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Effectiveness of Stellarium Application in Enhancing Student's Understanding: Astronomy Concepts in Physics Education

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ABSTRACT

Purpose -This study aims to address the challenges of teaching astronomy in higher education, particularly in institutions with limited observational infrastructure and urban light pollution. The purpose of this research is to investigate the effectiveness of Stellarium, a digital planetarium application, in enhancing students' conceptual understanding of astronomy concepts in Physics Education.

Methodology - A quasi-experimental research design was employed, utilizing a pretest-posttest control group format. The sample consisted of 30 undergraduate students enrolled in the astronomy course, who were purposively selected and divided into an experimental group and a control group. The research procedure involved the development of Stellarium-integrated instructional materials, the implementation of teaching interventions, and the administration of pretests and post-tests to assess conceptual understanding. Additional instruments included a questionnaire to capture students' perceptions and documentation of classroom activities. Data were analyzed using paired sample t-tests, independent sample tests, and descriptive statistics.

Findings - The results of the initial and final trials showed a significant increase in the experimental group's understanding of astronomical concepts. In contrast, the control group showed minimal improvement. The findings revealed a significant improvement in the experimental group's test scores, with an average gain of 16.6 points ($p < 0.05$). Students also expressed highly positive perceptions of Stellarium in terms of visual appeal, ease of use, learning motivation, and comprehension of celestial motion. These results suggest that Stellarium is an effective pedagogical tool for enhancing conceptual understanding of astronomy and fostering student engagement.

Contribution- The study contributes to the growing body of research on simulation-based learning and offers practical insights into integrating digital technologies in science education, particularly in resource-constrained institutions. It also offers a model for adapting global digital tools to local educational contexts, thereby supporting curriculum innovation in Indonesian higher education.

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INTRODUCTION

Astronomy is one of the fundamental branches of science that offers insight into the structure, origin, and phenomena of the universe. In the context of higher education, particularly in physics education programs, astronomy is a compulsory course designed to equip students with theoretical knowledge and observational skills related to celestial bodies. However, teaching astronomy poses significant challenges, especially in environments where a lack of facilities, light pollution, and adverse weather conditions constrain direct observation of the night sky.

At Universitas Muslim Nusantara (UMN) Al-Washliyah, the astronomy course has traditionally relied on conventional teaching methods such as lectures and printed materials (Mujib et al., 2024). These methods, while effective for delivering theoretical content, fall short of providing students with the experiential learning needed to fully grasp abstract astronomical concepts (Prasetyo & Arbi, 2024). The absence of observatory infrastructure, combined with the university's urban setting, limits opportunities for real-time sky observations and practical engagement. As a result, students often struggle to understand complex phenomena such as celestial motion, planetary alignment, and star constellations.

Although several studies have explored Stellarium's effectiveness in science education internationally, research focusing on its implementation in Indonesian higher education remains scarce (Maulana & Masturi, 2023). A preliminary search of the Garuda Ristekbrin and SINTA databases in 2023 revealed fewer than 15 peer-reviewed articles focusing on Stellarium in university-level astronomy education in Indonesia, compared to over 200 indexed publications in international databases such as Scopus and Google Scholar. This disparity underscores a significant research gap, particularly in the integration of Stellarium within the curriculum of teacher training institutions in Indonesia (Prima et al., 2017).

While Stellarium offers immersive real-time visual simulations that support conceptual learning, it is not without limitations. Pedagogically, the application may lack interactive feedback features or assessment integration, which are essential for formative evaluation (Khusnani et al., 2022). Technically, it requires moderate computational resources and familiarity with digital interfaces, which may pose challenges in institutions with limited ICT infrastructure or students with low digital literacy (Etriya, 2023) (Habibi et al., 2014). Moreover, the cultural and linguistic localization of Stellarium content remains minimal, making it less accessible to students in rural or non-English-speaking regions in Indonesia. Therefore, a critical understanding of Stellarium's strengths and constraints is crucial to ensure its effective adoption in diverse educational contexts (Mata et al., 2018).

According to UNESCO (2023), digital simulations are vital in transforming science education to meet 21st-century competencies. However, to maximize their impact, these tools must be contextualized within local pedagogical practices and resource constraints. At UMN Al-Washliyah, where the astronomy course faces infrastructural and environmental limitations, Stellarium's virtual simulation capabilities offer a promising but context-dependent solution. This study bridges global insights and local challenges by evaluating the applicability of Stellarium in enhancing astronomy learning within Indonesia's private university ecosystem.

In contrast to outdated policy references such as Soedibyo (2003), recent educational frameworks emphasize the role of immersive digital media in active learning. For instance, Salamah et al. (2023) highlight how visualization tools significantly improve students' grasp of spatial phenomena, while Hirsch & Kelly (2021) report increased engagement and comprehension through Stellarium in undergraduate science courses (Pilendia, 2022)(Mata et al., 2018). By aligning with these contemporary perspectives, this study proposes a grounded, data-driven exploration of Stellarium's potential in Indonesian higher education (Utomo & Madlazim, 2016).

METHODOLOGY

Research Design

This study utilized a quasi-experimental design with a pretest-posttest control group approach (Kuningan et al., 2021). This design was chosen to evaluate the comparative effectiveness of Stellarium-based instruction versus conventional lecture methods in enhancing conceptual understanding of astronomy. To maintain internal validity, the participants were randomly assigned to experimental and control groups after stratification based on their academic profiles. External variables such as prior knowledge, course materials, instructor, and duration of instruction were controlled to ensure homogeneity. Pretest scores were analyzed using an independent sample t-test to assess initial equivalence between groups prior to treatment.

Participants

The study involved 30 undergraduate students enrolled in an astronomy course at a private university in Indonesia. This research involved only 30 undergraduate students. In highly controlled, quantitative experiments, small numbers of participants can still yield statistically meaningful results, especially when the effects being measured are significant and the data variability is low. Using purposive sampling, students who actively participated in the course were selected and equally divided into an experimental group (n = 15) and a control group (n = 15). Although the sample size was limited, it was deemed adequate based on effect size estimations from previous studies on similar interventions, as well as conventional thresholds in educational research (Cohen, 1988). Furthermore, the small sample size was offset by the controlled experimental conditions and high treatment fidelity.

Instruments and Data Collection

Three instruments were used in this study. First, a conceptual understanding test consisting of 20 multiple-choice questions was developed to assess key astronomy concepts, including celestial motion, phases of the moon, and star constellations. Content validity was ensured through expert judgment by two astronomy education specialists, while instrument reliability was confirmed through a pilot test yielding a Cronbach's Alpha coefficient of 0.812.

Second, a Likert-scale questionnaire was administered to measure students' perceptions of Stellarium-based learning. The questionnaire comprised 15 items grouped into five indicators: (1) conceptual clarity, (2) visual appeal, (3) ease of use, (4) motivation to learn, and (5) comprehension of celestial motion. Each item used a 5-point scale ranging from "strongly disagree" to "strongly agree." Content validity was reviewed by instructional media experts, with a reliability score of 0.857.

Third, qualitative documentation included field notes, photographs, screenshots of Stellarium usage, and student reflections collected during learning sessions. These data served to triangulate the findings and provide contextual depth.

Table 1. Research Design

Group	Pretest	Treatment	Post-test post-test
Eksperimental Class	O1	(X1)	O3
Control Class	O2	(X2)	O4

The information is as follows: X1 is Stellarium-based learning, X2 is a Conventional lecture (without Stellarium), O1 is a Pretest Experimental Class, O2 is a Pretest Control, O3 is a Post-testPost-test Experimental Class, and O4 is a Post-testPost-test Control.

The subjects of this study were undergraduate students enrolled in the Astronomy course at the Physics Education Program, Universitas Muslim Nusantara (UMN) Al-Washliyah Medan. A total of 30 students participated in the study during the 2024 academic year. The sample was selected using purposive sampling, focusing on students who were actively attending the astronomy class during the even semester.

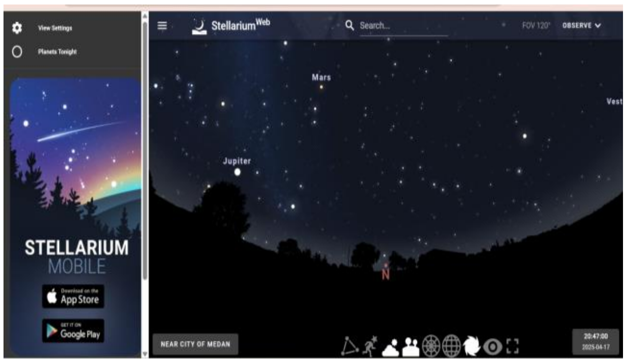
The participants were divided into two groups: an experimental group (15 students) that received instruction using the Stellarium application integrated into the learning activities. The control group (15 students) received instruction through conventional teaching methods, such as lectures, discussions, and textbooks, without the aid of digital simulations.

The selection of students was based on a homogeneous academic background, ensuring that all participants had similar levels of prior knowledge and were taking the same course under the same curriculum. The goal was to reduce confounding variables that could influence learning outcomes. This subject grouping allowed the researchers to compare the impact of technology-assisted instruction (via Stellarium) with traditional instruction in a controlled and measurable manner.

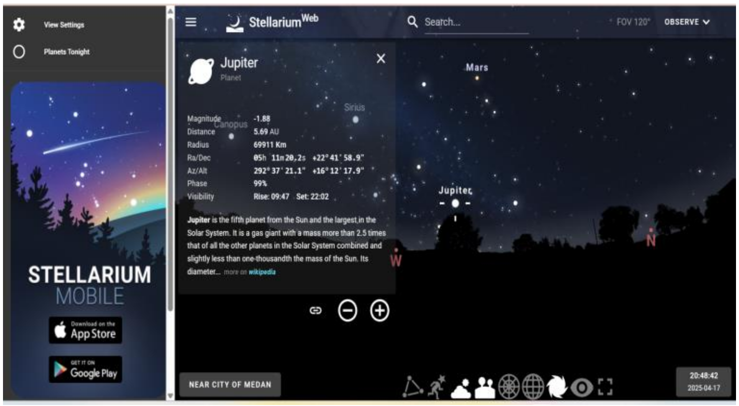
The instruments used in this research were tests and documentation. The tests consisted of a pretest and a post-test containing 20 multiple-choice questions designed to measure students' understanding of key astronomy concepts, including the phases of the moon, celestial motion, and the identification of stars and constellations. These instruments were used to assess students' cognitive achievement before and after the implementation of Stellarium in the experimental group and traditional teaching in the control group. The validity and reliability of the test instruments were ensured through expert judgment and pilot testing, following procedures outlined by Creswell. Furthermore, documentation was used to support qualitative observations and consisted of photographs of learning activities, screenshots of Stellarium usage during class, attendance records, and student performance summaries. These materials were collected throughout the study to provide contextual evidence of the learning process and engagement with Stellarium. The documentation also served to confirm the consistency between instructional activities and learning outcomes.

In this research, the media used to help students understand the learning material is the use of the following physical simulation (Mata et al., 2018) (Zotti & Wolf, 2025):

(a) The appearance of the solar system from the observer's perspective



(b) Changes in the shape of the solar system every hour



(c) The material of each solar system contained in Stellarium

Figure 1. Physical simulation by Stellarium

This combination of instruments enabled the researchers to obtain both quantitative data (from tests) and supportive qualitative insights (from documentation), providing a more comprehensive understanding of Stellarium's effectiveness in astronomy education (Indriani et al., 2024). The study was conducted in three main phases: preparation, implementation, and evaluation.

Preparation is completed when a literature review on technology-based astronomy learning is conducted, instructional materials are developed and integrated with Stellarium, research instruments include post-tests, pretests, student perception questionnaires, and observation sheets, and participants are assigned to experimental and control groups (Zotti et al., 2020). Implementation is done when both groups were assessed to measure baseline understanding of astronomy concepts (pretest), received interactive instruction using Stellarium for virtual astronomical observations and concept exploration (implementation), received traditional classroom lectures without simulation tools (control group), researchers monitored classroom engagement, student interactions, and instructional effectiveness (observations) (Santoso et al., 2024). Evaluation was conducted by administering the assessment to both groups to assess learning outcomes after the instructional intervention. The assessment was also distributed to the experimental group to evaluate students' perceptions of the Stellarium-based learning experience. Paired sample t-tests were used to determine the significance of score improvements within and between groups. Descriptive statistics were used for analyzing questionnaire responses (Choi & Shin, 2022).

Data Analysis

The pretest and post-test consist of 20 multiple-choice questions covering key concepts in astronomy. A five-point Likert scale assesses students' perceptions on five indicators: conceptual understanding, visual appeal, ease of use, motivation to learn, and comprehension of celestial motion. Statistical analyses were conducted using SPSS 25.0. The paired sample t-test was used to compare pretest and post-test post-test scores, while descriptive statistics summarized questionnaire data (Prima et al., 2017). This methodological approach enabled the researchers to rigorously evaluate the impact of Stellarium on conceptual understanding and learner engagement while controlling for potential external variables.

FINDINGS

Student Learning Outcomes

The results of the initial and final trials demonstrated a significant increase in the experimental group's understanding of astronomical concepts. The average score of the initial trial in the experimental group was 57.00. After entering the study using the Stellarium application, student learning outcomes increased to an average of 74.13, with a good range. In contrast, the control group showed minimal improvement. A paired sample t-test and an independent sample t-test confirmed the significance of the score difference in the experimental group, with $p < 0.05$, indicating that Stellarium had a statistically significant impact on student learning. As shown in the SPSS presentation table below :

Table 2. Descriptive Statistics

	N	Range	Min	Max	Mean	Std. Dev	Variance	Skewness		Kurtosis	
								Statistic	Std. Error	Statistic	Std. Error
pretest_exp	15	20	50	70	57.00	6.824	46.571	.892	.580	-.606	1.121
postest_exp	15	31	60	91	74.13	8.476	71.838	.373	.580	-.278	1.121
pretest_con	15	6	50	56	52.93	2.086	4.352	-.062	.580	-1.138	1.121
postest_con	15	6	58	64	60.73	2.086	4.352	.245	.580	-1.096	1.121

Table 2 showed the descriptive statistics reveal notable differences between the experimental and control groups in both the pretest and post-test phases. In the experimental group, the pretest scores ranged from 50 to 70, with a mean of 57.00 and a standard deviation of 6.824, indicating a moderate spread of scores. The distribution was positively skewed (skewness = 0.892), suggesting a tendency for higher scores, while the kurtosis value of -0.606 indicated a slightly flatter distribution compared to normal. After the intervention, the post-test scores in the experimental group increased substantially, ranging from 60 to 91 with a higher mean of 74.13 and a greater standard deviation of 8.476. The skewness decreased to 0.373, indicating the distribution became more symmetric, and the kurtosis value of -0.278 suggested the distribution was closer to normal, though still somewhat flat.

In contrast, the control group showed more stable and narrowly distributed scores. Their pretest scores ranged from 50 to 56, with a mean of 52.93 and a low standard deviation of 2.086, reflecting minimal variation among students. The skewness value of -0.062 indicated an almost symmetrical distribution, while the kurtosis of -1.138 suggested a notably flat distribution. Post-test scores in the control group ranged from 58 to 64, with a mean of 60.73 and the same standard deviation of 2.086, indicating consistent variability. The distribution showed a slight positive skew (skewness = 0.245) and remained platykurtic with a kurtosis of -1.096.

Overall, the experimental group not only showed a more significant increase in average performance from pretest to post-test, but also greater variability in scores, which may reflect the varying levels of impact the intervention had on different students. In contrast, the control group demonstrated a smaller improvement and maintained a more uniform distribution of scores, suggesting limited effect in the absence of the intervention.

Table 3. Descriptive

	Group			Statistic	Std. Error
post_test	Experiment	Mean		74.13	2.188
		95% Confidence Interval for Mean	Lower Bound	69.44	
			Upper Bound	78.83	
		5% Trimmed Mean		73.98	
		Median		74.00	
		Variance		71.838	
		Std. Deviation		8.476	
		Minimum		60	
		Maximum		91	
		Range		31	
		Interquartile Range		12	
		Skewness		.373	.580
		Kurtosis		-.278	1.121
	Control	Mean		60.73	.539
		95% Confidence Interval for Mean	Lower Bound	59.58	
			Upper Bound	61.89	
		5% Trimmed Mean		60.70	
		Median		60.00	
		Variance		4.352	
		Std. Deviation		2.086	
		Minimum		58	
		Maximum		64	
		Range		6	
		Interquartile Range		4	
		Skewness		.245	.580
		Kurtosis		-1.096	1.121

The descriptive statistics for the post-test scores reveal a clear distinction between the experimental and control groups. The experimental group achieved a mean score of 74.13 with a standard error of 2.188, while the control group's mean was considerably lower at 60.73 with a standard error of 0.539. The 95% confidence interval for the mean in the experimental group ranged from 69.44 to 78.83, indicating a wider and higher range of possible average scores, whereas the control group's interval was narrower and lower, between 59.58 and 61.89. This suggests that the experimental group not only performed better on average but also showed more variability in performance.

The median scores for both groups were quite close to their respective means—74.00 for the experimental group and 60.00 for the control group—indicating that the distributions were relatively symmetric. However, the standard deviation and variance further emphasize the contrast in score dispersion: the experimental group had a standard deviation of 8.476 and a variance of 71.838, compared to the control group's much smaller standard deviation of 2.086 and variance of 4.352. The experimental group's scores ranged from 60 to

91, spanning a range of 31 points, while the control group's scores only ranged from 58 to 64, a narrow 6-point range. The interquartile ranges also differ substantially, with the experimental groups at 12 and the control group's at only 4.

In terms of distribution shape, both groups showed slight positive skewness—0.373 for the experimental group and 0.245 for the control group—indicating a mild tendency toward higher scores. The kurtosis values were negative for both groups, with -0.278 for the experimental group and -1.096 for the control group, suggesting flatter distributions than the normal curve. Overall, these statistics indicate that the experimental group not only outperformed the control group in terms of average score but also exhibited a broader and more diverse range of performance outcomes, likely reflecting the effects of the experimental intervention.

Table 4. Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
post_test	Experiment	.111	15	.200*	.983	15	.988
	Control	.171	15	.200*	.917	15	.172

A test for normality is done to determine whether the data is normally distributed or not. No. For testing normality, researchers using SPSS typically set the significance level to 0.05 or 5% (Oktaviani & Notobroto, 2019). This test is used for insufficient samples to produce accurate decisions. As for results, test normality on the class experiment and control cannot be seen in the table. Based on the table above, values on significance on Experimental (0.200) and control (0.200). In the study, this level was used to measure normality, which corresponds to an α value of 0.05 or 5%. If the results obtained exceed α = 0.05 or 5%, then the data indicate a good normal distribution in both the class experiment and the class control.

Table 5. Paired Sample Test

		Paired Differences							
					95% Confidence Interval				
		Mean	Std. Deviation	Std. Error	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	pretest_exp - postest_exp	-17.133	4.190	1.082	-19.453	-14.813	-15.839	14	.000
Pair 2	pretest_con - postest_con	-7.800	.676	.175	-8.174	-7.426	-44.680	14	.000

The paired sample test (paired t-test) is a statistical test used to compare the means of two measurements taken from the same individual or object under two different conditions or at two different times (Derrick, 2022). From the table, post-test pretest experiment - post-test has a mean value (17.133), std. Deviation (4.190), std. Error means (1.082) while the pretest control - post-test control has a mean value (7.800), std. Deviation (0.676), std. Error mean (0.175).

These results highlight the effectiveness of Stellarium in presenting abstract astronomical concepts through interactive and visual simulations. By allowing students to observe celestial motion virtually and in real time, the application bridged the gap caused by the lack of observational facilities on campus (Ruknanto et al., 2023). The improvement in test scores suggests that students were better able to grasp difficult content, such as planetary rotation, star positioning, and seasonal changes in the night sky (Access, 2021).

In addition to test scores, student perceptions were also collected using a Likert-scale questionnaire. The results showed a consistently positive response across five measured aspects: Conceptual understanding (average score: 4.0), Visual appeal (4.4), Learning motivation (4.1), ease of use (4.3), and understanding of celestial motion (4.0).

DISCUSSION

Implications

The combination of improved test scores and favorable student perceptions indicates that Stellarium can serve as a high-impact educational tool in astronomy courses, particularly in institutions without access to telescopes or observatories (Riski et al., 2025). Its use supports a shift toward technology-enhanced learning in science education and aligns with modern pedagogical practices that emphasize active, visual, and student-centered instruction (Ayomi & Ali, 2025). This study offers novelty in the context of integrating real-time planetarium simulation technology in physics learning, especially astronomy. While many previous studies have only discussed the use of multimedia or learning videos, this study specifically evaluates the effectiveness of Stellarium as a learning aid based on its accurate night sky simulation that can be directly manipulated by students (Almeqbaali et al., 2022).

The Stellarium application allows students to observe stars, planets, and other astronomical phenomena without weather or time constraints, thus supporting an exploration-based learning approach (Maulana & Masturi, 2023). They stated that astronomical simulations can improve mastery of spatial and temporal concepts in physics. Additionally, the use of Stellarium contributes to the development of students' critical and analytical thinking skills, as they are encouraged to observe, predict, and explain astronomical phenomena more accurately (Marina & Prima, 2020).

Theoretically, this study enriches the literature on the effectiveness of simulation-based learning in astronomy education. The results of this study can be a basis for teachers and curriculum developers to integrate the Stellarium application into astronomy learning in schools. Furthermore, this study reinforces the notion that a technology-based learning approach can bridge the gap between abstract concepts and students' fundamental understanding of natural phenomena (Campbell et al., 2021).

The limitations of this study include the limited number of participants and the scope of the material studied. This study was conducted in only one school, with a limited number of students, and covered only a few basic astronomical concepts, including the movement of celestial bodies, moon phases, and the solar system (Chastenay et al., 2023). Another limitation lies in the technical skills of students in operating the application, which requires initial training (Nuryadin et al., 2025). Further research is recommended to encompass a broader population and incorporate additional variables, such as learning motivation, problem-solving ability, and long-term achievement, in order to gain a deeper understanding of astronomical concepts. In addition, comparative studies between different types of astronomical simulation applications will also provide deeper insights (Access, 2021).

The findings also highlight the potential of digital simulations in overcoming infrastructural limitations and enhancing access to quality education in urban and resource-constrained contexts (Campbell et al., 2021). Based on these outcomes, the integration of Stellarium into the formal astronomy curriculum is strongly recommended (Prima et al., 2017).

CONCLUSION

Based on the research results obtained from data analysis, normality tests, independent sample tests, and paired sample tests, the following conclusions can be drawn: The application of Stelarium has an influence. Student learning outcomes have a significant impact on stimulating students' ability to understand learning material, thereby enhancing student learning outcomes. After being given treatment after the pretest, the comparison of learning outcomes post-test was different, namely at the post-test (74.13) higher than at the pretest (57.00). The impact of this research will make it easier for students and teachers in the teaching and learning process, where teachers can provide direct practice related to the material being taught, and students can understand easily through Stellarium simulations, which can be used anywhere and anytime;

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REFERENCE

Access, O. (2021). Utilization of Stellarium-based activity : its effectiveness to the academic performance of Grade 11 STEM strand students Utilization of Stellarium-based activity : its effectiveness to the academic performance of Grade 11 STEM strand students. *Journal of Physics: Conference*. https://doi.org/10.1088/1742-6596/1835/1/012082

Almeqbaali, M., Ouhbi, S., & Fares, R. (2022). Empirically Evaluated Digital Solutions in Astronomy Education for Children and Adolescents Systematic Literature Review. *Digital Solution In Astronomy Education*.

Ayomi, G., & Ali, A. (2025). Peningkatan Keterlibatan Dan Berpikir Kritis Mahasiswa Calon Guru Sekolah Dasar Melalui Pemanfaatan Stellarium Dalam Pembelajaran Bumi Dan Antariksa. *Jurnal Pendidikan : Kajian Dan Implementasi*, *7*(2), 32–48.

Campbell, K. T., Ph, D., Harris, S. T., & Ed, D. (2021). Teachers' Perceptions of Principals' Supportive Behavior during COVID-19 *Journal of Education and Human Development*, *10*(1), 92–101. https://doi.org/10.15640/jehd.v10n1a8

Chastenay, P., Cormier, É., Lachance, C., Richard, J., & Richer, J. (2023). PD Days Under the Moon : Teaching Lunar Phases to In-Service Teachers by Doing Astronomy Like Astronomers Do and its Impact on Their Students ' Learning. *Astronomy Educational Journal*, *03*(1), 1–14. https://doi.org/10.32374/AEJ.2023.3.1.037ra

Choi, Y., & Shin, D. (2022). Middle School Students' Characteristics of Spatial Ability in Earth Science Activity using Orienteering. *Journal of The Korean Earth Science Society*, *6692*(5), 647–658. https://doi.org/https://doi.org/10.5467/JKESS.2022.43.5.647

Derrick, B. (2022). Review of the partially overlapping samples framework : Paired observations and independent observations in two samples. *The Quantitative Methods for Psychology*, *18*(1), 55–65. https://doi.org/10.20982/tqmp.18.1.p055

Etriya, R. (2023). Pemanfaatan Stellarium Dalam Pembelajaran IPA Untuk Meningkatkan Motivasi Belajar Siswa Kelas VI SDN 1 Dorokandang. *Jurnal Pendidikan, Sosial Da Humaniora*, *2*(3), 4–5.

Habibi, M., Waskito, S., & Masitoh, D. F. (2014). *Penggunaan Media Stellarium Untuk Meningkatkan Kemampuan Kognitif Dan Aktivitas Belajar Ipa Fisika Siswa Kelas Ixb Smp N 14 Surakarta Pada Materi Sistem Tata Surya*. *5*, 165–172.

Indriani, R., Khasanah, K., Sejati, S. S., Aprilia, D. D., & Aryanti, D. (2024). Efektivitas penerapan Stellarium Sebagai Media Pembelajaran Astronomi Terhadap Pemahaman Konsep Siswa Sekolah Dasar Dan Menengah Pertama Dalam Menentukan Waktu Shalat Maghrib. *Pendas : Jurnal Ilmiah Pendidikan Dasar*, *09*. https://doi.org/https://doi.org/10.23969/jp.v9i2.14964

Khusnani, A., Jufriansah, A., Wahyuningsih, W., Fitri, M., Rahman S., N. H. A., Yanto, Y., Subandi, Y. K., & Sulastri, E. (2022). Pemanfaatan Aplikasi Stellarium dan Alat Peraga Astronomi NASE (Network for Astronomy School Education) sebagai Pembelajaran Etnoastronomi. *Surya Abdimas*, *6*(4), 657–663. https://doi.org/10.37729/abdimas.v6i4.2114

Kuningan, N., Aditiany, V., Pratiwi, T., Aditiany, V., & Pratiwi, T. (2021). Pengaruh Media Pembelajaran Macromedia Flash Terhadap Hasil Belajar Siswa. *Equilibrium: Jurnal Penelitian Pendidikan Dan Ekonomi*, *18*(02), 13–20. https://doi.org/https://doi.org/10.25134/equi.v18i2.4420

Marina, R., & Prima, E. C. (2020). Stellarium is an Interactive Multimedia Tool to Enhance students' Understanding and Motivation in Learning About the Solar System. *EAI*. https://doi.org/10.4108/eai.12-10-2019.2296343

Mata, S., Astronomi, K., & Yogyakarta, U. N. (2018). *Tutorial Penggunaan Stellarium (Software Astronomi)*.

Maulana, M. I., & Masturi, M. (2023). Stellarium-Assisted Celestial Coordinate Learning to Enhance Students' Concept Comprehension and Digital Literacy. *Jurnal Penelitian Pembelajaran Fisika*, *14*(1), 1–8. https://doi.org/10.26877/jp2f.v14i1.14926

Nuryadin, A., Sulaeman, N. F., Fahrur, T., Tandra, R., Sari, E., & Putri, A. (2025). Pelatihan Perangkat Lunak Skyportal sebagai Aplikasi Observasi Astronomi bagi Siswa SMA di Samarinda. *Madaniya*, *6*(1), 205–213. https://doi.org/https://doi.org/10.53696/27214834.1115

Oktaviani, M. A., & Notobroto, H. B. (2019). Perbandingan Tingkat Konsistensi Normalitas Distribusi Metode. *Jurnal Biometrika Dan Kependudukan*, 127–135.

Pilendia, D. (2022). *Stellarium sebagai Media Pembelajaran Fenomena Astronomi: Kajian Literatur*. *8*(1), 525–532. https://doi.org/10.5281/zenodo.5899734

Prima, E. C., Putri, C. L., & Sudargo, F. (2017). Applying Pre and Post-Role-Plays Supported by Stellarium Virtual Observatory to Improve Students' Understanding of Learning Solar System. *Journal of Science Learning*, *1*(1), 1. https://doi.org/10.17509/jsl.v1i1.8708

Riski, Y., Surabaya, U. N., & Huda, M. N. (2025). Aplikasi Media Pembelajaran Stellarium untuk Meningkatkan Hasil Belajar Siswa pada Materi Tata Surya kelas VI Sekolah Indonesia Davao , Filipina. *METODIK DIDAKTIK : Jurnal Pendidikan Ke-SD-an 20(2)*, *February*. https://doi.org/10.17509/md.v20i2.79667

Ruknanto, A. M., Fatmawati, & Akib, F. (2023). Komparasi Software Stellarium Dan Accurate Times Dalam Penentuan Waktu Salat Duhur. *Hisabuna Jurnal Ilmu Falak*, *4*, 1–13. https://doi.org/https://doi.org/10.24252/hisabuna.v4i1.36131

Santoso, R., Samsudin, A., Sinaga, P., & Kohar, E. S. (2024). Development of Student Worksheet Assisted by Stellarium Website Through Design-Thinking Framework. *Indonesian Journal of Mathematics and Natural Science Education*, *5*(2). https://doi.org/10.35719/mass.v5i2.160

Utomo, P., & Madlazim. (2016). Pengembangan Perangkat Pembelajaran Inkuiri Terbimbing Menggunakan Software Stellarium Untuk Meningkatkan Keterampilan Proses Sains Siswa Pokok Bahasan Tata Surya. *Jurnal Inovasi Pendidikan Fisika (JIPF)*, *05*(03), 268–272.

Zotti, G., Hoffmann, S. M., Wolf, A., Chéreau, F., & Chéreau, G. (2020). The Simulated Sky : Stellarium for Cultural Astronomy Research. *Journal of Skyscape Archaeology, JSA 6.2*, *2* (2020), 221–258. https://doi.org/https://doi.org/10.1558/jsa.17822

Zotti, G., & Wolf, A. (2025). *Stellarium 25 . 1 User Guide*.