International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 13, No. 3, 2026, pp. 205-213.

ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

Effectiveness of Virtual Reality Simulations on Basic Science Process Skills of School Students

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Abstract

Building strong science process skills is really important because it helps students in school to watch, sort, measure, guess, plan, and share information about science. Traditional teaching in the classroom often doesn't give students much chance to work with the idea-based and hands-on parts of science. Using VR simulations is one way to make learning better by letting students interact and get deeply involved. This study looks into how well VR simulations can help VIII standard students develop their science process skills in school. The experiment utilized quasi-experimental research design with pre-test and post-test for the two groups. This design included 64 eighth graders who were equally divided into two groups consisting of 32 participants each. While the first group was taught through virtual reality simulation created by the researcher, the other group was taught using traditional teaching methods. The level of comprehension of basic science skills including observation, classification, measurement, inference, prediction, and communication was measured via test with 48 questions. The comparison was performed using statistical analysis to determine differences between the two groups and within them. The effect size was measured using Cohen's d. Results from the pre-test indicated the absence of a significant difference between those participants who were taught using VR technology and those who were not ($t = 0.059$, $p = .953$).The participants who were not taught using VR technology did not demonstrate any significant changes from the pre-test to the post-test ($t = 0.065$, $df = 30$, $p = .949$; Cohen's $d = 0.012$), whereas the group of participants who were exposed to VR demonstrated significant improvement as a result of using the technology ($t = 9.737$, $df = 30$, $p < .001$; Cohen's $d = 1.75$).At the same time, results from the post-test indicated significant differences between the two groups ($t = 8.058$, $df = 30$, $p < .001$; Cohen's $d = 2.02$).Thus, the results suggest that the utilization of VR simulations can

DOI: 10.71086/IAJSE/V13I3/IAJSE13108
Received: 30 May, 2026/Revised: 08 July 2026/Accepted: 17 August 2026/Published: 15 September 2026

significantly facilitate learning of basic skills in science and can become an efficient tool for supporting standard science courses. Further studies are required with larger samples, longer periods of using the technology and measures of retention.

Keywords: Virtual Reality, Science Process Skills, School Students, Science Education, Immersive Learning, Educational Technology.

Introduction

Some basic skills in science include looking closely, grouping things, measuring, making guesses, predicting outcomes, and sharing findings. These skills are important because they help students take part in real science activities. Learning these skills in school helps students not just remember facts, but also learn by asking questions and exploring. However, usual classroom activities may not be enough for students to fully grasp difficult ideas or practice hands-on learning in a safe and controlled setting.

Virtual Reality is a digital world where students can interact with objects, perform actions, and experience different situations as part of their learning. In science classes, Virtual Reality has the ability to offer experiences that are hard to do in a regular classroom, especially when it comes to understanding and practicing complex ideas that are hard to see or grasp. Hence, the study of the effectiveness of VR simulations in developing science process skills would be important in identifying how new educational technologies would complement traditional classroom practices.

The main thing this study adds to what know is that it tested a VR simulation to see if it helps VIII standard students improve their basic science process skills. The research compared students who learned using VR with those who learned through traditional methods. It used a quasi-experimental approach with pre and post tests to measure the effect of both teaching methods on six key science process skills. The study also used statistical analysis to find out if there was a difference between the two groups of students.

Based on the research goals and the planned comparison between teaching science using VR and traditional methods, these null hypotheses were created:

- **$H0_1$:** There is not a big difference in the pre-test scores for basic science process skills between the experimental group and the control group.
- **$H0_2$:** There is not a big difference between the scores students in the control group got on basic science process skills before and after the test.
- **$H0_3$:** There is not a big difference between the scores of basic science process skills on the pre-test and post-test for students in the experimental group.
- **$H0_4$:** After the test, there was not much difference in the basic science process skills scores between the group that received the experiment and the group that did not.

The rest of this paper is organized like Section 2 covers the literature review and explains where the research is lacking. Section 3 goes into detail about the research plan, who was involved, the tools used to measure things, how the VR simulation was created, how the data was collected, and how it was analyzed. Section 4 shows the results from testing the hypotheses. Section 5 discusses the main findings, their importance, any limitations of the study, and suggestions for future research where paper concludes in section 6.

Review of Related Studies

The latest studies suggest that immersive technology and simulation can help enhance science teaching by giving students the chance to visualize their concepts, interact with a virtual world, and participate in experiential activities. Computer simulations have been found helpful for developing science process skills as provide multiple chances for observation, experimentation, and inquiry learning (Çelik, 2022). Simulation and hands-on techniques have been observed to help improve students' practical science skills and process skills (Adebusuyi et al., 2023). Comparative analysis shows that real, virtual, and combination experiments affect concept formation and process skills in science (Anam et al., 2025).

Studies focused on VR applications have indicated positive impacts on learning performance in science. Immersive VR can be effective in improving learning performance and creating engaging experiences for the science learner (Liu et al., 2020; Cao et al., 2024; Chang et al., 2020). There is also meta-analytic evidence that immersive VR is effective in learning performance and skills (Yang et al., 2024; Wu et al., 2020). The application of VR in hands-on activity has been useful in helping students learn by doing in the virtual environment (Chen et al., 2020). Applications of VR in the science laboratory have also shown the potential of VR in science process skills (Artun et al., 2020).

Nevertheless, the research findings are not all positive. Even though immersion can make students more interested in their studies and enjoy them, this does not necessarily mean better learning results, proving that instructional design still matters (Makransky et al., 2021). Immersive VR learning may also comprise cognitive and affective elements which affect learning efficacy (Parong & Mayer, 2018; Parong & Mayer, 2021). Immersive VR learning has been shown to boost students' interest, motivation, and career goals related to science (Makransky et al., 2020). Furthermore, there are findings about the effectiveness of immersive VR learning in scientific inquiries and problem-solving tasks (Wu et al., 2021; Hu et al., 2016). The use of VR in the curriculum has shown promise in the sphere of chemistry education, and immersive VR classrooms have yielded results in academic performance, motivation, and cognitive load (Qorbani et al., 2024; Liu et al., 2022). The use of VR learning has also been compared to hands-on science activities (Lamb et al., 2018; Lamb et al., 2019).

Generally speaking, VR has been found to be an encouraging strategy for teaching sciences, but studies have indicated that its effectiveness is determined by certain variables, including instructional design, learner involvement, and type of learning activity. A key area that needs more attention is the fact that there aren't enough studies looking at how using VR simulations can help students develop more than one basic science skill at the same time in school settings.

Methodology of the Study

Research Design

In conducting this research, a quasi-experimental design with a pre-test and post-test using two groups was utilized. This helped us check how virtual reality (VR) simulations affect the basic Science Process Skills (SPS) of VIII standard students. By comparing the students' performance before and after the intervention, could see if learning through VR leads to better results than traditional classroom teaching. The study selected two classes of VIII standard students for the study.One class, with 32 students, was the experimental group (EG), and the other class, also with 32 students, was the control group (CG).

Study Area and Participants

This study was done with students in the eighth standard at a selected school in Tamil Nadu, India. All the students were in the same class and were given learning material that was relevant to the research. The school was chosen because there were eighth-standard students there, the VR-based teaching method was feasible, and the school was easy to access for the study. As the study involved already formed groups of students, there was no possibility of random allocation to either group. This is why a pretest was conducted prior to teaching to ensure equal knowledge level of the participants initially.

Sampling Method and Sample

The researchers selected the participants for the experiment using a method called purposive sampling. For this study, they included 64 students in the eighth standard, with 32 in the experimental group and the other 32 in the control group. The experimental group was made up of students from Section 8B, and the control group was made up of students from Section 8A. They used purposive sampling because the study required students of a specific grade level who could take part in the VR-based learning program. Before starting the intervention, both groups took a pre-test. The results showed that there was not a big difference in their initial SPS scores. The experimental group scored 10.25, and the control group scored 10.28. This showed that both groups started off with similar levels of performance.

Research Instrument

The researcher made their own questionnaire to check students' basic science process skills. The first version had 50 questions covering six key skills: observation, classifying, measuring, inferring, predicting, and communication. Teachers who taught basic science and physics helped check if the questions were good. After looking at the results, 48 questions were kept in the final version. For each right answer, they gave 1 point, and for each wrong answer, 0 points. This helped clearly show how well students were doing in basic science process skills. The test's reliability was checked using Cronbach's Alpha, which came out to 0.81.

Development of the VR-Based Learning Environment

A special VR learning setup was made to help students learn difficult and tricky science ideas. This setup lets students experience and explore these ideas in a way that feels real and engaging. The VR environment was built using Unity, and there were nine different learning tasks included. Each task was focused on a specific science concept, and students could take part in hands-on activities within the virtual world to better understand the material.

The Virtual Reality (VR) learning simulation was developed through the process of ADDIE instructional design which consists of five major stages; Analysis, Design, Development, Implementation, and Evaluation. In the Analysis stage, the challenges of learning science concepts have been analyzed. During the Design phase, the learning activities were planned. The simulation was then put into use and checked to see how well it helped with learning and improving Science Process Skills.

The VR activities were designed to give learners opportunities to look at virtual objects and events, sort out the information they see, take measurements, figure out how things are connected, guess what might happen next, and share what they learned. Once the VR tasks were done, students received extra lessons that helped them understand the concepts they explored in the virtual environment.

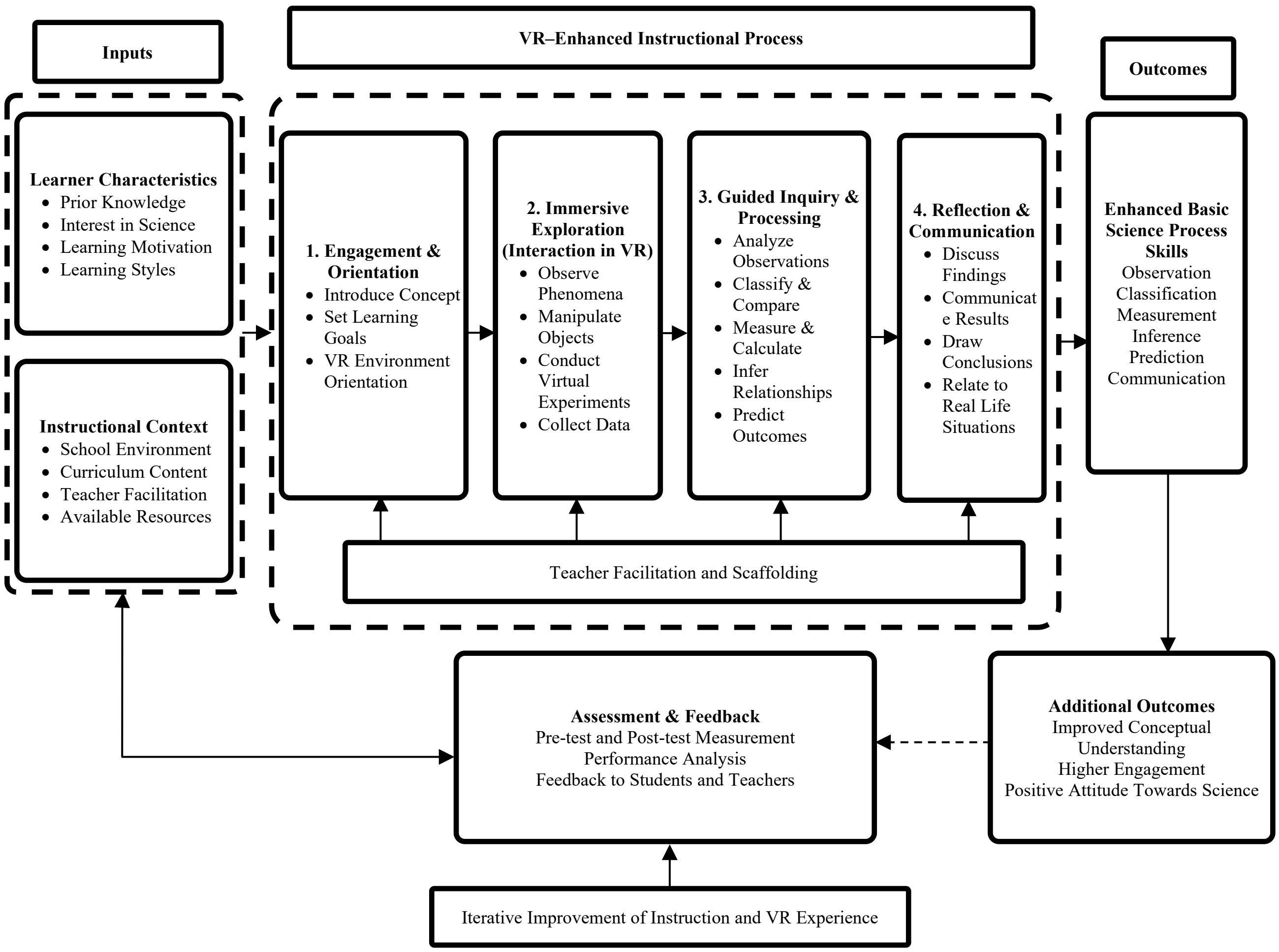

Fig. 1: Proposed VR-Enhanced Science Learning Framework for Developing Basic Science Process Skills

Fig. 1 shows how learner and contextual characteristics fit into the process of learning through a virtual reality-supported instructional process, including engagement, exploration, inquiry, and reflection. Assessment and feedback provide opportunities for constant improvement, whereas teacher guidance and scaffolding play an important role at each step. The framework is designed to help develop six important skills in scientific processes: observing, sorting things into groups, measuring, making educated guesses, predicting what might happen, and sharing information.

Data Collection Procedure

Systematic data collection was conducted through the pre-test, intervention, and post-test phases. In the first phase, both groups were given the Basic Science Process Skills test to determine their pre-existing skill level and make them comparable. For the experimental group, nine tasks based on the VR-based learning were conducted for observation, interaction, exploration, prediction, and discussion, where information was offered for each task. The control group underwent traditional classroom learning without any involvement in VR-based learning. In the end, both groups took the test again for post-test evaluation.

Technical Features of the VR Intervention

The virtual reality learning environment was created as an interactive 3D world with the use of Unity, which included nine activities that were linked to the science curriculum. Students were able to investigate virtual objects that could not be observed in the conventional classroom setting through these activities. Interaction was facilitated through activities such as observation, identification, classification, virtual measuring, conclusion making, prediction, and discussion. The design supported the learning objectives through linking the VR activities to the SPS dimensions tested in the research instrument.

Data Analysis

Both the pre-test and post-test data were analyzed using both descriptive and inferential statistics in order to determine the effectiveness of the VR treatment. The means and standard deviations provided measures for student performance in each group, while the independent and paired samples t-tests were used to determine differences between and within the groups respectively. The independent samples t-test would compare the performance of the experimental group and the control group, whereas the paired samples t-test would measure any change between the pre-test and post-test performance within each group. The level of statistical significance was 0.05, with $p < 0.05$ being statistically significant.

Statistical Analysis

In the process of conducting statistical tests, independent samples t-tests and paired samples t-tests were applied. The independent samples t-tests involved comparing the two groups whereas the paired samples t-tests involved analyzing the changes between the pre-tests and post-tests within each group. In all the hypotheses tested, a significance level of 0.05 (two-tailed) was used in testing the hypotheses. Effect sizes were analyzed using Cohen's d for determining the effect size whereas 95% confidence interval was used for determining the mean difference. Statistical significance was declared at $p < 0.05$.

Ethical and Administrative Considerations

Permission for the study was sought from the school authorities prior to its conduct. The objective and methodology of the study were elaborated to the participants, and only the data collected from the students were used for academic research purposes. The experiment was conducted in the natural environment of the students without disturbing their learning process.

Data Analysis

Descriptive Statistics

The descriptive statistics for the Basic Science Process Skills in the control and experimental group have been provided in table 1. There was no significant difference between the two groups in pre-test scores with the mean score being 10.28 (SD=2.02) in the control group and 10.25 (SD=2.21) in the experimental group. However, the post-test scores showed an improvement in both the groups where the mean score was 11.75 (SD=1.64) in the control group and 16.19 (SD=2.64) in the experimental group.

Table 1: Descriptive Statistics of Pre-Test and Post-Test Scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD
Control Group	10.28 ± 2.02	11.75 ± 1.64*
Experimental Group	10.25 ± 2.21	16.19 ± 2.64

Fig. 2 provides a comparison of the means of the pretest and posttest scores between the control group and the experimental group. There was a slight increase of the mean score from 10.28 to 11.75 in the control group, while there was a significant increase in the experimental group's mean score from 10.25 to 16.19.

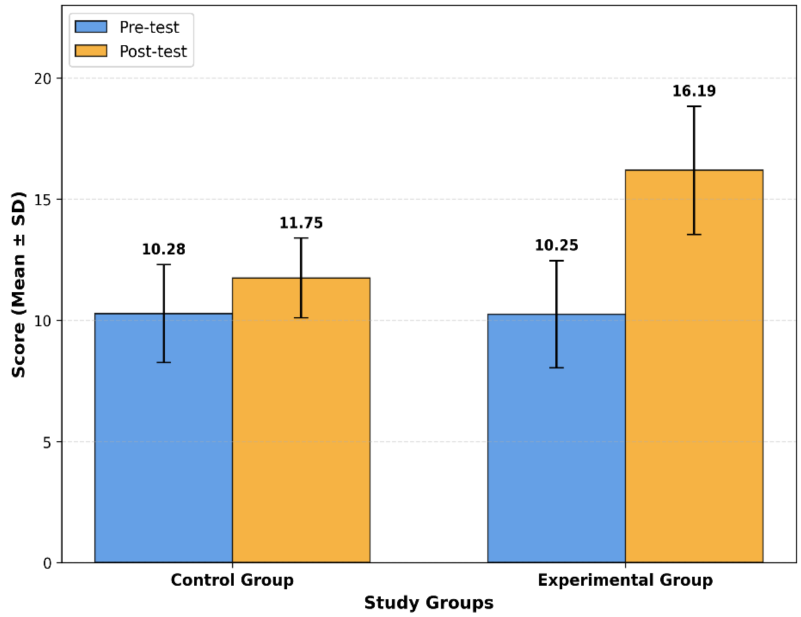

Fig. 2: Comparison of Pre-Test and Post-Test Scores Across Study Groups

H0 – 1

There was no major difference between the experimental group (EP) and the control group (CG) when it came to their performance in the pre-test for learning the basic SPS.

Table 2: Independent-Samples t-Test for Pre-Test Scores

Group	N	Mean	SD	Mean Difference	*t*	df	*p* (two-tailed)	Cohen's *d*	95% CI of Difference
Experimental	32	10.25	2.21	-0.03	0.059	32	.953	0.015	-1.066 to 1.006
Control	32	10.28	2.02						

As illustrated in table 2, there was no statistically significant difference between the two groups prior to the experiment, $t(32) = 0.059$, $p = 0.953$. In addition, the effect size of the study was negligible ($d = 0.015$), showing similar initial performance levels in the two groups. Finally, the 95% confidence interval for the mean difference varied from -1.066 to 1.006 and contained zero.

H0 – 2

There is no major difference between how well the CG performed on the pre-test and the post-test.

Table 3: Paired-Samples t-Test for Control Group Pre-Test and Post-Test Scores

Group	N	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	*t*	df	*p* (two-tailed)	Cohen's *d*	95% CI of Difference
Control	32	10.28 ± 2.02	11.75 ± 1.64	0.03*	0.065	30	.949	0.012	-0.913 to 0.973

Table 3 indicates that there is not much variation in the scores of the control group from the pre-test to post-test results, $t(30) = 0.065$, $p = .949$.

H0– 3

There is no significant difference in the performances of the experimental group before and after the test.

Table 4: Paired-Samples t-Test for Experimental Group Pre-Test and Post-Test Scores

Group	N	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	*t*	df	*p* (two-tailed)	Cohen's *d*	95% CI of Difference
Experimental	32	10.25 ± 2.21	16.19 ± 2.64	5.94	9.737	30	< .001	1.749	4.694 to 7.186

The performance of the experimental group, based on table 4, significantly improved as the average scores increased from 10.25 to 16.19 (average increase of 5.94), t = 9.737, p < .001. The large effect size (Cohen's d = 1.749) indicates that the intervention had a strong effect. The 95% confidence interval of the mean difference is 4.694

Ho– 4

There isn't a major difference in how well the EG and CG performed on the post-test.

Table 5: Independent-Samples t-Test for Experimental and Control Post-Test Scores

Group	N	Mean	SD	Mean Difference	*t*	df	*p* (two-tailed)	Cohen's *d*	95% CI of Difference
Experimental	32	16.19	2.64	4.44	8.058	30	< .001	2.015	3.315 to 5.565
Control	32	11.75	1.64						

As demonstrated in table 5, there is a marked difference between the two groups regarding the post-test score, t(30) = 8.058, p < .001. This is because the experimental group scored higher (M = 16.19, SD = 2.64) compared to the control group (M = 11.75, SD = 1.64). Effect size is large (d = 2.015) with 95% CI of 3.315–5

Table 6: Summary of Hypothesis Testing and Effect Sizes

Hypothesis	Comparison	Test	*t*	df	*p*	Cohen's *d*	95% CI	Decision
H0-1	EG vs CG pre-test	Independent	0.059	32	.953	0.015	-1.066 to 1.006	Not Significant
H0-2	CG pre-test vs post-test	Paired	0.065	30	.949	0.012	—	Not Significant
H0-3	EG pre-test vs post-test	Paired	9.737	30	< .001	1.749	4.694 to 7.186	Significant
H0-4	EG vs CG post-test	Independent	8.058	30	< .001	2.015	3.315 to 5.565	Significant

The results of the hypothesis test, including the t-values, p-values, effect sizes, and confidence intervals, are listed in table 6.

Discussion

The results proved that the use of simulation through virtual reality was highly effective in improving the basic Science Process Skills of the students. There was no statistical significance in the pre-test scores, indicating equal performance of both groups at the start of the study. Although there was little progress shown by the control group, the experimental group attained statistically significant scores in their post-tests with a high effect size. This shows that virtual reality was highly effective in improving the students' abilities in observation, classification, measurement, prediction, inference, and communication skills.

The results will have some significance in science teaching, especially when dealing with abstract topics that may not be easy to teach practically. Educators could use well-thought-out virtual reality technology in their lessons to help learners engage in experiential learning. This study has several limitations such as having a limited sample of only 64 students who were selected using the method of purposive sampling. It was limited in both time and scope, therefore, future researches must be conducted using a larger and more diverse sample size as well as better sampling methods.

Conclusion

In this experiment, the effect of VR Simulations on the development of the Basic Science Process Skills of the students was assessed. The results obtained show that VR-based learning caused much more improvements compared to the traditional classroom learning. Baseline analysis reveals that there were no statistically significant differences between the experimental group and the control group, t(32) = 0.059, p = .953, which implies equal level of the baseline performance. No statistically significant pre-test to post-test improvements were observed in the control group, t(30) = 0.065, p = .949, with negligible effect size (Cohen's d = 0.012). As evidenced by the post-test comparison, significantly better performance was found amongst the VR learners, t(30) = 8.058, p < .001, with a very large effect size (d = 2.02). This suggests that immersive and interactive VR systems can play a significant role in improving the learners' observational, classificatory, measurement, predictive, inferential, and communicative capabilities. However, the findings should be interpreted bearing in mind the small sample size, the use of purposive sampling, and the narrow research setting, all of which limit the external validity of the results.

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