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Effect of Solar System Scope Application as an Instructional Material on Students' Solar System Academic Achievement and Self-Efficacy

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Abstract

This study explored the impact of the Solar System Scope (SSS) application on Grade 11 students' academic achievement and self-efficacy towards the solar system concepts within their Physical Science subject. The study employed a quasi-experimental pretest-posttest design to compare the academic achievement of students who received instruction through traditional methods with those who received instruction through the SSS application. The data showed that students who were taught using the SSS application attained significantly higher levels of academic achievement in their posttest. Thus, findings revealed a significant improvement in academic achievement among students engaged with the SSS program compared to those following traditional instruction methods, as suggested by the significant difference in their pretest and posttest scores. The study also demonstrated a significant difference between the posttest scores of the SSS group and the conventional instruction group, indicating the effectiveness of the SSS application in enhancing students' understanding of solar system concepts. Furthermore, students were found to have a strong belief in their capability to accomplish activities and overcome difficulties while using the application, as indicated by their self-efficacy towards agreement with all of the statements related to self-efficacy ($M = 3.36$). Finally, the examination of the relationship between students' academic achievement in learning solar system concepts and their self-efficacy post-SSS application usage indicates an absence of significant correlation.

Subject Areas

Education, Physical Science, Planetary Science, Astronomy

Keywords

Solar System Scope Application, Academic Achievement, Self-Efficacy, Physical Science Education, Quasi-Experimental Design

1. Introduction

Technology is turning students into active learners in a dynamic, technology-driven environment. Technology in education is growing in the 21st century, leading to studies on its effects on student participation and achievement. Interactive whiteboards, educational apps, and multimedia resources for different learning styles make classes more engaging and successful [1].

In particular, Augmented Reality (AR) applications have emerged as powerful tools for enhancing students' academic performance. Research indicates that AR can significantly improve students' understanding of complex concepts in science education [2]. Studies emphasize the growing importance of technological literacy as a core 21st-century skill, highlighting the need to investigate how specific digital tools, such as AR applications, contribute to educational success [3]. The evolving role of technology in education also aligns with the principles of "Industrial Revolution 4.0", which underscores the importance of critical thinking and problem-solving [4].

Despite advancements, gaps remain in aligning science education with societal needs, particularly in enhancing students' self-efficacy [5] [6]. This study aims to address this gap by examining the impact of the Solar System Scope application on academic achievement and self-efficacy. Previous research has demonstrated that discovery learning models supported by applications like Solar System Scope can effectively enhance students' conceptual understanding and engagement [7] [8]. While prior research has focused on various applications, this study narrows its focus to provide a detailed evaluation of the Solar System Scope tool.

By investigating how the Solar System Scope application affects both academic achievement and self-efficacy, this study aims to investigate whether utilizing the Solar System Scope application can improve student academic achievement and self-efficacy in learning about solar system concepts. This study sought to answer the following questions:

1) How may the students' academic achievement in learning the solar system concepts be described before and after the use of the Solar System Scope application?

2) How may the students' self-efficacy be described after the use of the Solar System Scope application?

3) Is there a significant difference among the scores of students in the following:

a) Pretest and posttest results of the group that was taught using the traditional method;

b) Pretest and posttest results of the group that was taught using Solar Scope application; and

c) Posttest results of the group that was taught using the traditional method and the group that was taught using Solar Scope application.

4) Is there a significant relationship between the students' academic achievement in learning solar system concepts and their self-efficacy after using the Solar System Scope application?

2. Methodology

The study was conducted at Malacañang National High School, located in Brgy. Malacañang, Santa Rosa, Nueva Ecija. This rural school, with limited exposure to advanced technology, provided an ideal setting to assess the impact of integrating technology into educational practices. The study showed that students who used interactive digital tools, including AR and simulations, demonstrated higher levels of interest and engagement in science topics compared to those using traditional methods [9]. By introducing the Solar System Scope (SSS) application, the researchers explored how this innovative tool influenced students' academic performance and self-efficacy in learning solar system concepts. The study took place over four weeks, from the first week to the last week of April 2024, aligning with the school calendar and the coverage of the solar system topic in the Physical Science subject.

The study employed a quasi-experimental design in which students were divided into two groups: one group was taught using traditional instructional methods, while the other group was taught using the Solar System Scope application. The traditional methods used for the control group included teacher-led lectures supplemented with printed visual aids and textbook-based discussions. These approaches adhered to the standard teaching practices commonly employed at the school. Both groups underwent a pretest and a posttest to assess academic achievement. The quasi-experimental design was selected because it allowed researchers to control the application of the treatment (SSS) while maintaining a natural classroom setting, enhancing the study's validity.

The subjects of the study were Grade 11 students enrolled in the Humanities and Social Sciences (HUMSS) curriculum at Malacañang National High School during the second semester of the 2023-2024 academic year. The total population consisted of 50 students from two sections: 25 students were taught using traditional methods, and 25 students were taught using the SSS application.

The study employed purposive sampling to select students who met specific criteria. First, students were chosen based on their lack of prior exposure to the Solar System Scope application to focus on their initial interaction with the app. Second, the researchers stratified the sample by grouping students according to their academic grades. This ensured that each group included students with similar academic performance levels, reducing potential bias caused by variations in prior knowledge or ability. This method allowed for a fair and balanced evaluation of the app's usability and effectiveness.

The Solar System Scope (SSS) application served as a multimedia tool for teaching the solar system. It provided an interactive learning experience through auditory and visual elements such as models, text, sounds, and videos. A 30-item multiple-choice test was administered to both groups as a pretest and posttest to assess their academic achievement in understanding solar system concepts. The test was developed based on the Department of Education's Most Essential Learning Competencies (MELCs) for Physical Science and validated with a Cronbach's alpha of 0.785, indicating reliable internal consistency.

After the posttest, students who used the SSS application completed an 8-item self-efficacy questionnaire. This instrument had a Cronbach's alpha of 0.79, showing acceptable reliability for measuring self-efficacy [4]. The lesson plans, structured according to the 7 E's format, guided both groups through the study of the solar system. Activity sheets were distributed to further engage students and assess their understanding of the material. The 30-item multiple-choice test was constructed following a Table of Specifications (TOS), ensuring alignment with the MELCs and various cognitive levels based on Bloom's Taxonomy.

The researchers began by obtaining approval from the school principal and consent from parents or legal guardians. Both groups took the pretest at the start of the study to assess their prior knowledge. After four weeks, the experimental group used the SSS application, while the control group followed traditional methods. After the intervention, both groups completed the posttest, and the experimental group also completed the self-efficacy questionnaire. All tests and activities were supervised by the researchers to ensure consistency in administration.

The study employed descriptive statistics (frequency, mean, percentage) to describe the academic achievement and self-efficacy of the participants. A paired sample t-test was used to compare pretest and posttest scores. An independent sample t-test was conducted to compare posttest scores between the two groups at a 0.01 significance level. Furthermore, Pearson's correlation coefficient (r) was calculated to examine the relationship between students' academic achievement and self-efficacy when using the SSS application. This correlation measured the strength and direction of the relationship between these variables

3. Results and Discussions

3.1. Achievement of the Students Who Were Taught Using the Traditional Way of Instruction in Learning Solar System Concepts

The achievement of students taught using traditional instruction methods showed minimal improvement. In the pretest, the mean score was 13.92 (SD = 5.16), while the posttest mean score increased slightly to 14.84 (SD = 3.87). The p-value of 0.217 indicated no statistically significant difference in scores ($p > 0.05$). Showing this result, there was a small shift towards higher scores, and the majority of students remained within the satisfactory range (see **Table 1**).

Table 1. Achievement of the students who were taught using the traditional way of instruction in learning solar system concepts.

Scores	Verbal Description	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
25 - 30	Outstanding	0	0	1	4
19 - 24	Very satisfactory	3	12	4	16
13 - 18	Satisfactory	14	56	13	52
7 - 12	Fairly satisfactory	5	20	7	28
0 - 6	Did not meet expectations	3	12	0	0
	Total	25	100%	25	100%

3.2. Achievement of the Students Who Were Taught Using the Solar System Scope Application in Learning Solar System

In contrast, the group utilizing the Solar System Scope Application (SSS App) demonstrated significant improvements. The pretest mean score was 15.40 (SD = 4.21), while the posttest mean soared to 19.16 (SD = 3.01). A t-value of −6.471 and a p-value of.000 indicates a highly significant difference ($p < 0.01$). This illustrates the marked improvement, with 48% of students achieving a very satisfactory level in the posttest compared to 28% in the pretest (see Table 2).

Table 2. Achievement of the students who were taught using the solar system scope application in learning solar system.

Scores	Verbal Description	Pretest		Posttest	
		Frequency	Percentage (%)	Frequency	Percentage (%)
25 - 30	Outstanding	0	0	0	0
19 - 24	Very satisfactory	7	28	12	48
13 - 18	Satisfactory	11	44	13	52
7 - 12	Fairly satisfactory	7	28	0	0
0 - 6	Did not meet expectations	0	0	0	0
	Total	25	100%	25	100%

3.3. Students' Self-Efficacy after the Use of the Solar System Scope Application

Self-efficacy assessments after using the SSS app showed high agreement levels across various statements, with mean ratings ranging from 3.24 to 3.44 and an overall average of 3.36, indicating an "Agree" interpretation. The highest agreement was noted for statements suggesting motivation, optimism, independence, and confidence, supporting the efficacy of the SSS app in enhancing student engagement during learning activities. However, despite the high self-efficacy ratings, no significant correlation was observed between self-efficacy and academic performance. This outcome suggests that while the app positively influences students' perceptions of their abilities, other factors beyond self-efficacy, such as prior knowledge, study habits, or instructional quality, might play an important role in determining academic success. Further research is needed to explore these dynamics (see Table 3).

3.4. Difference in the Achievement of Students Who Were Taught Using the Traditional Method of Instruction

The comparison of students' academic achievement in learning solar system concepts before and after traditional instruction showed no significant improvement. The pretest mean score was 13.92 (SD = 5.16), while the posttest mean score was 14.84 (SD = 3.87), resulting in an average difference of −0.92 and a non-significant p-value of 0.217. This indicates that traditional methods did not effectively enhance students' understanding, possibly due to limited engagement and reliance on PowerPoint presentations. Educators should consider alternative instructional approaches for better learning outcomes (see Table 4).

Table 3. Students' self-efficacy after the use of the solar system scope application.

Statements	Mean	Verbal Description
1. I will be able to finish most of the activities assigned to me using the Solar System Scope Application.	3.44	Agree
2. When facing difficulties using Solar System Scope Application, I am confident that I will accomplish them.	3.24	Agree
3. In doing activities involving the Solar System Scope Application, I believe that I can achieve outcomes that are important to me.	3.24	Agree
4. I believe I can succeed at most of the activities using the Solar System Scope Application that I set my mind to accomplish.	3.36	Agree
5. I will be able to overcome many challenges in doing activity using the Solar System Scope Application successfully.	3.44	Agree
6. I am confident that I can perform effectively on the activities related to the Solar System Scope Application.	3.44	Agree
7. Compared to others, I can excel in most of the activities using the Solar System Scope Application.	3.32	Agree
8. Even when using the Solar System Scope Application is tough, I can perform quite well.	3.40	Agree
Overall Mean	3.36	Agree

Legend: Strongly agree (3.46 - 4.00); Agree (2.50 - 3.45); Disagree (1.50 - 2.49); Strongly disagree (1.00 - 1.49).

Table 4. Difference in the achievement of students who were taught using the traditional method of instruction.

Group That Was Taught Using Traditional Way of Instruction	MEAN	SD	Mean Difference	df	t	p-value
Pretest scores	13. 92	5.16	−0.92	24	−1.268	0.217^{ns}
Posttest scores	14. 84	3.87				

Note: ns = no significant difference (p > 0.05).

3.5. Difference in the Achievement of Students Who Were Taught Using the Solar System Scope Application in Learning Solar System Concepts

The group using the Solar System Scope (SSS) application showed significant improvement in academic achievement, with a pretest mean score of 15.40 (SD = 4.21), increasing to 19.16 (SD = 3.01) in the posttest. The mean difference was −3.76, with a t-value of −6.471 and a highly significant p-value of 0.000. This indicates that the SSS app effectively enhanced students' understanding of the Solar System (see Table 5).

3.6. Difference in the Achievements of the Two Groups in Learning Solar System Concepts after Conducting Traditional Instruction and Using Solar System Scope

The performance comparison between the two instructional methods revealed a significant difference favoring the SSS app group. The mean difference was −4.32 with a t-value of −4.406 and a p-value of 0.000, indicating that the SSS app significantly outperformed traditional instruction (see Table 6).

3.7. Relationship between the Students' Academic Achievement in Learning the Solar System Concepts and Their Self-Efficacy after Using the Solar System Scope Application

This finding implied that the use of the Solar System Scope application may have improved students' academic outcomes in learning solar system concepts without having a substantial effect on their self-efficacy. Educators and curriculum designers should have noted that while the app could enhance students' understanding of solar system concepts, it might be the subject (see Table 7).

This lack of correlation may be influenced by factors such as prior knowledge,

Table 5. Difference in the achievement of students who were taught using the solar system scope application in learning solar system concepts.

Group Taught Using SSS App	Mean	SD	Mean Difference	df	t	p-value
Pretest scores	15.40	4.21	−3.76	24	−6.471	0.000**
Posttest scores	19.16	3.01				

Note: **Highly significant at 0.01 level (2-tailed).

Table 6. Difference in the achievements of the two groups in learning solar system concepts after conducting traditional instruction and using solar system scope.

Groups	N	Mean	SD	MEAN Difference	df	t	p-value
Traditional	25	14.84	3.87	−4.32	45.256	−4.406	0.000*
SSS App	25	19.16	3.01				

Note: *Highly significant at 0.01 level (2-tailed).

Table 7. Relationship between the students' academic achievement in learning the solar system concepts and their self-efficacy after using the solar system scope application.

Academic Achievement	Self-Efficacy	
	r	p-value
	−0.107	0.801^{ns}

Note: ns = no significant difference (p > 0.05).

where students with prior familiarity may achieve high scores without increased confidence, and the learning environment, where limited engagement or collaboration, could hinder self-efficacy. Additionally, teacher support in the form of encouragement, guidance, and constructive feedback may have been insufficient to boost students' confidence alongside their academic performance.

These findings, aligned with other studies, show that self-efficacy could be influenced by a variety of factors beyond academic achievement. The study emphasized that self-efficacy was shaped by mastery experiences, vicarious experiences, verbal persuasion, and physiological states [10]. In this case, although the application may have improved mastery experiences, it appeared to have had little impact on self-efficacy. A study on the use of technology in online classes found that self-efficacy does not significantly affect students' academic performance. Despite high levels of self-efficacy, it did not influence their academic outcomes. The study recommended strengthening the learning environment to maximize students' experiences and improve performance [11].

4. Conclusion

There has been a significant improvement in students' academic achievement in understanding the solar system after utilizing the Solar System Scope application. This suggests the application may be effective in enhancing learning outcomes. Differences in engagement and motivation were observed between the two groups. Students who used the Solar System Scope application demonstrated higher levels of engagement, showing increased motivation, optimism, and confidence, as indicated by their self-efficacy assessments. However, this higher engagement did not lead to a significant overall improvement in self-efficacy compared to students who did not use the Solar System Scope application. This suggests that while the app improved engagement, students who did not use the app did not show a notable difference in motivation or self-efficacy, highlighting the need for additional strategies to enhance self-efficacy across both groups. There is a significant difference among the scores attained by the two groups in their pretest and posttest about solar system concepts (see **Appendix**), highlighting the superiority of interactive digital tools in teaching solar system concepts. Additionally, there is a significant relationship between academic achievement and self-efficacy, but there is an absence of statistically significant correlation. This suggests that while the Solar System Scope application effectively improves academic outcomes, its influence on self-efficacy is not evident. Based on these conclusions, future research could explore strategies to enhance self-efficacy alongside the application of interactive digital tools.

Conflicts of Interest

The authors declare no conflicts of interest.

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Appendix

Pretest and Posttest Assessments in Physical Science

Direction: Carefully read each question and all answer choices before encircling the most accurate response. Choose the option that best aligns with the information provided or implied in the question.

1. The Sun is the center of the Solar System. Which of the following is the primary composition of the Sun?

   a) Hydrogen and helium　b) Methane and nitrogen
   c) Carbon dioxide and oxygen　d) Water and ice

2. The temperature on this planet changes significantly compared to the others. Which of the following planets is the innermost and smallest planet of the Solar System?

   a) Venus　b) Mercury　c) Mars　d) Earth

3. Which of the following causes Venus to be inhospitable?

   a) Lack of atmosphere　b) Cold temperatures
   c) Dense atmosphere and runaway greenhouse effect　d) High volcanic activity

4. What is the structure form of Earth's internal composition?

   a) Atmosphere, lithosphere, hydrosphere
   b) Crust, mantle, outer core, inner core
   c) Tectonic plates, atmosphere, lithosphere
   d) Crust, hydrosphere, mantle

5. Which planet has two small moons named Phobos and Deimos?

   a) Mars　b) Jupiter　c) Saturn　d) Neptune

6. How is Saturn's composition different from Jupiter's?

   a) Saturn has a solid surface, while Jupiter does not.
   b) Jupiter is less dense than Saturn.
   c) Saturn has prominent rings, while Jupiter does not.
   d) Saturn has a higher percentage of hydrogen.

7. Which unique feature sets Uranus apart from other gas giants in our solar system?

   a) Its bright and noticeable ring system.
   b) The way it tilts in one direction, making it spin on its side.
   c) It's a massive collection of moons, with Titan being the biggest.
   d) It has a thick atmosphere mostly made up of hydrogen and helium.

8. When was Uranus discovered, and who made the discovery?

   a) 1761, Galileo Galilei　b) 1781, William Herschel
   c) 1846, Johannes Kepler　d) 1877, Percival Lowell

9. Which feature of Neptune is most noticeable in terms of color?

a) Reddish surface b) Greenish hue
c) Vivid blue color d) Dark brown clouds

10. How does the Moon influence Earth?

a) Causes earthquakes b) Creates tidal movements
c) Influences atmospheric pressure d) Causes solar eclipses

11. Imagine you were planning a virtual trip using the Solar System Scope app and you wanted to focus on Mars. What engaging features or tools would you use to learn more about the red planet's surface and moons?

a) Zoom and rotate functions b) Sound effects and music
c) Text-based information panels d) Bright color schemes

12. As part of an educational project, you are tasked with creating a 3D model that accurately represents the unique ring system of Saturn. What specific details and characteristics would you incorporate into your model to ensure accuracy and educational value?

a) Varying ring thickness and composition b) Colorful lighting effects
c) Abstract shapes and patterns d) Rapid motion animations

13. If a new moon orbiting Neptune is discovered, describe the criteria and examinations astronomers could use to confirm and identify it.

a) Size, color, and distance from Neptune
b) Sound emissions and atmospheric conditions
c) Surface temperature and weather patterns
d) Magnetic field strength and composition

14. Let's say you are in charge of making a teaching game for the Solar System Scope app that is all about how the Moon affects the tides. What kinds of interactive features would you use to show and describe how gravitational forces affect the moves of the tides on Earth?

a) Drag-and-drop puzzle pieces b) Real-time tide animations
c) Background music and ambient sounds d) Quiz-style pop-up questions

15. You were selected to propose a Venus visit to study its extreme circumstances as a space scientist. List the most critical scientific and technological tools your spaceship needs to study Venus's surface and atmosphere.

a) Video devices with extended lenses
b) Shields that don't get damaged by heat and infrared spectrometers
c) Audio recorders and sensors that measure the air pressure
d) Graphical user interfaces and touch screens

16. What makes Earth unique among the planets in our solar system?

a) It has the highest number of moons.
b) It is the smallest terrestrial planet.
c) It is the only planet with a predominantly gaseous composition.
d) It supports a diverse range of life forms.

17. Why is Earth often referred to as the "Blue Planet"?

a) Due to its small size compared to other planets.
b) Because it has a predominantly blue surface.
c) It has a thick layer of sulfuric acid clouds.
d) It is the only planet with liquid water on its surface.

18. Which factor contributes to the importance of Earth for sustaining life?

a) Its extreme temperatures. b) The presence of a magnetic field.
c) Lack of atmosphere. d) Rapid rotation on its axis.

19. How long does it take for the Moon to go around the Earth once?

a) 24 hours b) 27 days c) 59 days d) 365 days

20. What role do the other seven planets play in supporting life on Earth?

a) They contribute to Earth's gravitational pull.
b) They provide resources for human consumption.
c) They protect Earth from asteroid impacts.
d) They have no impact on life on Earth.

21. Which of the following is the central object of our solar system, comprising 99.86% of its mass?

a) Sun b) Jupiter c) Mercury d) Saturn

22. Which planet in our solar system experiences extreme changes in temperature and is closest to the Sun?

a) Sun b) Jupiter c) Mercury d) Saturn

23. Which planet, similar in size to Earth, is known for its hot, dense atmosphere and sulfuric acid clouds?

a) Mars b) Venus c) Jupiter d) Saturn

24. What is Earth's only natural satellite that influences Earth's tides?

a) Luna b) Mars c) Titan d) Moon

25. Which is the largest gas giant in our solar system, characterized by a gaseous composition and lacking a solid surface?

a) Jupiter b) Saturn c) Uranus d) Neptune

26. Which planet is recognized for its reddish surface caused by iron oxide?

a) Mars b) Venus c) Jupiter d) Saturn

27. The sixth planet in our solar system, known for its prominent rings and shepherd moons. Which of the following is described?

    a) Sun b) Jupiter c) Mercury d) Saturn

28. Which planet, known as a gas giant, was discovered in 1781 by William Herschel with a cyan color due to methane absorption?

    a) Mars b) Earth c) Uranus d) Venus

29. How does the Moon's gravitational pull cause the ocean tides on Earth to rise and fall?

    a) Tidal Movements b) Solar Flares
    c) Earthquakes d) Aurora Borealis

30. Considering Saturn's characteristics, if you were explaining to someone why Saturn is less dense than Jupiter, one would emphasize a specific feature.

    a) Strong magnetic field b) Thick atmospheric layers
    c) Prominent rings d) Intense storms