono et al., 2020).

Method

Research Design

This study employed a quasi-experimental one-group pre-test post-test design to evaluate the impact of Stellarium-assisted instruction on students' understanding of Earth and space science concepts. This design is commonly used in classroom-based research where control groups and random assignment are not feasible.

Participants

The participants consisted of 10 tenth-grade students (5 male and 5 female) from a vocational high school in Yogyakarta, Indonesia. The small sample size reflects authentic classroom conditions commonly found in vocational schools, particularly in semi-rural areas (Dewi et al., 2021).

Instruments

Three instruments were used for data collection. First, a cognitive achievement test consisting of 10 multiple-choice items was developed to assess students' understanding of Earth's rotation, revolution, lunar phases, and eclipses. Second, a student response questionnaire with 10 Likert-scale items was used to capture students' motivation, engagement, and perceptions of Stellarium-assisted learning (Keller, 2010). Third, a structured observation sheet containing 11 indicators was employed to document student participation, collaboration, technical skills, and conceptual understanding during the learning process.

Procedure

The intervention was conducted over three instructional sessions (3 × 40 minutes). In the first session, students completed the pre-test and were introduced to Stellarium and its basic features (Stellarium.org, 2025). The second session focused on guided exploration, where students worked in small groups to observe and analyze astronomical phenomena using Stellarium. In the third session, students presented their findings, engaged in class discussions, and completed the post-test and questionnaire.

Data Analysis

Learning improvement was analyzed using the normalized gain (N-Gain) formula (Hake, 1999). Questionnaire data were analyzed descriptively to determine trends in student responses, while observation data were summarized qualitatively.

Results and Discussion

The results of the cognitive tests indicate a clear improvement in students' understanding after Stellarium-assisted instruction. Table 1 shows an increase in students' mean scores after Stellarium-assisted instruction, indicating improved conceptual understanding of Earth and space science.

Table 1. Students' pre-test and post-test scores

Test Type	N	Mean	Minimum	Maximum
Pre-Test	10	45.5	30	60
Post-Test	10	72.0	60	85

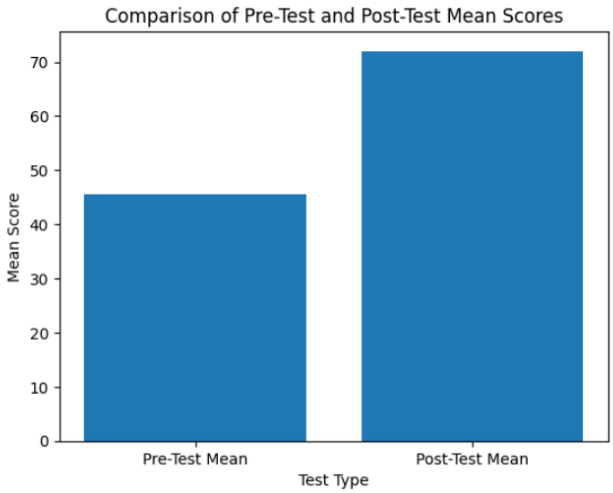

Figure 1. Comparison of pre-test and post-test mean scores

Figure 1 illustrates the comparison between students' mean pre-test and post-test scores. The increase in the post-test mean score indicates an improvement in students' conceptual understanding after Stellarium-assisted instruction. Figure 1 demonstrates a clear increase in the mean score from the pre-test to the post-test, indicating that students achieved higher learning outcomes after participating in Stellarium-assisted instruction. The substantial difference between the two bars suggests that the use of interactive visualization effectively supported students in understanding abstract Earth and space science concepts (Tsai & Lin, 2019). This improvement implies that learners were better able to internalize relationships between celestial movements and observable phenomena, such as the distinction between Earth's rotation and revolution. The visual evidence presented in Figure 1 strengthens the quantitative findings reported in Table 1. and confirms that the integration of Stellarium contributed positively to students' conceptual understanding (Wibisono et al., 2020).

Table 2. Normalized gain (N-Gain) analysis

Indicator	Value
Mean Pre-Test Score	45,5
Mean Post Test Score	72,0
N-Gain	0,48
Gain Category	Medium

The average pre-test score was 45.5, while the average post-test score increased to 72.0. The calculated N-Gain score of 0.48 falls within the medium category, indicating a meaningful improvement in conceptual understanding. Based on Hake's classification, the N-Gain value of 0.48 indicates a medium level of learning improvement (Hake, 1999).

This medium level of learning gain suggests that the instructional intervention was effective in facilitating students' conceptual development, although there remains room for further improvement. The interactive features of Stellarium allowed students to observe astronomical phenomena dynamically, supporting the transition from fragmented prior knowledge toward more coherent scientific understanding (Nordin & Faiz, 2020). Rather than achieving surface-level recall, students demonstrated improved ability to relate celestial motions to observable outcomes, indicating deeper cognitive processing (Duit & Gropengießer, 2015). In vocational education contexts, where science learning is often constrained by limited instructional time and varying academic readiness, achieving a medium N-Gain reflects a substantial pedagogical impact and highlights the potential of interactive digital media to enhance conceptual learning efficiency (Liu et al., 2020).

Classroom observations further support these findings. Students demonstrated increased engagement, actively collaborated with peers, and showed improved ability to explain Earth's rotation and revolution, lunar phases, and eclipse phenomena. Many students independently explored Stellarium features beyond initial instructions, reflecting curiosity and active learning behavior (Keller, 2010). Most students expressed positive perceptions toward the use of Stellarium, particularly in terms of motivation, engagement, and conceptual clarity.

Table 3. Summary of student response questionnaire

Aspect Evaluated	Agreement (%)
Learning is more interesting	85%
Increased learning motivation	90%
Easier understanding of concepts	80%
Active participation during learning	85%
Desire to use similar media again	80%

Student response questionnaire results reveal overwhelmingly positive perceptions. More than 85% of students reported that Stellarium made learning more enjoyable, while 90% indicated increased motivation and interest in astronomy. Additionally, most students expressed a desire for similar digital media to be used in future lessons. From a theoretical perspective, these findings align with constructivist learning and conceptual change theories (Duit & Gropengießer, 2015; Treagust & Duit, 2008). Stellarium functions as a cognitive visualization tool that enables learners to observe and manipulate abstract phenomena, thereby facilitating conceptual restructuring (Tsai & Lin, 2019). The interactive environment encourages active engagement, peer discussion, and reflective thinking, all of which are essential components of meaningful learning (Keller, 2010).

In the context of vocational education, the findings are particularly significant (Hidayati & Kusumawardhani, 2020). Increased motivation and engagement suggest that interactive digital media can reduce the perceived gap between general science subjects and vocational relevance (Wulandari & Wibowo, 2019). Moreover, the use of Stellarium contributes to the development of digital literacy, an essential competency for the modern workforce

(OECD, 2019; UNESCO, 2017). Despite these positive outcomes, the study has limitations. The absence of a control group limits causal inference, and the small sample size restricts generalizability. Nevertheless, the study provides valuable empirical evidence supporting the integration of open-source digital tools in vocational science education (Dewi et al., 2021).

Conclusion

This study concludes that Stellarium is an effective interactive digital medium for enhancing vocational high school students' understanding of Earth and space science concepts. The use of Stellarium resulted in medium-level learning gains, increased student engagement, and positive learning experiences. These findings underscore the potential of technology-enhanced learning to address conceptual difficulties and motivational challenges in vocational science education.

Recommendations

Teachers are encouraged to integrate Stellarium as a complementary instructional tool accompanied by structured guidance and reflective discussion. Schools should support the adoption of accessible digital learning resources to promote innovation in vocational education. Future research should involve larger samples, comparative experimental designs, and longitudinal analysis to examine long-term impacts on scientific literacy and employability skills.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article belongs entirely to the authors.

Conflict of Interest

* The authors declare no conflict of interest.

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References

Becker, K., & Park, K. (2011). Effects of computer-based simulations on student learning in science. *Journal of Science Education and Technology, 20*(3), 234–245. https://doi.org/10.1007/s10956-010-9231-9

Dewi, J., Widodo, S., & Nursalam, H. (2021). Implementation of technology-enhanced learning in vocational schools in Indonesia. *Journal of Technical Education and Training, 13*(2), 50–62.

Duit, R., & Gropengießer, H. (2015). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 37*(7), 1073–1094. https://doi.org/10.1080/09500693.2015.1040365

Hake, R. R. (1999). Analyzing change/gain scores. *Indiana University*.

Hidayati, A., & Kusumawardhani, I. (2020). Curriculum relevance and vocational school employability. *Jurnal Pendidikan, 20*(1), 45–56.

Keller, J. M. (2010). *Motivational design for learning and performance: The ARCS model approach*. Springer.

Liu, R. G., Ong, P. S., & Subramaniam, S. (2020). The impact of simulation-based learning in physics: A meta-analysis. *International Journal of Science Education, 42*(6), 873–892. https://doi.org/10.1080/09500693.2020.1725718

Nordin, M. B., & Faiz, K. R. (2020). Immersive learning using augmented reality for astronomy education. *Education and Information Technologies, 25*(3), 1637–1656. https://doi.org/10.1007/s10639-019-10027-1

OECD. (2019). *Future of education and skills 2030: OECD learning compass 2030*. OECD Publishing.

Stellarium.org. (2025). *Stellarium astronomy software*. https://stellarium.org

Treagust, D. F., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education, 3*, 297–328. https://doi.org/10.1007/s11422-008-9090-4

Tsai, Y., & Lin, C. (2019). Exploring the effectiveness of digital planetariums for astronomy education. *International Journal of Science and Mathematics Education, 17*, 1265–1284. https://doi.org/10.1007/s10763-018-9907-6

UNESCO. (2017). *Education for sustainable development goals: Learning objectives*. UNESCO Publishing.

Wibisono, A. N., Rachman, A. R., & Purnomo, S. (2020). The use of Stellarium to improve students' understanding of astronomy. *Journal of Physics: Conference Series, 1567*(3), 012045. https://doi.org/10.1088/1742-6596/1567/3/012045

Wulandari, S., & Wibowo, A. (2019). Technical competence, soft skills, and internship experiences toward employability of vocational school graduates. *Jurnal Pendidikan Vokasi, 9*(2), 123–134.

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