



Research Article

Effectiveness Of Pop-Up Books On Astronomy Proficiency Among Grade IX Learners

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Abstract

Grounded in constructivist learning theory, this study investigated the impact of pop-up books as interactive instructional materials on the astronomy proficiency of Grade IX learners. While traditional methods remain the standard, this research sought to determine if tactile, three-dimensional media could significantly enhance academic achievement in the study of constellations. A quasi-experimental pre-test/post-test design was utilized with a sample of 60 students (n=30 per group). The experimental group was taught using custom-designed pop-up books, while the control group received conventional instruction. Data were analyzed using paired-samples t-tests to measure within-group growth and independent samples t-tests to compare between-group performance. Results showed no significant difference in pre-test scores, establishing baseline equivalence. Although both groups demonstrated significant improvement from pre-test to post-test ($p < .05$), no statistically significant difference was found in the post-test scores or mean gain scores between the experimental and control groups. These findings suggest that while pop-up books are a viable supplementary tool, they do not provide a superior statistical advantage over traditional methods for improving proficiency. Practically, the results imply that educators may utilize pop-up books to diversify instructional media without compromising academic standards, though they should not be viewed as a replacement for established pedagogical practices.

Keywords: Pop-up books; Astronomy education; Interactive learning materials; Academic achievement; Quasi-experimental design

1. Introduction

In the contemporary educational landscape, mastering astronomy poses a unique challenge for Grade IX learners. While the subject is inherently fascinating, it requires a high degree of spatial visualization and the ability to grasp abstract, large-scale phenomena that cannot be observed directly in a traditional classroom setting (Yair, 2018). This often results in significant "cognitive gaps," where students struggle to translate two-dimensional textbook diagrams into three-dimensional mental models, ultimately leading to lower academic proficiency and poor retention of astronomical concepts.

As educators seek to improve student outcomes, the integration of multimodal learning tools—specifically pop-up books—has emerged as a compelling instructional strategy. Unlike static materials, pop-up books provide a dynamic, three-dimensional representation of celestial mechanics. By physically manipulating paper engineering, students engage in a tactile exploration of space, which translates abstract orbital paths and planetary scales into tangible, measurable learning experiences (Kazeykina, 2024). This study is grounded in Constructivist Learning Theory, which posits that learners actively build knowledge through experiences rather than passively absorbing information. Pop-up books operationalize this by serving as "scaffolds" that bridge the gap between concrete observation and abstract theory. Furthermore, this approach aligns with Cognitive Load Theory; by externalizing complex spatial relationships into 3D pop-up structures, the extraneous cognitive load is reduced, allowing the learner's working memory to focus on the essential conceptual schemas of astronomy. This multimodal interaction—combining visual, tactile, and linguistic input—strengthens the neural pathways associated with conceptual understanding and long-term proficiency (Pouw et al., 2014).

While broad research exists on the general benefits of interactive media in science education, a specific void remains regarding the quantifiable impact of paper-engineered interactive tools on standardized proficiency scores in astronomy. Previous studies (e.g., Raffa, 2020) have frequently focused on qualitative "engagement" or "student interest," yet there is a lack of empirical evidence demonstrating how these tools translate into measurable academic achievement (pretest vs. posttest performance).

Most existing literature addresses digital simulations or software-based modeling; however, these resources are often inaccessible in resource-constrained environments like Alabel National High School. There is a critical need to investigate whether low-cost, high-engagement physical tools like pop-up books can effectively bridge the proficiency gap in secondary science education. This research aims to evaluate the effectiveness of pop-up books in enhancing astronomy proficiency among Grade IX students at Alabel National

High School. By analyzing the shift in pretest and posttest scores, this study seeks to determine if the transition from 2D representations to 3D interactive models leads to a statistically significant gain in academic achievement. The findings will provide a foundation for integrating tangible, interactive instructional designs into the science curriculum, offering a scalable solution to improve conceptual mastery in complex scientific domains.

2. Materials and Methods

2.1. Research Design

This study will employ a quasi-experimental, non-equivalent control group design. As noted by Raiyn (2016), this design is optimal for educational research where random assignment of individual students is impractical due to existing classroom structures. The study utilizes an experimental group, which will be taught using pop-up books as a primary instructional scaffold, and a control group, which will receive traditional lecture-based instruction using standard 2D textbook visuals. To address the conceptual focus of the study, astronomy proficiency—defined as the students' ability to understand, apply, and analyze astronomical concepts—will be the primary dependent variable. This will be measured through standardized pre-test and post-test instruments to quantify academic achievement and gain scores.

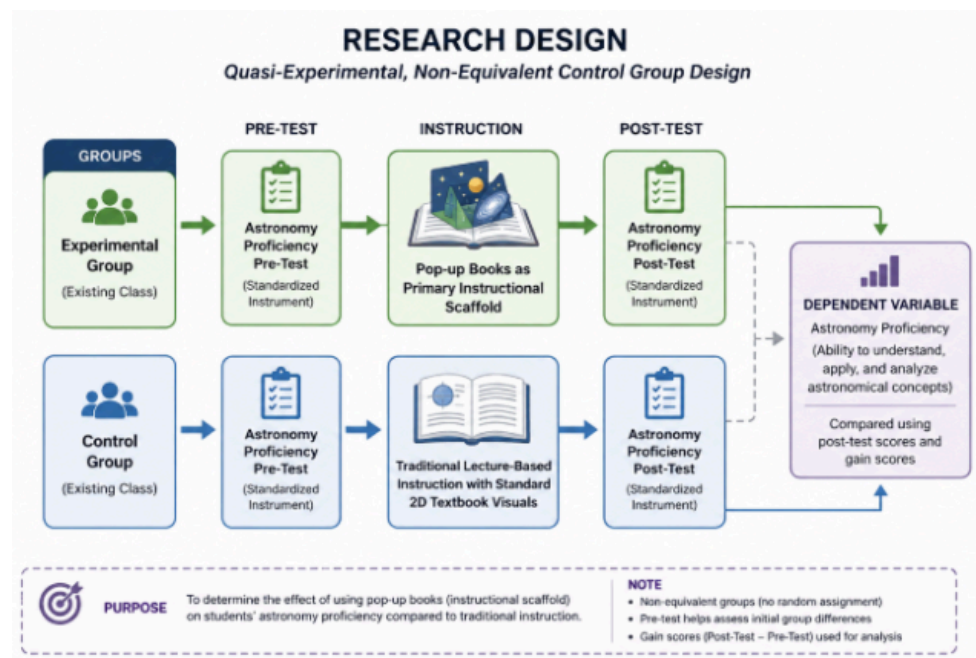


Figure 1. Research Design

2.2. Respondents and Sampling Procedure

The research will involve Grade IX learners enrolled in the Special Program in the Arts (SPA) at Alabel National High School during the 2025–2026 academic year. A purposive sampling technique will be utilized to select two intact sections currently undertaking the astronomy unit within the science curriculum. This approach ensures that the respondents have the requisite background and academic focus necessary for meaningful participation in the study. To maintain the integrity of the data, specific inclusion and exclusion criteria have been established. Participation is limited to regularly enrolled Grade IX SPA students who have not previously covered the specific astronomy modules being tested. Conversely, students will be excluded if they have excessive absences—defined as missing more than 20% of the intervention—or if they have previously enrolled in advanced science electives that might skew the results.

Due to the specialized nature of the target group, certain limitations of scope must be acknowledged. Because the sample is drawn exclusively from a single program at one institution, the findings primarily offer internal validity rather than broad external application. Consequently, the generalizability of the findings to the wider population of Grade IX learners may be limited, a factor that will be thoroughly addressed in the discussion of the research results.

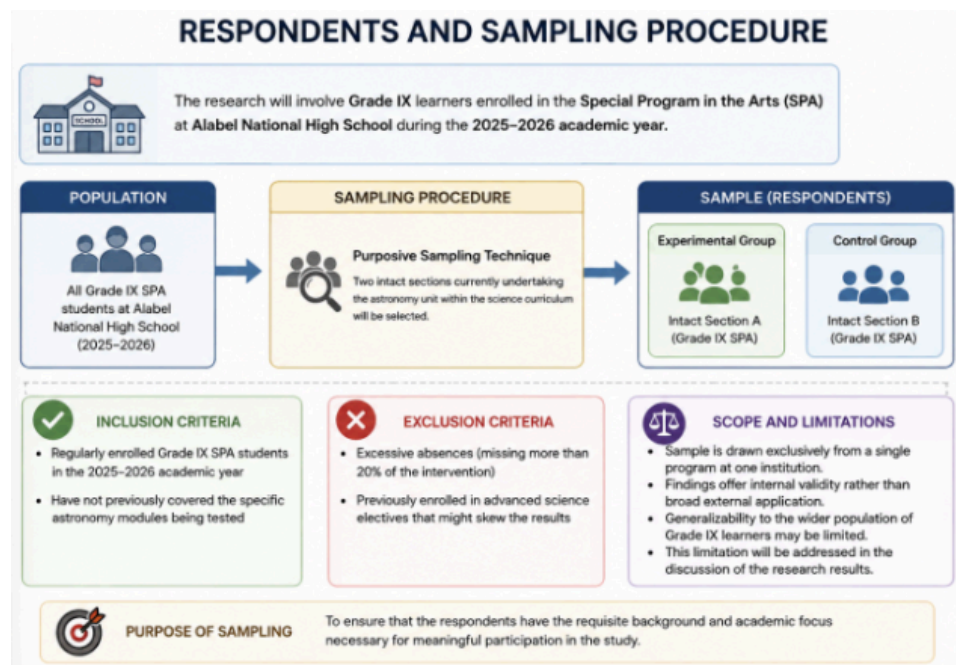


Figure 2. Research Respondents and Sampling Procedure

2.3. Research Instruments

To ensure the rigorous measurement of astronomy proficiency, three primary tools will be utilized in this study. The central instrument is the Astronomy Proficiency Test (APT), a 40-item multiple-choice assessment focusing on Earth's motion, eclipses, and planetary systems. To guarantee content validity, the APT was subjected to expert validation by a panel of three Master Teachers in Science. Furthermore, a pilot study was conducted with a non-participating Grade IX section ($n=30$) to refine the instrument before actual implementation. The reliability of the APT was confirmed through statistical analysis, yielding a Cronbach's Alpha coefficient of 0.84, which indicates high internal consistency. To ensure the quality of individual questions, an item analysis was performed to verify that difficulty and discrimination indices remained within the acceptable ranges of 0.30 to 0.70. This ensures that the test differentiates between various levels of student understanding and provides a stable measurement of academic achievement.

In addition to the proficiency test, a Multimodal Learning Perception Survey and a standardized Instructional Framework will be employed. The survey utilizes a 5-point Likert scale to capture student perceptions of the pop-up books' utility, serving as a secondary data point to triangulate with proficiency scores. Meanwhile, the Instructional Framework consists of a detailed lesson plan for both groups to ensure the core content remains identical, isolating the medium of delivery—3D pop-up models versus 2D standard visuals—as the sole variable.

2.4. Data Collection and Analysis

The data collection process follows a systematic three-phase structure designed to measure the impact of the intervention on astronomy proficiency. In Phase I (Pre-Intervention), both the experimental and control groups will be administered the Astronomy Proficiency Test (APT) pre-test. This initial assessment is critical for establishing a baseline of prior knowledge and ensuring the comparability of the two groups before the experimental variable is introduced. During Phase II (Intervention), the groups will undergo different instructional treatments over a two-week period. The experimental group will engage in daily 60-minute sessions utilizing pop-up books, which allow for the tactile manipulation of paper models of the solar system. Concurrently, the control group will receive the same curriculum delivered through traditional instructional methods, such as lectures and standard 2D visual aids, to maintain a controlled comparison of the delivery mediums.

In the final stage, Phase III (Post-Intervention), both groups will complete a post-test, which consists of a shuffled version of the APT to assess learning gains. Following this, the experimental group will participate in a perception survey designed to gather qualitative context regarding their performance and their experience with the interactive materials. All collected

data will then be prepared for consolidation and rigorous statistical evaluation. The analysis of the quantitative data will be performed using SPSS version 27, beginning with assumptions testing to ensure the validity of statistical inferences through the Shapiro-Wilk test for normality and Levene's Test for homogeneity of variance. Inferential statistics, specifically Independent Samples t-tests and Paired Samples t-tests, will be used to compare post-test scores between groups and measure within-group gains, respectively. Finally, the practical significance will be determined by calculating Cohen's d effect size, with all results reported at a 95% confidence interval and a significance level of $\alpha = 0.05$.

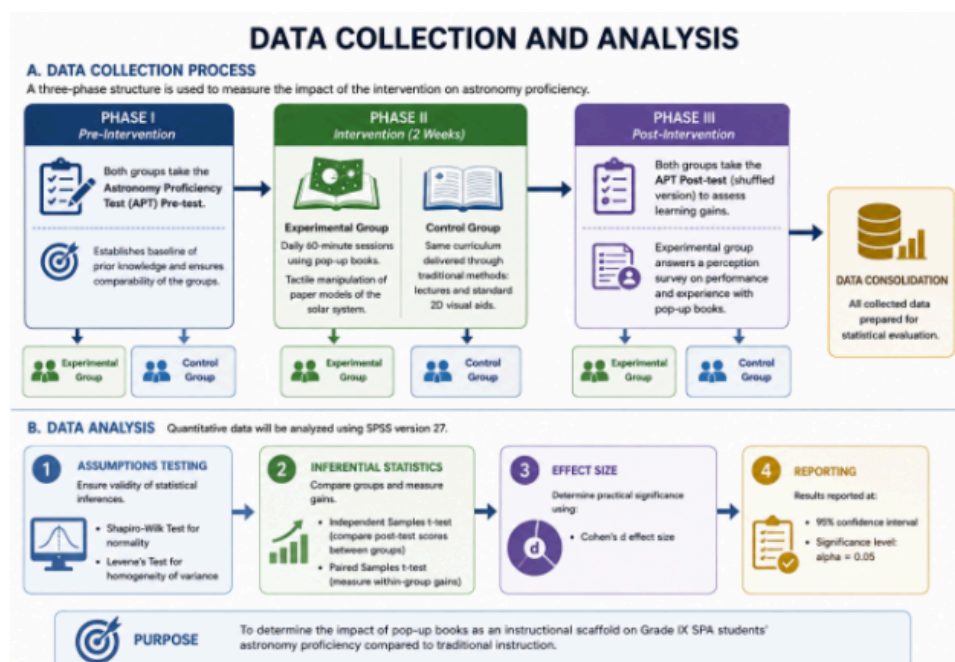


Figure 3. Data Collection and Analysis

2.5. Ethical Considerations

This research on the utilization of pop-up books to enhance astronomy proficiency among Grade IX learners is guided by a set of ethical considerations designed to ensure the protection and respect of all participants involved. The research protocol and related documents were submitted for formal review and granted a Certificate of Exemption from review by the Mindanao State University-General Santos Institutional Ethics Review Committee (MSU-General Santos IERC).

The study is officially approved under Approval No. 037-2025-MSUGSC-IERC with Study Protocol Code 2025-059-SR. The

approval was granted on 13 February 2025 and remains valid until 13 February 2026.

Prior to participation, all participants (and their guardians, where applicable) will be provided with comprehensive information regarding the research purpose, procedures, potential risks, and benefits. Consent forms will be clear and accessible, allowing participants to ask questions and withdraw from the study at any time without consequence.

Special attention will be given to the welfare of the Grade IX learners involved in the study. This includes creating a safe learning environment during the research activities and ensuring that the content of the pop-up books is age-appropriate and educationally relevant.

In accordance with investigator responsibilities, the study will abide by the provisions of the Data Privacy Act of 2012. Participants' identities and personal information will be kept anonymous, and any identifying information will be removed from the research findings. Only aggregated data will be reported to ensure that individual participants cannot be identified. Participation in the study will be entirely voluntary. Participants will be informed that they can refuse to participate or withdraw from the study at any stage without any penalty or loss of benefits.

After the completion of the study, participants will be debriefed to provide additional information about the research, including the importance of their contributions and the potential implications for learning strategies in astronomy. The research design aims to minimize any potential risks or discomfort to participants, as the study involves non-sensitive information. This includes careful consideration of the instructional methods and materials used to ensure they are engaging and supportive of learners' needs.

By adhering to these ethical considerations, the research will respect and protect the rights and welfare of participants while contributing valuable insights into effective learning strategies in astronomy.

3. Results

This section presents the analysis and interpretation of the data gathered to determine the proficiency level in Astronomy among Grade IX learners using pop-up books.

3.1. Proficiency level of students before and after the study

This study described the level of mastery of the students in Astronomy using pop-up books as an intervention tool before and after the study. The results are shown in the table below.

Table 1. Proficiency level of students before and after the study

Scores	%	Control Group				Experimental Group				Description
		Pretest		Posttest		Pretest		Posttest		
		f	%	f	%	%	f	%		
27-30	90-100%	0	0	7	20	0	7	20	Advanced	
23-26	75-89%	0	0	17	48.57	0	0	17	48.57	Proficient
18-22	60-74%	4	11.43	5	14.29	4	11.43	5	14.29	Developing
15-17	50-59%	8	22.86	2	5.71	8	22.86	2	5.71	Emerging
Below 15	Below 50%	23	65.71	4	11.43	23	65.71	4	11.43	Beginning
Total	100%	35	100%	35	100	35	100	35	100	
Mean		12.17		21.91		13.06		22.49		
SD		3.24		3.14		3.45		5.11		
Description		Beginning		Developing		Beginning		Developing		

Table 1 reveals differences in the levels of proficiency in constellations among Grade IX students in both the control and experimental groups before and after the study. In the control group, the mean score increased from 12.17 (SD = 3.24) in the pretest to 21.91 (SD = 3.14) in the posttest, indicating a shift from the Beginning to the Developing proficiency level. This improvement suggests progress in student proficiency of constellation concepts. Initially, a large majority of students—23 (65.71%)—were classified under the Beginning level, and 8 students (22.86%) were at the Emerging level. By the posttest, only 4 students (11.43%) remained in the Beginning category, while 2 students (5.71%) were at Emerging, 5 (14.29%) reached the Developing level, 17 (48.57%) advanced to Proficient, and 7 (20%) achieved Advanced proficiency. This distribution reflects a broad improvement across all levels.

In contrast, the experimental group, which utilized pop-up books as an intervention tool, demonstrated comparable yet slightly higher gains. The mean score rose from 13.06 (SD = 3.45) in the pretest to 22.49 (SD = 5.11) in the posttest, similarly moving from the Beginning to the Developing proficiency level. Before the intervention, 23 students (65.71%) were in the Beginning category, 8 (22.86%) were Emerging, and 4 (11.43%) were Developing. After the intervention, none of the students remained in the lowest levels without change: only 4 students (11.43%) were still in the Beginning level, 2 (5.71%) were at

Emerging, 5 (14.29%) remained in the Developing group, while a larger number of students—17 (48.57%)—reached Proficient and 7 (20%) achieved Advanced proficiency.

Overall, the results suggest that pop-up books were, to an extent, effective intervention for enhancing students' proficiency in constellation. Although both groups showed meaningful gains in their posttest performance, the experimental group demonstrated a slightly higher mean score and a consistent pattern of upward movement into higher proficiency levels. This indicates that using pop-up books as a visual and interactive learning aid helped facilitate deeper understanding and retention of constellation concepts among Grade IX learners.

3.2. Difference between the pretest mean scores of the control and experimental group

This study also ascertained the significance of the difference between the pretest mean scores of the control and experimental group. The results are shown in the table below.

Table 2. Difference between the pretest mean scores of the control and experimental group

Groups	mean	SD	t-statistic	p-value	Remarks	Decision
Control	12.17	3.24	1.11	0.271	Not significant	Accept Ho
Experimental	13.06	3.45				

Table 2 shows that there is no significant difference between the pretest mean scores of the control and experimental groups prior to the implementation of pop-up books as an intervention ($t = 1.11$, $p = 0.271 > 0.05$).

The control group had a mean score of 12.17 with a standard deviation of 3.24, while the experimental group had a slightly higher mean of 13.06 with a standard deviation of 3.45. Since the p-value of 0.271 is greater than the 0.05 significance level, the result confirms the absence of a meaningful difference in the baseline proficiency levels of the two groups. Hence, the first null hypothesis (H_0), which states that there is no significant difference between the pretest scores of the two groups, is accepted.

This indicates that both groups began the study with relatively similar levels of proficiency in constellations. Such equivalence ensures that any significant differences found in the posttest outcomes can be more confidently attributed to the effect of the pop-up book intervention rather than to pre-existing disparities in student performance.

3.3. Difference between the posttest mean scores of the control and experimental group

This study also figured out the significance of the difference between the posttest mean scores of the control and experimental group. The results are shown in the table below.

Table 3. Difference between the posttest mean scores of the control and experimental group

Groups	mean	SD	t-statistic	p-value	Remarks	Decision
Control	21.91	3.14	0.56	0.575	Not Significant	Accept Ho
Experimental	22.49	5.11				

Table 3 shows that there is no significant difference between the posttest mean scores of the control and experimental groups after the implementation of the pop-up book intervention ($t = 0.56$, $p = 0.575 > 0.05$). The control group obtained a mean score of 21.91 with a standard deviation of 3.14, while the experimental group had a slightly higher mean score of 22.49 with a standard deviation of 5.11. Since the p-value of 0.57 exceeds the 0.05 significance level, the result indicates that the difference in posttest performance between the two groups is not statistically significant. Therefore, the second null hypothesis (H_0), which states that there is no significant difference between the posttest scores of the control and experimental groups, is accepted. This implies that while both groups showed improvement in their proficiency levels in constellation, the observed difference between them cannot be attributed with confidence to the use of pop-up books as an intervention. Other factors may have contributed to the outcome, and the intervention alone did not produce a statistically measurable advantage.

3.4. Difference between pretest and posttest mean scores of the control group

Through this study, it is apparent that the significance of the difference between the pretest and posttest mean scores of the control group. The results are shown in the table below.

Table 4. Difference between pretest and posttest mean scores of the control group

Groups	mean	SD	t-statistic	p-value	Remarks	Decision
Pretest	12.17	3.24	-12.78	0.000	Significant	Reject Ho
Posttest	21.91	3.14				

Table 4 reveals a significant difference between the pretest and posttest mean scores of the control group in relation to their proficiency level in constellation ($t = -12.78$, $p = 0.000 < 0.05$). The mean score of the control group increased from 12.17 with a standard deviation of 3.24 in the pretest to 21.91

with a standard deviation of 3.14 in the posttest. Since the p-value of 0.000 is less than the 0.05 significance level, the result indicates that the improvement in scores is statistically significant. Therefore, the third null hypothesis (H_0), which states that there is no significant difference between the pretest and posttest scores of the control group, is rejected.

This suggests that the learners in the control group made substantial gains in their constellation proficiency over the course of the study, even without the specific use of pop-up books. The improvement may be attributed to general instructional methods or other contributing factors present during the study.

3.5 Difference between pretest and post-test mean scores of the experimental group

This confirms earlier indications that the significance of the difference between the pretest and posttest mean scores of the experimental group. The results are shown in the table below.

Table 5. Difference between pretest and posttest mean scores of the experimental group

Groups	mean	SD	t-statistic	p-value	Remarks	Decision
Pretest	13.06	3.45	-9.05	0.000	Significant	Reject H_0
Posttest	22.49	5.11				

Table 5 reveals a significant difference between the pretest and posttest mean scores of the experimental group in relation to their proficiency level in constellation ($t = -9.05$, $p = 0.000 < 0.05$). The mean score of the experimental group increased from 13.06 with a standard deviation of 3.45 in the pretest to 22.49 with a standard deviation of 5.11 in the posttest. Since the p-value of 0.000 is less than the 0.05 significance level, the result confirms that the improvement in scores is statistically significant. Hence, the fourth null hypothesis (H_0), which states that there is no significant difference between the pretest and posttest scores of the experimental group, is rejected. This indicates that the use of pop-up books as an intervention had a considerable positive impact on enhancing the constellation proficiency levels of Grade IX learners. The significant improvement suggests that pop-up books were beneficial instructional tools in facilitating proficiency of constellation concepts.

3.6 Difference between the mean gain scores of the control and experimental group

This emphasizes the significance of the difference between the mean gain scores of the control and experimental group. The results are shown in the table below.

Table 6. Difference between the mean gain scores of the control and experimental group

Groups	mean	SD	t-statistic	p-value	Remarks	Decision
Control	9.74	3.63	-0.34	0.737	Not significant	Accept Ho
Experimental	9.43	4.16				

Table 6 shows that there is no significant difference between the mean gain scores of the control and experimental groups ($t = -0.34$, $p = 0.737 > 0.05$). The control group obtained a mean gain score of 9.74 with a standard deviation of 3.63, while the experimental group had a slightly lower mean gain of 9.43 with a standard deviation of 4.16. Since the p-value of 0.737 is greater than the 0.05 significance level, the result confirms that the observed difference in gain scores is not statistically significant. Hence, the fifth null hypothesis (H_0), which states that there is no significant difference in the mean gain scores between the control and experimental groups, is accepted. This suggests that while both groups showed improvement from pretest to posttest, the use of pop-up books as an intervention did not result in a statistically significant advantage over the traditional method in terms of overall gain in constellation proficiency.

My Theorem or hypothesis 1.

The hypothesis of this study was tested at 0.05 level of significance.

H01: There is no significant difference in the pre-test mean scores between the control group and the experimental group.

H02: There is no significant difference in the post-test mean scores between the control group and the experimental group.

H03: There is no significant difference in the pre-test and post-test scores of the control group.

H04: There is no significant difference in the pre-test and post-test scores of the experimental group.

H05: There is no significant difference in the mean gain scores of the control group and the experimental group.

My Proof of Theorem or hypothesis 1.

The hypotheses of this study were tested using a 0.05 level of significance to determine whether meaningful differences exist between and within the control and experimental groups.

For H01, the computed p-value (0.271) is greater than 0.05, indicating no significant difference between the pre-test mean scores of the control and experimental groups. Thus, H01 is accepted.

For H02, the p-value (0.575) exceeds the 0.05 level of significance, showing no significant difference between the post-test mean scores of both groups. Therefore, H02 is accepted.

For H03, the p-value (0.000) is less than 0.05, indicating a significant difference between the pre-test and post-test scores of the control group. Hence, H03 is rejected.

Similarly, for H04, the computed p-value (0.000) is below 0.05, confirming a significant difference between the pre-test and post-test scores of the experimental group. Therefore, H04 is rejected.

Finally, for H05, the p-value (0.737) is greater than 0.05, indicating no significant difference in the mean gain scores between the control and experimental groups. Thus, H05 is accepted.

Overall, the findings reveal that while both groups demonstrated significant improvement over time, there were no statistically significant differences between the groups in terms of pre-test scores, post-test scores, and mean gain scores. This implies that the intervention using pop-up books contributed to learning but did not produce a significantly greater effect compared to the traditional method of instruction.

4. Discussion

The findings reveal that while both instructional approaches led to significant improvements in student performance, the use of pop-up books did not yield a statistically superior outcome in astronomy proficiency compared to traditional instruction.

4.1. Interpretation of Proficiency and Mastery

The transition of both groups from a "Beginning" to a "Developing" level indicates that Grade IX learners are responsive to structured astronomy curriculum regardless of the specific medium.

The high percentage of students reaching "Proficient" and "Advanced" levels suggests that the core educational content was effectively delivered in both settings. The slightly higher mean in the experimental group (22.49 vs 21.91) may suggest a positive, albeit non-significant, trend toward the benefits of tactile proficiency in understanding spatial concepts like planetary motion.

4.2. Theoretical and Practical Implications

From a theoretical standpoint, these results suggest that while interactive materials like pop-up books align with constructivist principles of active learning, they may function as a supplemental rather than a transformative tool for immediate proficiency gains. The lack of a significant difference in gain scores ($p=0.737$) implies that traditional visuals—when paired with effective teacher instruction—remain a robust method for teaching abstract science concepts.

4.3. Educational Significance

The practical significance of this study lies in its validation of both methods as effective for classroom use. While pop-up books did not produce a statistically significant "advantage" in test scores, they provide an alternative instructional path that may support different learning styles or increase classroom variety.

For educators, this means that while pop-up books are effective tools for learning, their implementation should be balanced with existing traditional methods that have also proven successful in achieving proficiency goals. Future research might explore whether these interactive tools provide better results for long-term retention rather than immediate academic proficiency.

5. Conclusion and Recommendation

Based on the statistical analysis and findings of the study, the following conclusions are drawn:

Baseline Parity: The lack of a significant difference between the pre-test mean scores of the control and experimental groups indicates that students possessed nearly identical levels of prior knowledge in astronomy before the study began. This confirms that the groups were well-matched for a comparative study.

Instructional Effectiveness: Both the traditional lecture method and the pop-up book intervention were beneficial in significantly increasing student proficiency. The significant growth within both groups from pre-test to post-test confirms that both 2D and 3D visual scaffolds support academic achievement in Grade IX astronomy.

Comparative Impact: While the experimental group demonstrated a slightly higher post-test mean score, the difference was not statistically significant. This implies that the observed advantage of pop-up books cannot be attributed with statistical confidence over the traditional method for immediate proficiency gains.



Learning Gains: There was no significant difference in the mean gain scores between the two groups. Therefore, while pop-up books are a positive instructional tool, they did not provide a statistically superior advantage over traditional lecture methods in terms of overall gain in astronomy proficiency.

Refinement of Effectiveness Claims: Pop-up books are a reasonable supplemental instructional resource that supports learner proficiency; however, they do not produce statistically significant improvements in astronomy proficiency compared to high-quality traditional instruction within a short-term intervention period.

Recommendations

To further enhance the quality of science instruction and build upon the findings of this study, the following recommendations are offered:

For Science Teachers:

Tactile Integration: Utilize pop-up books as a supplemental tool specifically for kinesthetic learners or to introduce complex spatial concepts, such as planetary orbits and eclipses, where 3D visualization is critical.

Instructional Variety: Maintain a balance between traditional lectures and interactive materials to prevent "cognitive overload" and keep students engaged through diverse instructional delivery methods.

For Curriculum Planners:

Resource Development: Invest in the design and production of low-cost, paper-engineered interactive materials for topics that require high spatial reasoning, ensuring these resources are available for schools with limited digital access.

Teacher Training: Conduct workshops on the creation and pedagogical integration of multimodal tools like pop-up books into the existing science curriculum to enhance classroom interaction.

For Future Researchers:

Extended Intervention Duration: Future studies should implement the intervention over a longer period (e.g., a full quarter) to determine if interactive tools contribute more significantly to long-term retention rather than immediate test performance.

Expanded Sampling: Replicate the study with a larger and more diverse

sample size across multiple schools to improve the external validity and generalizability of the findings beyond a specialized program.

Mixed-Methods Approach: Incorporate qualitative measures, such as focus group discussions or structured interviews, to capture deeper insights into how interactive tools influence student motivation and conceptual change.

Digital Integration: Explore the comparative or combined effectiveness of physical pop-up books and 3D digital simulations/Augmented Reality (AR) to determine which medium best supports astronomy proficiency in the modern classroom.

6. Limitations of the Study

This section defines the boundaries of the research, identifying the specific areas covered by the investigation as well as the inherent constraints that may impact the generalizability of the findings.

6.1. Scope and Delimitations

The primary focus of this study is to evaluate the impact of pop-up books on the astronomy proficiency of Grade IX learners at Alabel National High School. The investigation specifically targets the academic year 2025–2026 and utilizes a quasi-experimental design to compare a control group receiving traditional instruction with an experimental group utilizing 3D paper-engineered materials. The curriculum is delimited to core astronomical concepts such as Earth's motion, eclipses, and planetary systems as outlined in the Grade IX science standards. Furthermore, the study is restricted to students enrolled in the Special Program in the Arts (SPA), focusing on whether tactile, multimodal tools can bridge conceptual gaps in abstract scientific domains.

6.2. Limitations of the Study

While the research was conducted with rigorous ethical and methodological oversight, several inherent limitations must be acknowledged:

Non-Randomization: Due to the use of a quasi-experimental design, participants were not randomly assigned to groups; instead, intact school sections were used, which may introduce selection bias or affect the equivalency of the groups despite pre-test baseline checks.

Small Sample Size: The study was conducted with a limited number of respondents (n=70) from a single specialized program at one institution, which significantly restricts the external validity and generalizability of the findings to larger or more diverse student populations.

Short Intervention Duration: The instructional intervention was carried out over a two-week period, which may be sufficient to observe immediate academic gains but is likely too short to measure profound shifts in cognitive development or deep conceptual mastery.

Absence of Delayed Retention Testing: Data collection was restricted to immediate post-test results. Consequently, the study cannot determine whether the use of pop-up books leads to better long-term retention of astronomical concepts compared to traditional methods.

Teacher Effect: Although a standardized instructional framework was used, the inherent differences in teaching style, delivery, or classroom management between the control and experimental sessions could act as confounding variables.

Single-School Setting: Because the research was conducted solely at Alabel National High School, local factors such as specific school resources, classroom environment, and student demographics may have influenced the outcomes in ways that are not representative of other educational settings.

Measurement Scope: The study focused exclusively on academic proficiency through standardized testing and did not include a mixed-methods follow-up to explore qualitative changes in student motivation or behavioral engagement.

Supplementary Details

Supplementary Materials & Data availability statement (If Applicable):
Not applicable.

Author Contributions:

Research Adviser, Almera M. Sales, MST; Validators, Rolicel A. Tribunalo, MTI, Ana G. Pingoy, MT, Jason A. Guanzon, MST Physics; Ethical Review Committee, Thucydides L. Salunga, PhD; Statistician, Rhumer S. Lanojan, MAED.

Funding:

This research received no external funding.

Institutional Review Board Statement:

The study is officially approved under Approval No. 037-2025-MSUGSC-IERC with Study Protocol Code 2025-059-SR. The approval was granted on 13 February 2025 and remains valid until 13 February 2026.



Informed Consent Statement:

The study adhered to ethical standards in research involving human participants. Prior to data collection, participants were provided with a comprehensive informed consent form detailing the purpose of the study, procedures, potential risks and benefits, confidentiality measures, and their rights, including voluntary participation and the option to withdraw at any time without

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Conflicts of Interest:

The authors declare no conflict of interest. The researchers affirm that the conduct of the study, including its design, data collection, analysis, interpretation of results, and preparation of the manuscript, was carried out independently and without any influence from external organizations or funding bodies. No financial or personal relationships that could have inappropriately influenced the outcomes of this research were identified.

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