Research Article

Effect of Online Learning Augmented Reality Programme on Academic Achievement in Science

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Abstract

This research explores the effect of NCERT-based Augmented Reality (AR) applications and conventional teaching on academic achievement in Science subjects in online classes. The sample consisted of 28 students from class IX of a government girl's senior secondary school in Sonepat, Haryana, India, during the academic session 2021-2022. The sample was selected based on academic scores attained by students in the previous VIII class in the science subject. Due to the experimental nature of the study, the students were equally and randomly segregated into the control and experimental group. A Self-constructed Science achievement test was implemented before and after the experiment. The control group was taught with traditional teaching, and the experimental group was taught by NCERT-based AR application on the theme "The Fundamental unit of life" in Science subject, and the application was shown to the students through Zoom online learning programme. The intervention programme was administered for four weeks. The data obtained were analyzed by applying the 't'-test. The research findings revealed that students' achievement in Science courses increased significantly with the use of NCERT-based AR applications. Moreover, the students keenly observed and showed interest in the 3-dimensional images. So, it is supportive and considerate in enhancing students' academic success. The research study has applications for in-service or pre-service teachers, policymakers of the curriculum framework, and secondary school students.

Keywords: NCERT-based Augmented Reality application, Student's Achievement, Online Learning Programme

Introduction

With the advancement in technology, there is a rapid expansion in various ways of learning and economic sustainability. Various mediums like virtual learning environments, augmented reality (AR), virtual reality (VR), and mixed reality (MR) are creating vulnerable and incredible prospects for enhancing motivation, achievement, and learning in different subject areas and educational settings. With the practical and affordable development in augmented reality, virtual simulated reality, and mixed hybrid reality, the learner got the chance to be acquainted with an immersive learning environment in and outside of the classroom (Liu et al., 2017). A vast majority of enterprises in education technology are using simulated virtual reality to provide real-life experiences in the classroom to motivate and grasp the student's attention.

Science education is a way of acquiring problem-solving skills, asking questions, applying learned skills, and developing critical thinking, communication, and organisation skills. Because of the

above benefits of teaching science subjects in the future and present life, subjects must be prudently and pragmatically designed and applied with innovative methodologies and techniques to enhance motivation and success among students (Nurita et al., 2017). There are various innovative methodologies and applications like role-playing (Wulandari, 2018), experimentation (Shana and Abulibdeh, 2020), and Gamification (Kalogiannakis et al., 2021; Hursen and Bas, 2019) in science subject that enhances academic success and motivation to learn new concepts of science. In contrast, it was observed that the traditional instructional method used by the teacher in a science course is poor in remembering skills among students (Aina and Langenhoven, 2015). Though in the traditional learning method, learners immediately recall only forty-two percent of the information; a week later, this rate diminishes to twenty percent (Bok, 2006). Therefore, the above findings indicate that student-centred and up-to-date activities should nurture students' curiosity, interest, academic success, and motivation. An effective learning environment including modern technologies like visual effects, simulation, and three-dimensional visualisation tools in the teaching-learning process enhances the student's interest, motivation, collaboration, the skills to remember and understand the concepts clearly and enjoyable (Price and Lee, 2013; Raja and Nagasubramani, 2018). According to societal demands, the perspective on science education has evolved with time (DeBoer, 2000). Therefore, the inclusion of the prevalent application of current technology in science education is augmented reality (AR) which solves current problems of science learning (Tsai and Wen, 2005; Chen and Tsai, 2012; Lin et al., 2019). Augmented reality is a technology that supports the interaction and collaboration between virtuality and reality, which supplements each other (Azuma, 1997). It is the amalgamation of digitalization with concrete objects, which allows a real-world user to interconnect with the digital apparatus impeccably. Therefore, augmented reality is one of the innovative technology used in the teaching-learning process (Timur and Ozdemir, 2018), which contribute to the current learning environment (Ozdemir, 2017) and brings new possibilities for transforming education (Wu et al., 2013, Huang et al., 2016).

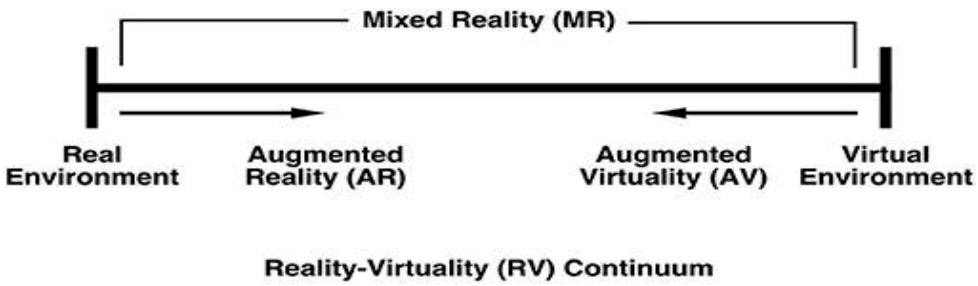
Augmented Reality

Augmented reality (AR) is a technology that overlays a computer-simulated image of the existing domain, thus providing a multifaceted observation. It is a simultaneous association where simulated and factual phenomenon exists collectively (Azuma et al., 2001; Carmigniani and Furht, 2011). It is a three-dimensional technology that helps to comprehend and recognize the existing domain enclosed by items produced in computer-generated settings (Leung and Blauw, 2020). Additionally, augmented reality (AR) is a technology-based representation that connects real and virtual spaces (Diegmann et al., 2015). In AR, an innovative learning environment and new opportunities are available to facilitate learning (Huang et al., 2016). The functioning of augmented reality is possible with the help of mobile technology that connects the real-world environment by visually overlaying and linking a current view with virtual objects.

On the other hand, virtual reality is the replication of computer-generated insightful information (Panciroli et al., 2018). It is experienced in a simulated learning environment by computer technology in which one's actions moderately govern the surrounding learning environment

(Merriam-Webster.com Dictionary). Therefore, augmented reality helps in understanding facts or information about concepts in an actual environment that seems to be challenging to imagine and explain (Del Cerro Velazquez and Morales Mendez, 2018). The structure and organisation of mixed reality are shown in Figure 1.

Figure-1: Structure and Organisation of Augmented Reality and Virtuality (Milgram et al., 1995)

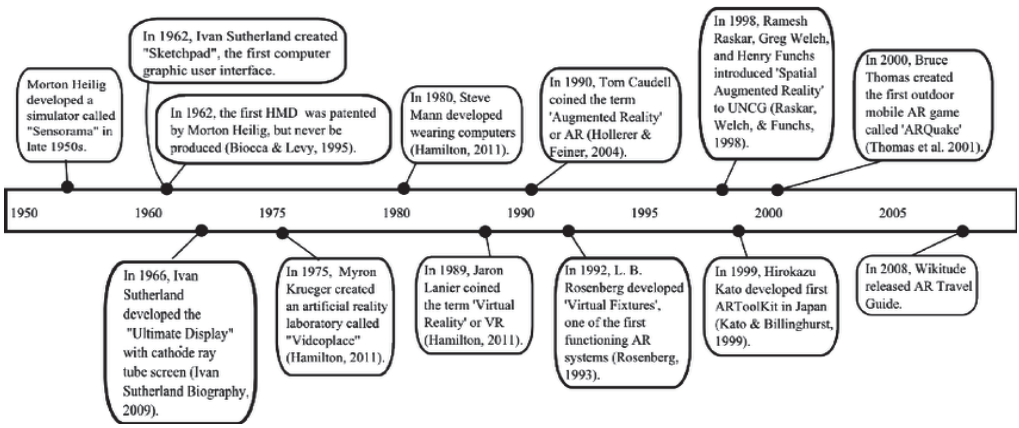


Source: frvir-02-647997-g001.jpg (510×184) (frontiersin.org)

Genesis of Augmented Reality

Caudell and Mizell (1992) used the augmented reality model for demonstration in companies, and with the progression in technology and innovation, the use of computers and phones has become simpler and more accessible in a diverse environment (Johnson et al., 2010). As a result, the various technical tools are applicable in many areas, including scientific research and art activities (Kapur, 2019). Augmented reality applications substitute the technological tools and applications used in diverse areas. Therefore, the topic of how the augmented reality application started and emerged. Additionally, how did advancements and inventions begin after being created? Figure 2 shows this information as a timeline.

Figure-2: Genesis of augmented reality (cited by Yuen et al., 2011)



Source: History-of-AR-a-brief-timeline.png (850×396) (researchgate.net)

Review of related literature

Learning is perceived as influenced by learners' experience, interest, and approach toward the technological environment (Norman, 2004; Preece et al., 2007). Augmented reality provides a realistic environment in a particular situation, like teaching imperceptible happenings, representing hazardous conditions, personifying intangible thoughts, and explaining complex evidence (Walczak et al., 2006). Augmented reality applications can enhance the teaching-learning opportunities that assist learning (Wu et al., 2013; Huang et al., 2016) by influencing the current learning environment (Johnson et al., 2014; Ozdemir, 2017). It is an innovative and advanced technology applied in educational settings (Timur and Ozdemir, 2018). The augmented reality application can focus the student's attention by bringing vivid reality to a course (Winkler et al., 2002). Together, the virtual and physical element demonstrations allow viewers to see how three-dimensional things relate to abstract ideas (Arvanitis et al., 2009). Augmented reality application is capable of enhancing interest among learners (Sotiriou and Bogner, 2011), symbolizes learning and wisdom (Kaufmann Schmalstieg, & Wagner, 2000), and increases the three-dimensional capabilities of the learners (Kaufmann et al., 2005; Martin-Gutierrez et al., 2010), increases motivation and students engagement in the lesson (Klopfer and Squire, 2008; Sotiriou and Bogner, 2011; Di Serio et al., 2013). AR application can attain higher-level cognitive skills (Dunleavy et al., 2009). Therefore, AR application used in educational settings produces positive and constructive outcomes. Tsai and Wen (2005), Chen and Tsai (2012), and Lin et al. (2019) research findings supported the importance of technology and competence in science learning. Palmer (1999) suggested in his study that if AR is used in Science subjects, learners clearly understand abstract and complex concepts. For instance, in some Science topics where the learner finds difficulty in understanding and learning, AR technology assists in visualising the three-dimensional object's image (Wu et al., 2013). AR applications developed for educational purposes are less adapted or modified according to the learning environment (Cuendet et al., 2013). Furthermore, the research on the effects and implementation of AR is in the zygotic stage, and to understand the benefits of augmented reality, the frequency of research in this area must be enhanced.

The literature review shows the vacuum of learning science among secondary students, and the present research addresses the existing gap in the Indian context.

Envisioned e-Pathshala AR Application-An Initiative of NCERT

The fundamental aim of contemporary education is to increase quality aspects at all stages of learning. The digital resources facilitate the learner to move beyond the classroom and textbooks, offer a vivid, experiential learning environment, and develop problem-solving approaches among learners. In the digitalization context, the e-Pathshala AR Application is an initiative of NCERT under the guidance of the Ministry of Education-Government of India, directed to invigorate the textbooks, augment or intensify learner-to-learner, teacher-to-teacher, and learner to teacher. Through augmented interaction, the learner will be able to understand the concept by experimentation rather than through reading and memorization. Augmented reality's purpose is to change inactive listeners to active listeners. Therefore, the e-Pathshala AR application is an effort toward Prime Minister "Digital

India" by exploring different technology areas.

Rationale

The rationale of the study was to discover an augmented reality-based teaching strategy that helps students in attaining academic achievement. In augmented reality, students can gain a three-dimensional experience of content or subject in a virtual environment. A positive environment is created, which thereby enhances their academic achievement. The performance of the student must be compared with their past experiences. The study's rationale was to employ an augmented reality application launched by NCERT, New Delhi, India, and identify the effect on students' academic achievement.

Objectives

The research study is intended to recognize and understand the following objectives:

I. To employ an augmented reality application launched by the NCERT, New Delhi.

II. To find out the effect of AR application on the academic achievement of secondary school students in science.

Hypothesis

The following hypothesis was developed based on the literature review:

> Augmented reality application has a significant positive effect on academic achievement in science.

Methodology

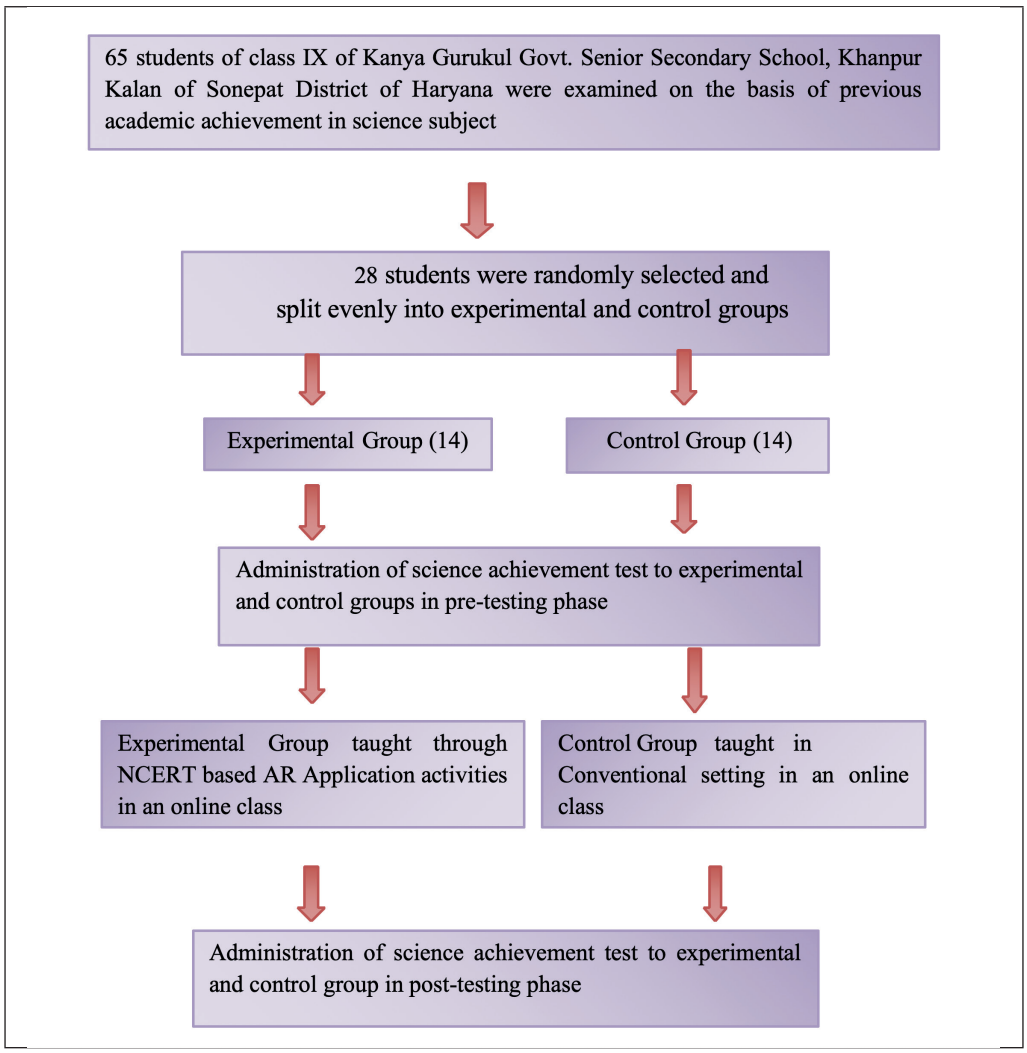
This section includes research design, sample, tools, experimental procedure, and data analysis and interpretation. In the present research, the NCERT e-pathshala AR application (intervention) was an independent variable, and the score attained by subjects in the science achievement test was a dependent variable.

Research Design and Procedure

The "pre-test, post-test true experimental design" was used to determine how the NCERT-based e-Pathshala augmented reality application affects students' academic achievement. In a true experimental design, students were randomly selected and split evenly into experimental and control groups. Considering the research design, the academic achievement test was applied as a pre-test to determine the level of attainment in Science subjects among ninth-class students. After the pre-test, the students were exposed to the NCERT-based e-Pathshala augmented reality application as an intervention programme in the experimental group, and the control group was taught through the traditional method. Then, post-testing was done to find out the success of the applied programme. The above procedure determines to what extent the applied programme affects students' academic attainment. Finally, the AR application was shown to the students through Zoom online learning platform.

Considering the specific design, an academic achievement test of sixteen items was applied as a pre-test to determine the level of attainment in science among ninth-class students. After pre-testing, the students were exposed to the NCERT-based e-Pathshala augmented reality application as an intervention programme, and after that, post-testing was done to determine the program's effectiveness. The steps of the intervention programme are shown in Figure 3.

Figure-3: Flow chart of Experimental Design



Sample

The study sample comprised 48 secondary school students studying in Kanya Gurukul Government Senior Secondary School, Khanpur Kalan, Sonepat, Haryana, in the academic session 2021-2022. The school was selected through a convenient sampling technique. This was because of school closures during lockdown due to the COVID-19 pandemic, and finding an appropriate number of students in the online learning programme was challenging.

Tools

A self-made science achievement test was developed to assess student achievement in science by considering the content and objective of science teaching. The chapter for achievement test construction was "The fundamental unit of life" (syllabus of ninth class followed by Haryana Board of School Education), prescribed by NCERT. Initially, 20 items were included in the planning phase related to four domains of instructional objectives, i.e., knowledge, understanding, application,

and skill. The test items of selected content were multiple choice questions of one mark each. Students had to give their responses on the same question-cum-answer sheet, and the time for attempting the test was 35 minutes. The scoring key was also prepared for the above said questions.

The try-out of the achievement test was governed by a sample of 100 students of class X, and scoring was done accordingly. Subsequently, item analysis is done to determine the item quality and was exhibited in two ways, i.e., item difficulty value and discriminating power. The scoring sheet for each student for item analysis was arranged from highest to lowest score in descending order. The item analysis is done on the top twenty-seven per cent and bottom twenty-seven per cent test scores (Kelley's method 1939).

a. The given formula calculated the difficulty value of each item of the achievement test:

$$\text{Difficulty Value (D.V.)} = \frac{\text{Number of students who answered the items correctly in upper group and in lower group}}{\text{Total number of students}}$$

Based on difficulty value, too difficult and too easy items were deleted. The calculated difficulty value ranges from +0.20 to +0.80, and items below +0.20 and above +0.80 were rejected.

b. Similarly, discriminating power value is employed to discriminate between above average and below average learners and calculated by formula;

Discriminating Power=N_U -N_L / N

N_U and N_L =Number of students who answered the items correctly in the upper and lower group

N=Number of students who answered the items correctly in each group

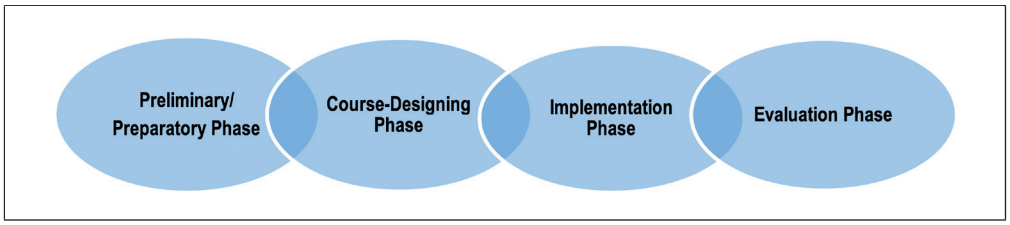
The calculated discriminative power value ranges between +0.20 (lowest value) to +0.50 (highest value). Items below +0.20 and above +0.50 were rejected. Therefore, the final science achievement test includes questions with acceptable discriminative power indexes (+0.20 to +0.50) and item difficulty value indexes (+0.20 to +0.80). Eventually, 16 items were selected and retained for the final science achievement test.

The split-half and Cronbach's alpha methods were used to calculate the science achievement test's reliability and validity, and the results showed that they were, respectively, 0.69 and 0.82 and were found reliable. The validity of the achievement test was determined by establishing content and face validity. Subject experts reassessed items selected for achievement test construction, the specialized teacher in science teaching was involved in assessment and evaluation, and the language expert edited test items. The ambiguous items were adapted, modified, and reworded in simple sentences and lucid language.

Experimental Process of the Research

The experimental research process comprises four phases: preliminary/ preparatory phase, course designing phase, implementation phase (application of NCERT-based e-pathshala AR application), and evaluation phase, as shown in Figure 4.

Figure-4: Experimental Process of Research



I. Preliminary/ Preparatory Phase:

In this phase, prior consent was taken from the students who were willing to participate. A need-based analysis survey was conducted to know the interest and aptitude of learners toward the online learning environment to avoid boredom in learning and a pre-test was applied.

II. Course–Designing Phase:

After considering the needs and requirements of the learner, the technical supported Science course design based on the NCERT e-pathshala AR application was applied. The design of the course was a four-week augmented reality-based activity prepared on the theme "The Fundamental Unit of Life." In the course-designing phase, persistent help was taken from science teachers and curriculum developer professionals who understand the use of augmented reality applications.

III. Implementation Phase:

Before the execution of a four-week experimental programme, an orientation programme was conducted, where students were informed about NCERT-based e-pathshala augmented reality applications, and a pre-test was conducted. After the orientation, the execution of the course with the topic "The Fundamental Unit of Life" was initiated.

IV. Evaluation Phase

In this phase, students' views were taken about the augmented reality teaching method, whether the content taught through this application accomplished the objective or not was noted, and a post-test was applied. Detailed information about the four-week experimental process is shown in Table 1.

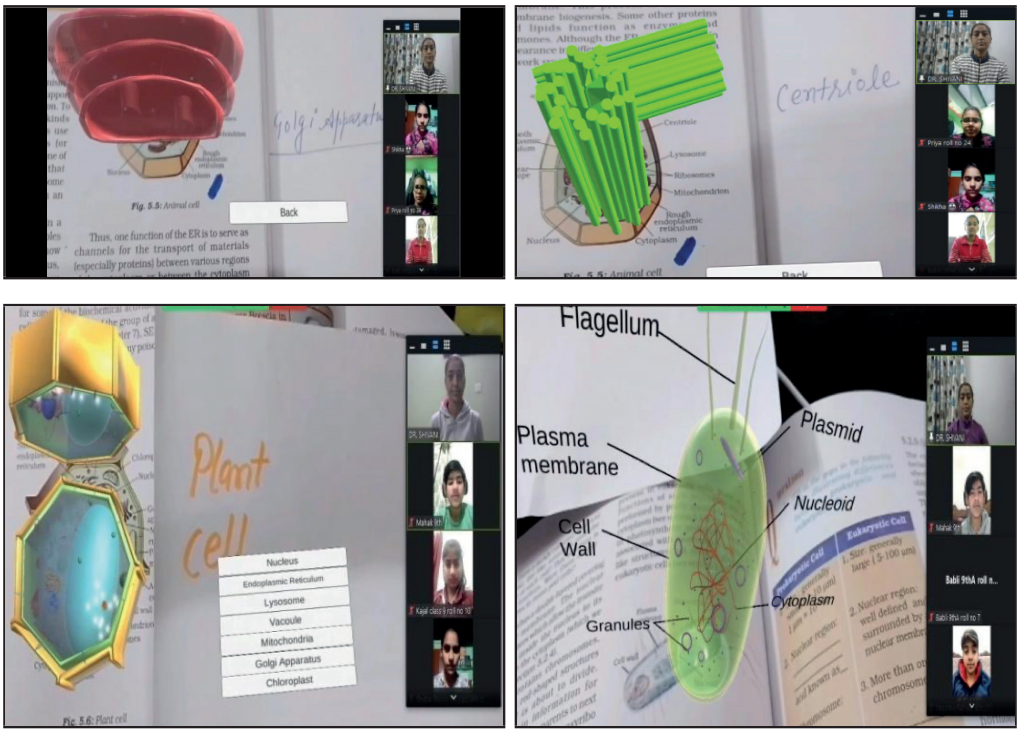
Table-1: Information about four week's course design

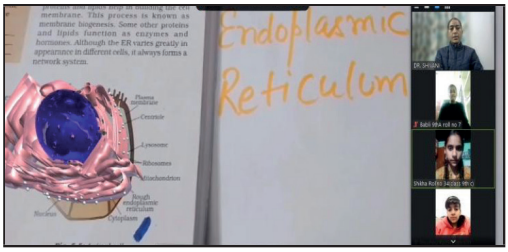
Week	Topic	Learning objectives	Learning activities	Learning outcome
First week	The Fundamental Unit of Life	To understand that all living organisms are made up of cells. To know the basic cell composition in an AR environment	Displaying the formation and structure of a cell in an AR environment and by adding video	To give examples of cell composition in leaf peels, root tips, onion peels, etc.

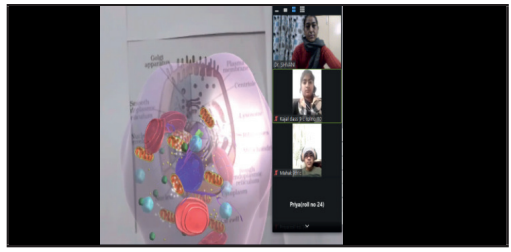
Week	Topic	Learning objectives	Learning activities	Learning outcome
Second week	The Fundamental Unit of Life	To understand the structural and functional system of organelles present in an animal cell in an AR environment	Demonstrating and displaying the structural and functional system of organelles present in an animal cell in an AR environment	Realizing the importance of different cell organelles present in animal cell
Third week	The Fundamental Unit of Life	To understand the structural and functional system of organelles present in a plant cell in an AR environment	Demonstrating and displaying the structural and functional system of organelles present in a plant cell in an AR environment	Realizing the importance of different cell organelles present in plant cell
Fourth week	The Fundamental Unit of Life	To differentiate between animal and plant cells in an augmented reality setting	Elucidating the differences between animal and plant cells in an augmented reality setting	Necessary information about the significant differences between plant cell and animal cells

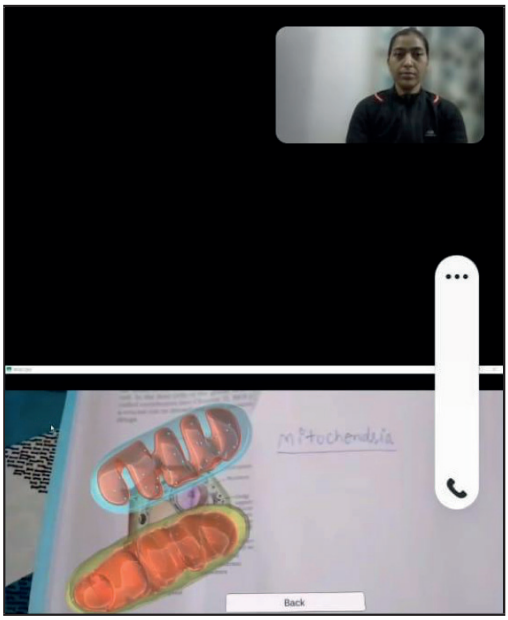
Some glimpses of the use of NCERT-based applications are shown below in Figure 5.

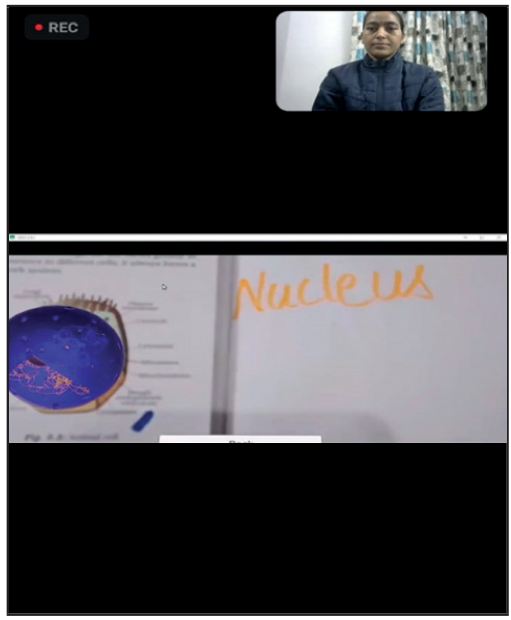
Figure-5: Glimpses of the use of NCERT-based applications











Results

The mean, standard deviation, and degree of freedom of pre-testing and post-testing scores of the students in both groups were computed and tested for significance of difference by using paired sample "t" test. Before this Shapiro-Wilk Test was applied to determine the normality of the data, it was observed that data is normally distributed. Therefore, the results obtained are shown in Table 2.

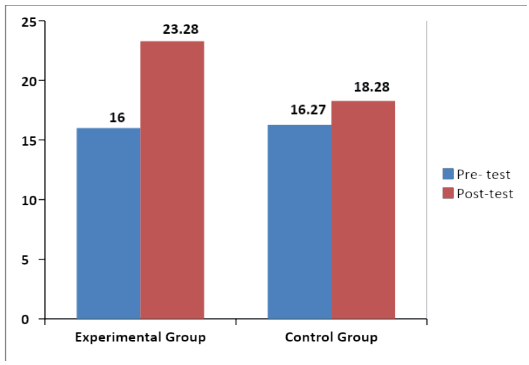
Table-2: Academic Achievement Mean Scores of the Experimental Group and Control Group

Variable	Phase	Group	N	Mean	SD	df	't' Value	Significance Level
Science Academic Achievement	Pre-testing	Experimental Group	14	16.00	6.65	13	0.69	Not-significant at 0.05 level
		Control Group	14	16.27	5.96			
	Post-testing	Experimental Group	14	23.28	6.25	13	2.16	Significant at 0.05
		Control Group	14	18.28	5.96			

Table 2 indicates that at the pre-testing phase, the mean and standard deviation scores of the experimental group were 16.00 and 6.65, whereas the mean and standard deviation for the control group were 16.27 and 5.96, and the 't value of both groups were 0.69 at 13 degrees of freedom which is not-significant at 0.05 level. It means students in both experimental and control groups have the same level of academic achievement before the onset of the intervention programme.

Further, it is also evident from Table 2 that the post-test mean and standard deviation value for the experimental group were 23.28 and 6.25, respectively, whereas, for the control group, it was found to be 18.28 and 5.96. For a one-tailed test, at a 5% significance level, the critical table value of 't' with the degree of freedom 13 is 1.71, and our computed 't' value is 2.16. Hence, it is greater than the critical table 't' value of 1.71. Therefore, it is to be taken as significant at a 5% significance level but does not reach 2.50 and is not significant at 0.01 levels. It reveals that the experimental group students attained higher academic success than the control group after the intervention of augmented reality in online classes. The graphical representation of the above results is given in Figure 6.

Figure-6: Graphical presentation of Academic Achievement results



It is depicted in figure 6 that there is an enhancement in post-test scores in both groups to pre-test scores. Further, it also revealed that the improvement is highly visible in the experimental group in comparison to the control group.

Comparison of Academic Achievement Gain Scores

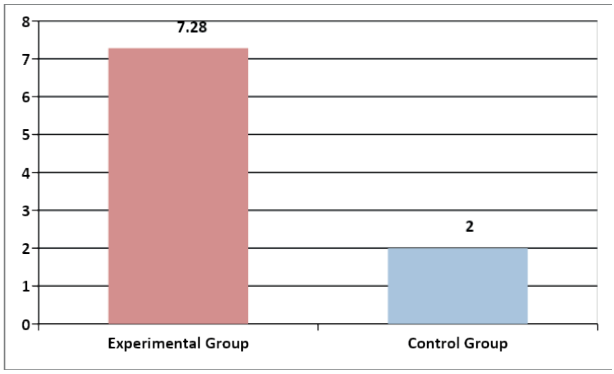
The mean and standard deviation of the gained academic achievement scores of both experimental and control groups were 7.28± 2.16, whereas, for control groups, it was 2.00±2.48. The "t" value for both groups was 2.16 and was found significant at 0.05 levels. The gain score difference of the experimental group is three times greater than the control group and is shown in Table 3.

Table-3: Gain score difference between the experimental group and control group

Variable	Group	N	Mean	SD	"t" value	Significance levels
Academic Achievement	Experimental Group	14	7.28	2.16	2.16	Significant at 0.05 levels
	Control Group	14	2.00	2.48		

Further, the experimental group has shown higher academic attainment after their exposure to augmented reality-based intervention than the control group. Therefore, it is concluded that teaching with augmented reality applications significantly positively affects academic success. This can be graphically represented in Fig. 7.

Figure-7: Mean Gain Scores of Academic Achievement



Therefore, it is concluded that students of the experimental and control groups differ significantly from each other. So it is concluded that augmented reality teaching has a positive advantage over the traditional method.

Discussion

It is clear from the results that using AR applications in Science learning is effective. Petrov and Atanasova (2020) supported the results, and Lin et al. (2019), confirmed that the use of augmented reality in STEM education helps in acquiring the skill to discover, train, and correlate with STEM education, and also the augmented application has a positive effect on spatial ability on medium achievers mathematics students. Research studies (Dede, 2009; Chang et al., 2016; Hwang et al., 2016; Cetin and Turkan, 2021) confirm that augmented reality complements student-teacher interaction and enhances academic achievement. The findings are incongruent with Kumaran, Santhi, and Anand (2007), reflecting that developing augmented reality applications helps in learning the various application domains of civil engineering.

Conclusion

The present study justified that augmented reality application in science helps increase learners' academic achievement. Besides research findings, it was also observed by the researchers that augmented reality is effective in creating a world that does not exist physically, and students were showing keen interest and curiosity towards 3-dimensional images and were more focused on Science learning. Furthermore, the finance issue was also resolved because no such costly gadgets are required in augmented reality applications in the teaching-learning process. Therefore, it is suggested that augmented reality helps to bring reality to the classroom and develop divergent thinking among learners.

Educational Implications/ Recommendations

The outcomes of this research may be helpful for researchers, students and teachers, and policy planners. AR application is an exciting and innovative way of teaching which helps significantly in raising the students' achievement, updating knowledge, solving

queries, motivation, comprehensive understanding and application of the concept, and positive attitude towards science subject. This form of learning eases the learning cost and is accessible training simulations to different-stage learners. For implementing the AR application, the positive attitude of teachers, facilities like proper space, seating arrangement, different improved digital learning materials, internet connectivity, etc., need to be at every learning end to make the academic atmosphere more lively and exciting. The effect of AR application can be further extended to other variables like scientific creativity, scientific attitude, science self-efficacy, science process skills, and laboratory skills by conducting experiments in the virtual and simulated learning environment. NCERT's e-Pathshala AR application is presently applicable for class IX and X science subjects only. Therefore, a similar application can be extended to the achievement of learners of different age groups, grade levels, and different subject areas. Hence provisions should be made in teacher education programmes to explore the possibilities of practising innovative e- Pathshala AR applications like models.

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