



Impact of ICT Integrated Pedagogy on Children's Comprehension and Learning Outcomes in Science at Upper Primary Level

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Authors' contributions

This work was carried out in collaboration between all authors. Author AKM designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author RM managed the analyses of the study. Author Deepshikha managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJESS/2021/v15i1130367

Editor(s):

(1) Dr. M. Camino Escolar-Llamazares, University of Burgos, Spain.

Reviewers:

(1) Aravind B. R., Vellore Institute of Technology, India.

(2) Ghaouar Nesrine, Badji Mokhtar Annaba University, Algeria.

(3) Indah Suciati, Alkhairaat University, Indonesia.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/65097>

Original Research Article

Received 29 November 2020

Accepted 01 February 2021

Published 17 February 2021

ABSTRACT

This study investigated the impact of ICT integrated pedagogy on learning outcomes in science of upper primary students. A quasi-experimental (Pre-tests and post-tests with control group) research design was adopted to conduct the study. One hundred and twenty five class VIII children were the participants. The experimental group was taught with the help of ICT integrated pedagogy whereas the control group was taught by traditional chalk and talk pedagogy. The data were analyzed using descriptive and inferential statistics. The results indicated a statistically significant difference in comprehension and learning outcomes of a science topic i.e. Cell: Structure and Function of experimental group and control groups. Children of the experimental group had better learning outcomes in science than control groups. This trend was also reflected in personal interviews. Therefore, it is suggested that ICT integrated pedagogy ought to be employed in the teaching of science at the upper primary level to enhance conceptual understanding and learning outcomes in the subject.

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Keywords: Information and communication technology (ICT); cell; learning outcomes; upper primary; multimedia; computer animation.

1. INTRODUCTION

In the twenty-first century of scientific and technological age the conventional pedagogic method is not sufficient to generate interest among the children for science. The traditional one-way teaching method i.e. didactic method which is a teacher-centered classroom setting where students are passive listeners is adopted by majority of school teachers. This type of teaching does not entertain interactions with the student; instead, it focuses on presenting factual content of the subject matter by using lecture and question-and-answer technique. It is based on rote learning of concepts, facts and principles. In this chalkboard and textbook dominated pedagogy, the teacher passes the information and the children are the passive recipient of information. Teaching methods play a very important role in enhancing the learning skills and outcomes of the children. The method of teaching has to be amended and new fascinating and innovative ways ought to be followed for effective teaching of science [1-3].

Effective teaching-learning engages children in grasping the subject in such a way that they construct purposeful and intelligible knowledge. The emergence of Information and Communication Technology (ICT) in educational practice has remodelled pedagogy and learning to a lot of viable and effective technique [4,5]. The benefits of using ICT, in the case of science education, embody facilitating visualization, streamlining the transfer of information between teachers and students. In ICT integrated pedagogy, materials like animations, animated pictures and multimedia software etc are used in the classroom. The graphics like computer animations and simulations are particularly vital when representing abstract phenomena of science that learners cannot observe or expertise directly. Utilization of computer animations alongside demonstrating teaching ways and techniques in addition to the children effectively participating in the process ensure the provision of an effective and proficient education ([6], Khan et al. 2015; [7,8]). The integration of technology in teaching and learning is quickly turning into one among the foremost significant focuses of study in educational research.

A number of studies have been carried out in the last two decades to investigate the relationship

between ICT and quality of education but these studies give mixed findings on the impact of ICT on the students' achievements. Several experts in agreement that, ICT have the potential to form an efficient interactive learning surrounding promoting children's intellectual qualities through higher-order thinking, problem-solving, better communication skills and deep understanding of the concepts to be taught and culminate in the accomplishment of educational goals and objectives [9,10,11]. The study of Ellis and Loveless [12] affirmed that the prospective roles of ICT in education cannot be overlooked, and also indicated that school education pedagogy could neither be isolated from academic achievement nor from the teaching process and innovation. The study of Chan et al. [13] made a similar observation that ICT has an immense significance in democratizing the education and fulfilling dynamic demands of children. Likewise, Wastiau et al. [14] indicated that the integration of ICT in teaching-learning process has positive effects. Hussain et al. [15] in their study observed that ICT had a positive impact on students' academic achievement and retention capacity. They also observed that ICT was more enthralling, fruitful and valuable in teaching of science when compared with the conventional chalk and talk techniques of teaching. The researchers like Abdullahi [16], Kreijns et al. [17], Sanchez et al. [18], Solar et al. [19] and Sabi [20] have all opined that the integration of ICT enhances the quality of learning and improves the quality of children's achievement. This is in accordance with the study by Gallego et al. [21] who argued that a country needs to implement ICT policies and regulations effectively and vigorously at all levels of education for successful improvement of the quality of education. The findings of Basri et al. [22] revealed that there exists a positive relationship between ICT adoption and academic performance of children. An additional finding also stated that ICT adoption resulted in the improvement of the performance of female students more than the male.

Several researchers have argued in a different way regarding the impact of ICT and the academic performance of children. Venkatesh et al. [23] in their study observed that no actual effects of ICT exist in education since all research done so far are based on the socio-economic background of children and implant

characteristics of the school. Lin et al. [24] pointed out that there is no clear cut evidence of any strong impact of the application of ICT in learning outcomes of children. Similarly, Babaheidari and Svensson [25] observed no clear impact of ICT on students' performance. Cruz-Jesus et al. [26] critically analyzed various studies related to the impact of ICT on educational institutions in Europe. Their findings indicated that evidences in favour of impact of ICT adoption on students' performance are limited. None of these studies provided any substantive findings to establish that ICT integrated pedagogy had a positive impact on students' performance.

Such mixed results confirm that there is inadequate factual evidence of the ICT impact on students' achievement, and also, there is an absence of well-developed and reliable theoretical studies to support the benefits resulting from ICT implementation. Consequently, it cannot be assumed that the utilization of ICT transforms science education altogether for the better. In this context, it is relevant to study the impact of ICT integrated pedagogy on learning outcomes in science at the upper primary level.

1.1 Statement of the Problem

Based on the identified research gaps, a need was felt to verify that the integration of ICT has a positive or negative impact on learning outcomes of students at upper primary level. The proposed research was also undertaken to explore how far the adoption of technology integrated pedagogy with content will facilitate to reinforce children understanding of abstract science concepts. "Cell: Structure and Functions" of class VIII NCERT textbook was selected for the study. The microscopic nature of cells and their usual invisibility to the naked eye makes it cognitively inaccessible to children. Then how children perceive that cells are the building blocks of living organisms and cellular components work together to carry out life functions as these are abstract in nature? The investigators intend to search out how far the utilization of ICT integration in teaching 'Cell: Structure and Functions' will contribute to upper primary children in understanding of concepts and achieving the learning outcomes.

1.2 Objectives of the Study

The researchers seek to meet the following research objectives in this study:

1. To study the effectiveness of ICT integrated pedagogy in enhancing learning outcomes in science of upper primary children in comparison to traditional method.
2. To compare the learning outcomes in science of male and female upper primary children taught through ICT integrated pedagogy and traditional method.

1.3 Hypotheses of the Study

Based on the research objectives, the following null hypotheses were formulated for testing the significance at 0.05 levels.

1. There is no significant difference in the mean learning outcomes in science of upper primary children taught through ICT integrated pedagogy and traditional chalk and talk pedagogy.
2. There is no significant difference in the mean learning outcomes in science of male and female upper primary children taught through ICT integrated pedagogy and traditional chalk and talk pedagogy.

2. METHODS

2.1 Research Design

The design adopted for this study was Quasi-experimental Pretest - Posttest randomized experimental and control group design [27]. The independent variable is ICT integrated pedagogy and the dependent variable is learning outcomes in science. The experimental design has three stages such as pre-test, intervention and post-test.

Pre-Test: Here the investigator has prepared and standardized the achievement test in science basing on the chapter 'Cell structure and functions'. Further, instructional material/plan by using ICT integrated pedagogy and traditional were designed and validated by taking experts comments and suggestions. After taking permission from the schools, the investigators used separate sections as control and experimental group and conducted pre-test on all participants. The answer sheets were evaluated as per the scoring key developed by the investigators.

Intervention: This is the main stage of experiment where investigators applied ICT integrated pedagogy and traditional pedagogy in

experimental group and control groups respectively. The attention was given on the activities of intervention as planned. The investigator has observed the teaching and learning of students during the experimentation.

Post-Test: At the end of intervention, post test was conducted on both control and experimental groups by use of test developed for the purpose. The investigator has tried to administer the post-test in the same condition as it was done for pre-test. All the answer script of students were evaluated and scores recorded separately for data analysis. The details of research design are presented in the following table.

2.2 Sample and Sampling Technique

The sample for this study was one hundred twenty five upper primary students of class VIII from two identified coeducational Jawahar Navodaya Vidyalaya (JNV) of the State of Odisha, India. In one of the JNV (Khorda) there were two sections of class VIII. One section was randomly selected having fifty children (twenty five boys and twenty five girls) was made experimental group (EG) (Table 1). They were taught Cell structure and Functions by ICT integrated pedagogy. The other section was having thirty five children (twenty three boys and thirteen girls) was made control group 1 (CG1). The children of control group were taught by conventional teaching method using a teacher-centered strategy. To verify the accuracy of the result, investigators randomly selected one section of class VIII in another JNV having forty children (twenty three boys and seventeen girls) as second control group (CG2) (Table 1).

2.3 Research Instruments

The tools developed by the investigators were used during the study as follows:

Instructional tools: Lesson plan on ICT integrated pedagogy consisting of animations, audio-video material and PPT were developed and validated with the help of experts. The PPT on Cell structure and Functions with animations, images and audio-video material were used. ICT integration was done in the different phases of teaching from introduction to closure of the lesson. Lesson plan for the traditional teaching method included following steps: introduction, presentation and evaluation was used.

Measuring tools: Two sets of equivalent statement based questions (SBQ) were

developed, one set for pre-test and the other for post-test for assessing comprehension and learning outcomes in science (Cell structure and functions). Each set consisted of total of 28 statements and each with two alternative choices i.e. agree and disagree. It consisted of both true and false statements randomly interspersed to avoid guessing by the students. Statement based questions were in a 2 point scale. For a correct statement, choice agree was given one mark while disagree was awarded zero mark. For a false statement, choice disagree was awarded one mark while agree choice was awarded zero. Content validity of the test was ensured by incorporating suggestions and comments of experts and other teachers. An interview was done on selected students for getting views on ICT integrated pedagogy.

2.4 Procedure of Experiment

Pre-experimental phase: The investigators visited the selected schools for official permission from the two JNV school authorities. A test was conducted to verify the compatibility of knowledge on 'Cell: Structure and Functions' of all three groups. Instructional materials and pre-test were developed for this chapter based on ICT integrated pedagogy and traditional method. The pre test was conducted for all three groups.

Experimental phase: After the pre-test, the three groups were intervened by two different methods of teaching separately. The experimental group was taught by ICT integrated pedagogy while control groups were taught by traditional chalk-board method. During the transaction of the topic in the experimental group, the researcher used PPT, audio-videos and animations in addition to board. An effective classroom environment was created by the researchers by which students were motivated towards active participation and interaction. In the traditional group, the researchers transacted the topic by lecture method using black-board, charts and interacted with students by asking questions in between.

Post-experimental phase: After the completion of intervention, post test was administered by using another set of statement based questions on all three groups. A comparison was made on the basis of scores of children of experimental and control groups of students to find out the effectiveness of ICT integrated pedagogy in terms of learning outcomes in science. Seven

Table 1. Research design

Group	Pre-test	Independent variable	Post-test
Experimental group (n = 50)	T ₁	ICT integrated constructivist approach	T ₂
Control group I (n=35)	T ₁	Traditional approach (Lecture method)	T ₂
Control group II (n=40)	T ₁	Traditional approach (Lecture method)	T ₂

students from each group were randomly selected for personal interview.

2.5 Method of Data Analysis

Descriptive and Inferential analysis were done to test the hypotheses. t-Test and Analysis of Variance (ANOVA) statistic were used to analyze the pretest and posttest data. The mean scores of the three groups of students i.e. one experimental and two control groups and mean scores of boys and girls were used for comparison. Computer statistical package for the Social Sciences (SPSS) version 22 was used for analyzing the data. The probability level of 0.05 was used for testing the hypotheses.

3. RESULTS AND DISCUSSION

The most important finding from this study was that ICT integrated pedagogy had a significant effect on the experimental group children's accomplishment and learning outcomes of the topic Cell: Structure and Functions from the analysis of data of the pretest and posttest. To explore the effectiveness of ICT integrated pedagogy on students learning outcomes on the topic 'Cell: Structure and Functions', a comparison of mean scores of experimental group and control groups was done through 'F' test, post-hoc analysis and means plot.

The analysis of the data demonstrated a significant difference ($p < 0.000$) between all three groups for learning outcomes of the chapter Cell: Structure and Functions as indicated by the 'F' value. The results clearly revealed that there was highly significant difference between the mean posttest scores of experimental group and both control groups for concepts of Cell: Structure and Functions. The null hypotheses "there is no significant difference in the mean learning outcomes in science of upper primary children taught through ICT integrated pedagogy and traditional method' is rejected at 0.01 levels (Table 2). The investigators have done Post-hoc analysis to find out the significant difference between groups.

Further, when investigators compared the dependent variable i.e. mean posttest score of one group with another independently, it was observed that (Table 3):

- I. A highly significant difference between experimental group and control group 1 ($p < 0.000$) and with control group 2 ($p < 0.000$).
- II. A highly significant difference between control group 1 and experimental group ($p < 0.000$) but no significant difference with control group 2.
- III. A highly significant difference between control group 2 and experimental group ($p < 0.000$) but no significant difference with control group 1.

It can be concluded that ICT integrated pedagogy has significant effect on the learning outcomes in science at upper primary level. The post-test means of three groups are presented in Fig. 1.

The results of the responses to statement based questions of the study revealed that before intervention, the difference in mean pretest scores was not significant between experimental group and the two control groups. The mean pretest scores were 14.56, 13.86 and 16.53 of experimental group, control group 1 and control group 2 respectively. After intervention, the posttest scores were 25.68, 20.09 and 19.9 for experimental group, control group 1 and control group 2 respectively (Fig. 2). The results of the pretest and posttest shows there is increase in mean achievement scores of all three groups. However, the mean achievement score of experimental group is 11.12 which is significantly higher than control group 1 (6.229) and control group 2 (3.375) (Fig. 3). The mean scores of pretest and posttest results demonstrated that all the three groups have different levels of conceptual clarity on Cell: Structure and Functions after intervention.

The above result (Table 4) indicated that 'F' is significant at 0.01 levels. So the investigators have done post hoc analysis which is mentioned below.

Table 2. 'F' value of means of post-test of all three groups

Groups	Sum of Squares	df	Mean Square	'F'	Significance level
Between Groups	973.065	2	486.533	49.579	.000
Within Groups	1197.223	122	9.813		
Total	2170.288	124			

Table 3. Post-hoc analysis of control and experimental groups

Groups		Mean difference (I-J)	Std. error	Significance level
Experimental	Control 1	5.594	.690	.000
	Control 2	5.780	.665	.000
Control 1	Experimental	-5.594	.690	.000
	Control 2	.186	.725	1.000
Control 2	Experimental	-5.780	.665	.000
	Control 1	-.186	.725	1.000

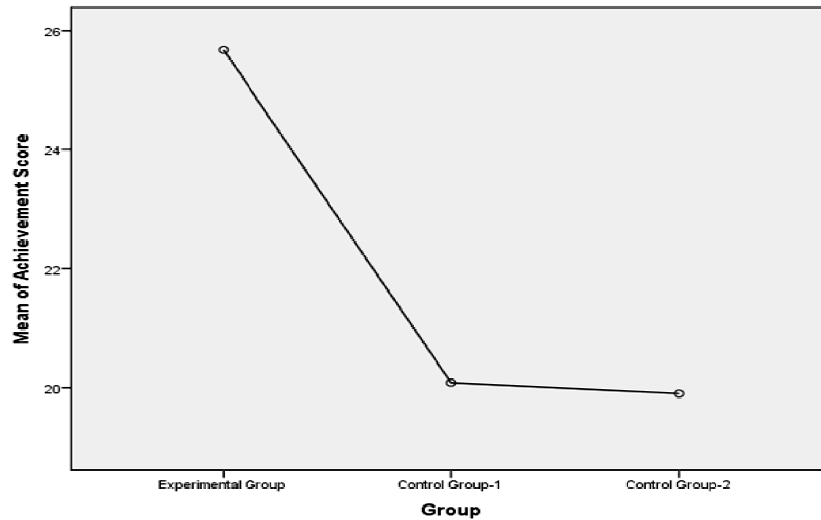


Fig. 1. The post-test means plot of experimental group and two control groups

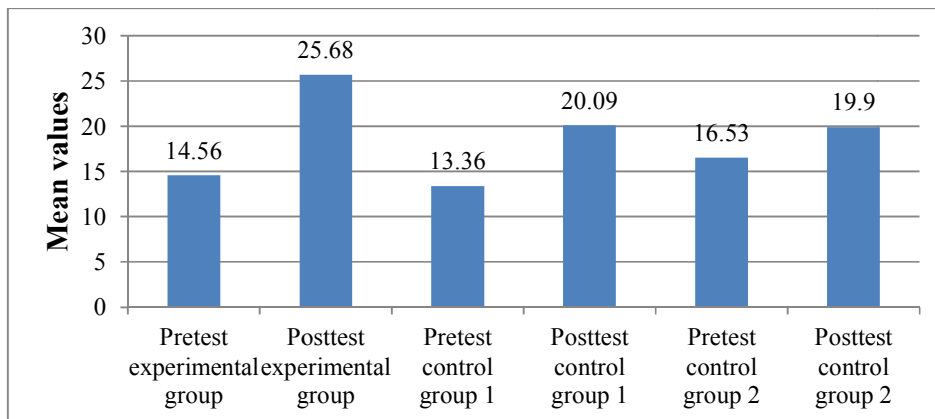


Fig. 2. Mean achievement scores of pre test and post test of three groups

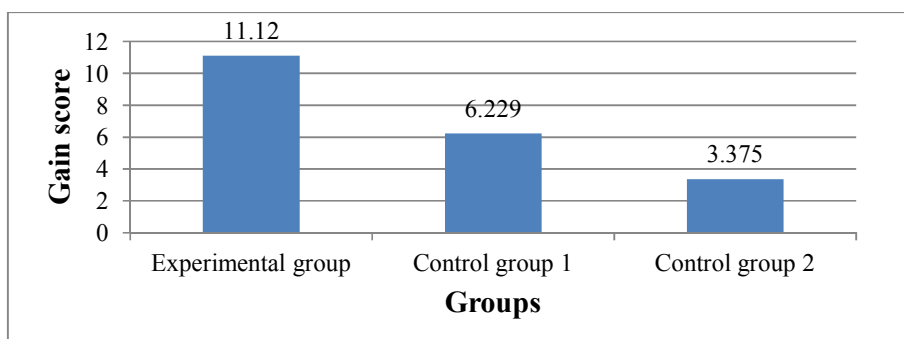


Fig. 3. Difference in gain scores between pre-test and post-test of three groups

Table 4. F-test for gain scores of experimental group, control group 1 and control group 2.

Group	Sum of squares	df	Mean square	F	Significance
Between groups	1337.194	2	668.597	20.518	.000
Within groups	3975.398	122	32.585		
Total	5312.592	124			

The post hoc analysis of gain scores of all three groups clearly showed that there is significant difference between the experimental group and control groups (Table 5, Fig. 4). The upper primary children of experimental group taught through ICT integrated pedagogy had better comprehension and learning outcomes of Cell: Structure and Functions than children of control groups taught through traditional chalk and talk pedagogy. To compare the impact of ICT integrated pedagogy on learning outcomes in science of boys and girls, the investigators used t-test, and line graphs.

The high significant difference in the mean scores and standard deviation of the children in the control groups and experimental group suggested that the children of the experimental group gained significantly after treatment compared to children of control groups. The findings of the present study indicate that the

learning skills encouraged by the integration of ICT, such as computer animations and PPT, appear to be an effective way to emphasize understanding rather than acquisition of factual information. The results are consistent with Safdar, Yousuf, Parveen and Behlol [28], Ziden, Ismail, Spien and Kumutha [29], Aloraini [30], Agrahari and Singh [31], Avinash and Shailja [32], Mohapatra and Mohapatra [33], Harris et al. (2016) and Kareem [7] who found that the application of ICT in teaching and learning has a positive effect on student achievement scores in science at secondary level and more compelling and effective than the conventional teaching approach. Similarly, Okoro and Ekpo [34] concluded that students performed well who were taught through ICT as compared to those who were taught via conventional instructional strategy. Similar observations have also been stated by Balci et al. [35], Ceylan and Geban [36] and while studying the effectiveness of ICT

Table 5. Post hoc analysis of gain scores of experimental group, control group 1 and control group 2

Groups	Mean difference (I-J)	Std. Error	Significance
Control group 1	3.034	1.258	.052
Experimental group			
Control group 2	7.745	1.211	.000
Experimental group	-3.034	1.258	.052
Control group 1			
Control group 2	4.711	1.321	.002
Experimental group	-7.745	1.211	.000
Control group 2			
Control group 1	-4.711	1.32	.002

integrated pedagogy. This contradicts with the findings of Cener, Acun and Demirhan [37] who concluded that ICT does not have any effect on students' achievement scores. Similarly, Mbaeze, Ukwandu and Anudu [38] reported that there was no significant relationship between ICT and students' academic performance.

The comparison of the mean pretest and posttest scores of children of experimental group revealed that the mean difference in 't' value

was highly significant ($p < 0.000$) with df 49 (Table 6). The mean and individual pretest and posttest scores of experimental group boys and girls showed significant improvement ($p < 0.000$) in comprehension and learning outcomes of concepts of Cell: Structure and Functions (Table 7; Figs. 5 and 6). However, the analysis of data showed no significant difference in improvement between boys and girls related to understanding of the topic (Table 7, Fig. 7).

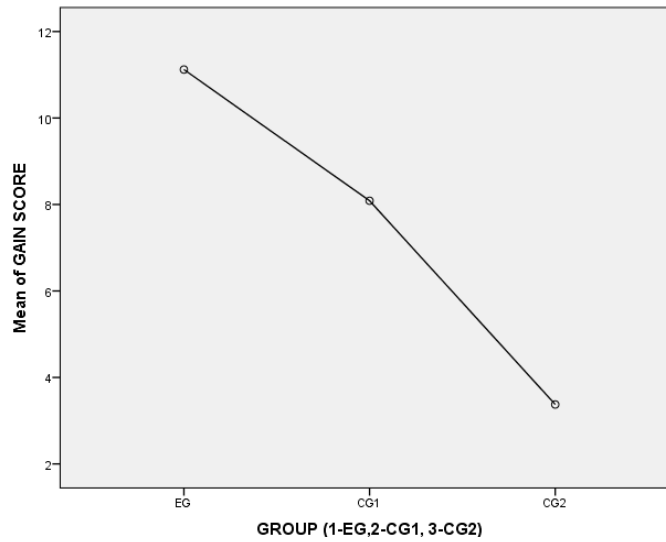


Fig. 4. Means plots of gain scores of experimental group (EG), control group 1 (CG1) and control group 2 (CG2)

Table 6. 't' Test of experimental group in relation to their knowledge about the concepts before and after ICT integrated teaching

Experimental group	N	Mean	S.D.	't'	df	Significance level
Pre-test	50	14.56	3.764	-18.314	49	0.000
Post-test	50	25.68	3.100			

Table 7. t-Test for pretest and post-test of boys and girls of experimental group (EG)

Groups	N	Mean	Std. Deviation	df	t	Sig. (2-tailed)
Pair 1	Pre-test boys EG	25	13.96	2.031	24	-15.132 .000
	Post-test boys EG	25	25.52	3.318		
Pair 2	Pre-test girls EG	25	15.16	4.905	24	-9.094 .000
	Post-test girls EG	25	25.84	2.925		
Pair 3	Post-test boys EG	25	25.52	3.318	24	-.356 .725
	Post-test girls EG	25	25.84	2.925		

The results of the present study showed some improvement by the children of control group 1 and 2 in comprehension of Cell: Structure and Functions. The mean difference in 't' value was highly significant ($p < 0.000$) with df 34 (Table 8) for control group 1 and 39 (Table 9) for control group 2. The achievement scores of boys and girls of control groups 1 and 2 showed improvement to some extent by traditional teaching pedagogy reflected by their pretest and posttest results (Figs. 8, 9, 11 and 12). However, there was no significant difference between the boys and girls improvement of the concepts of the science topic in both control group 1 and 2 (Figs. 10 and 13).

as well as of how compatible these processes were with a given learning situation. ICT appeared to allow children to achieve this and has positive effects on children's learning outcomes compared with being passive recipients of information as in chalk and talk with no improvement in learning outcomes [30,2]. In the individual interviews, when children of ICT integrated pedagogy group were asked: Did the ICT activities such as computer animation and power point presentations helped you in gaining a better understanding of the topic Cell: Structure and Functions? All the interviewees gave an affirmative response to the question. The children said that the computer animations helped them to visualize the abstract concepts of cell in a concrete manner. It clearly showed the nucleus and different parts of a cell and we could

An effective teaching makes children more aware of their own knowledge and cognitive processes,

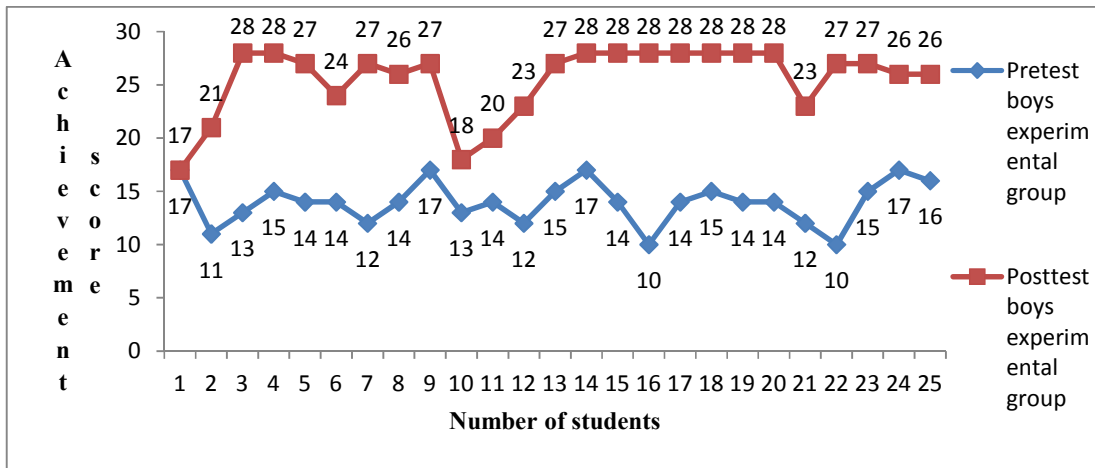


Fig. 5. Experimental group boys showing improvement of post test scores over pretest

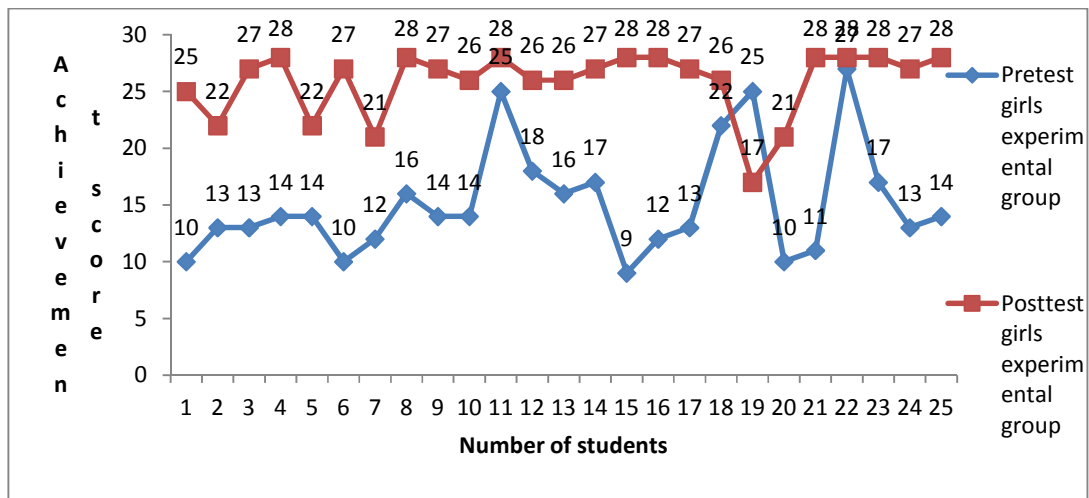


Fig. 6. Experimental group girls showing improvement of post test scores over pre-test

see them in front of our eyes. It helped them more than the lesson in the class and “broke the routine” of the traditional chalk and talk format. Children suggested that they would like to have such activities in other science topics too. Rotbain et al. [39] in their study while teaching molecular biology by integrating ICT also reported similar feedback of students.

In view of the aforementioned findings, this study has been able to establish that the hypotheses are acceptable because there was a statistically

significant difference between pretest and posttest mean scores of the children taught by integration of ICT and the children taught by chalkboard and textbook dominated method. This finding of the present study corroborates similar research findings of McClean et al. [40], O’Day [41] and Asli et al. [42]. The reasons for the results are that the novelty of ICT integrated learning instruction material makes it attractive enough for children. They can see movement and changes in the colorful diagrams and graphics which is quite motivating.

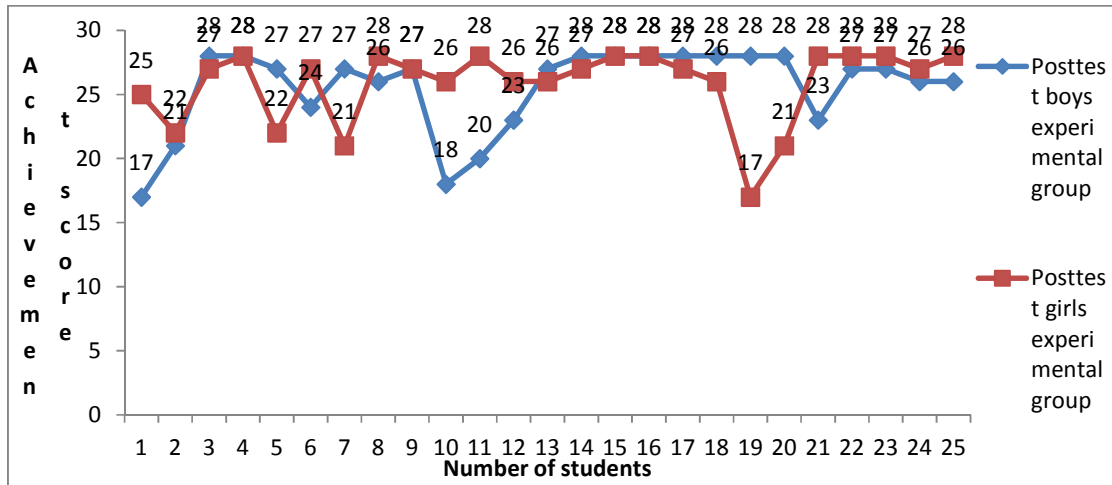


Fig. 7. Comparison of post test scores of boys with girls of experimental group.

Table 8. ‘t’ Test of control group 1 in relation to their knowledge about the concepts before and after traditional teaching

Control group 1	N	Mean	S.D.	‘t’	df	Significance level
Pre-test	35	13.86	2.303	-8.741	34	0.000
Post-test	35	20.09	3.175			

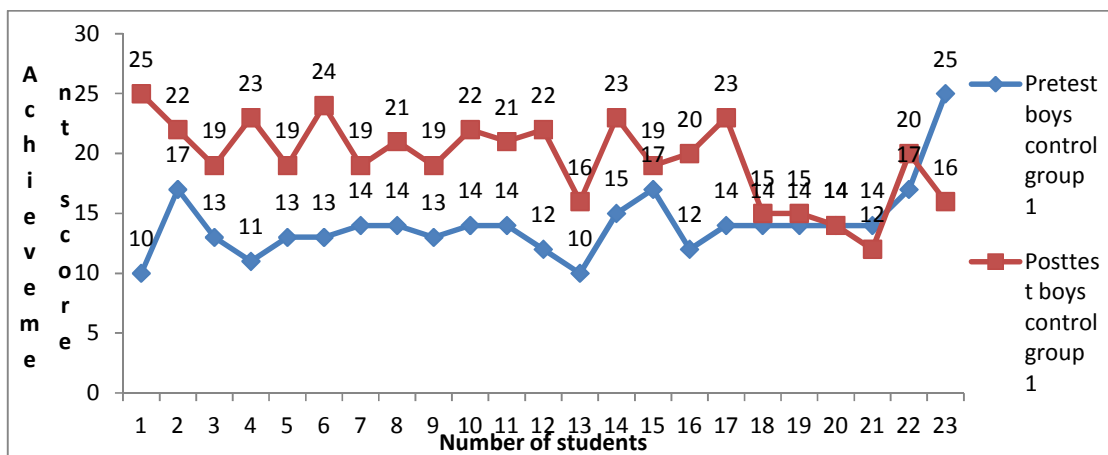


Fig. 8. Control group 1 boys showing improvement of post test scores over pre-test

The findings of the present study revealed that gender has no significant effect on children's learning outcomes in experimental group in which the topic was discussed by ICT integrated pedagogy. But the findings of this study is contrary to the finding of Bosede [43] and Basri et al. [22] that children's academic achievement in science in ICT integrated instruction is influenced by gender with male children out performed the female children.

3.1 Educational Implications

- ICTs can and can empower teachers and learners, transforming teaching and learning processes from being highly teacher-dominated to child-centred.

- This transformation will end in increased learning gains for children, creating and allowing for opportunities for learners to develop their creativity, problem-solving abilities, informational reasoning skills, communication skills, and other higher-order thinking skills.
- Exposure to ICT from an early age has changed the way during which child approach learning, with children tending to use rapid trial and error, instead of systematic, approaches.
- Children also appear to possess different preferences for the way in which they receive information – pertaining to receive it quickly, to access it during a more haphazard fashion and also enjoying the chance to multi-task.

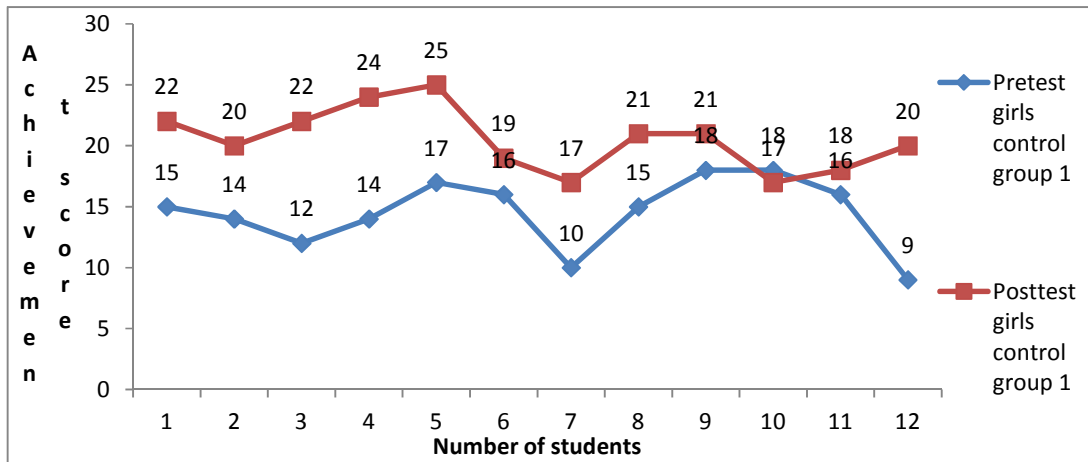


Fig. 9. Control group 1 girls showing improvement of post test scores over pre-test

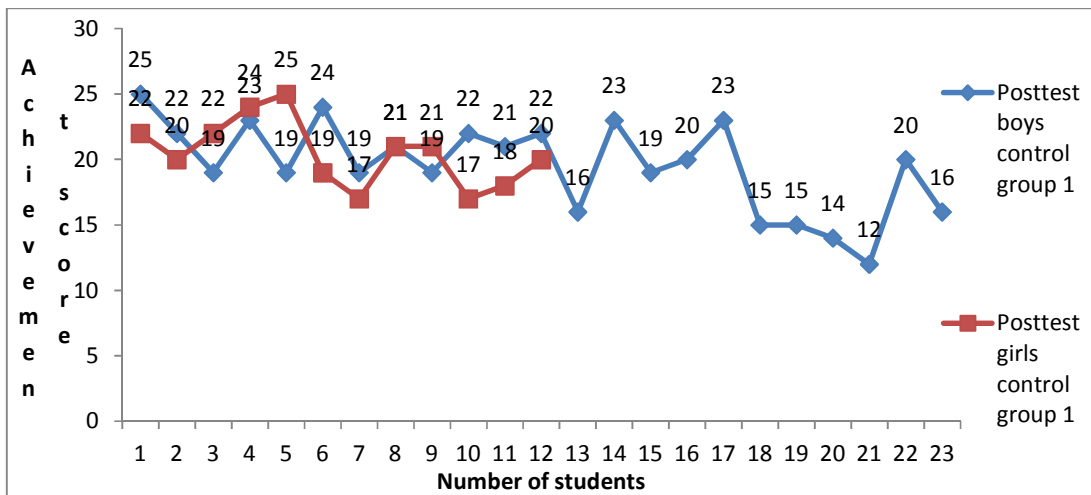


Fig. 10. Comparison of post test scores of boys with girls of control group 1

- More sophisticated ICTs have the potential to transform the nature of the learning experience and create a more interactive and engaging learning environment for children.
- The investigators recommend that the utilization of ICT is capable of remodeling children from passive receptacles of information into active learners, to be used to teach science in more meaningful learning. Visual representations most liked for displaying multiple relationships and processes that are tough to elucidate with text alone. These graphics offer an extra means of representing information, and once designed and chosen rigorously, have the potential for improving conceptual learning.
- Curriculum planners should include and enforce the utilization of ICT and computer education training into the school curricula.

Table 9. 't' Test of control group 2 in relation to their knowledge about the concepts before and after traditional teaching

Control group 2	N	Mean	S.D.	't'	df	Significance level
Pre-test	40	16.53	2.481	-9.635	39	0.000
Post-test	40	19.90	3.136			

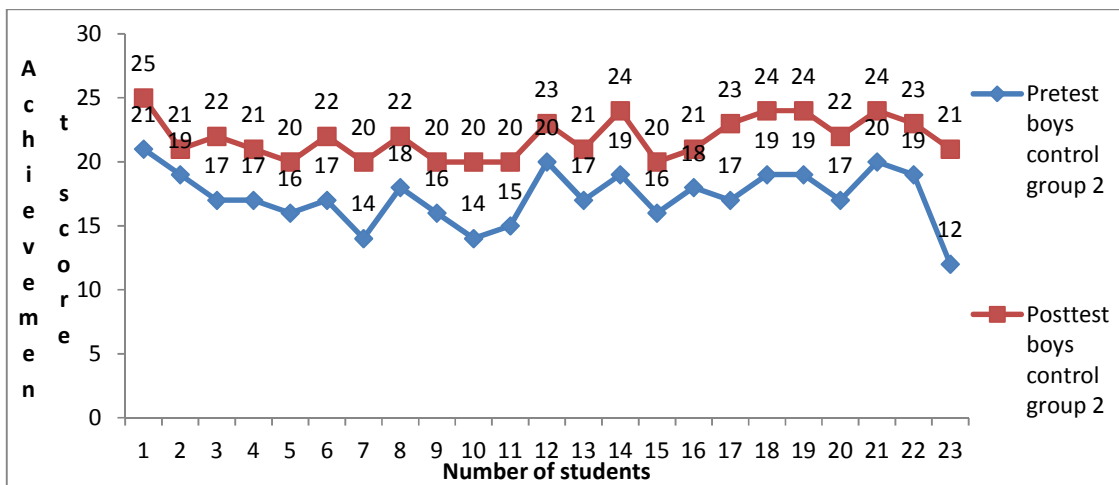


Fig. 11. Control group 2 boys showing improvement of post test scores over pretest

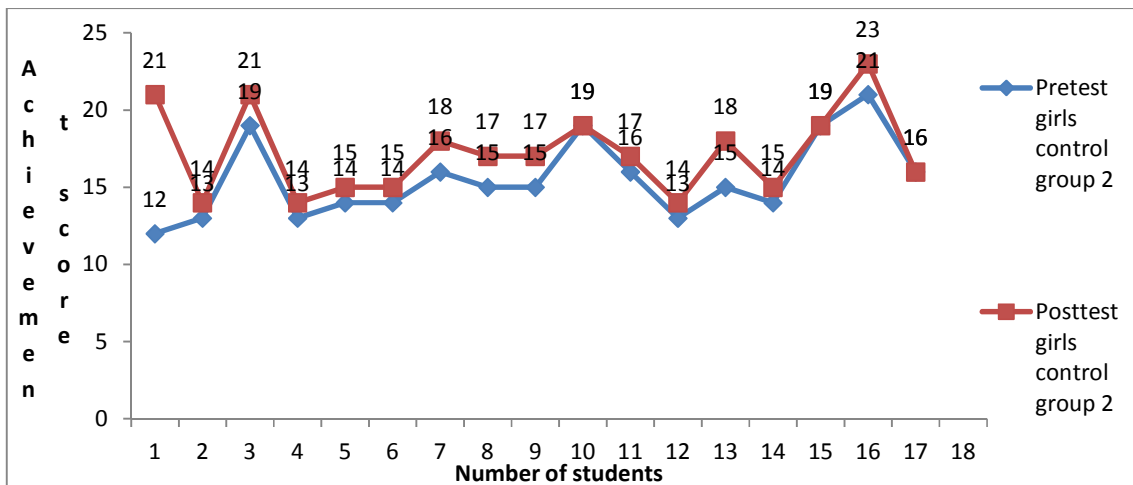


Fig. 12. Control group 2 girls showing improvement of post test scores over pre-test.

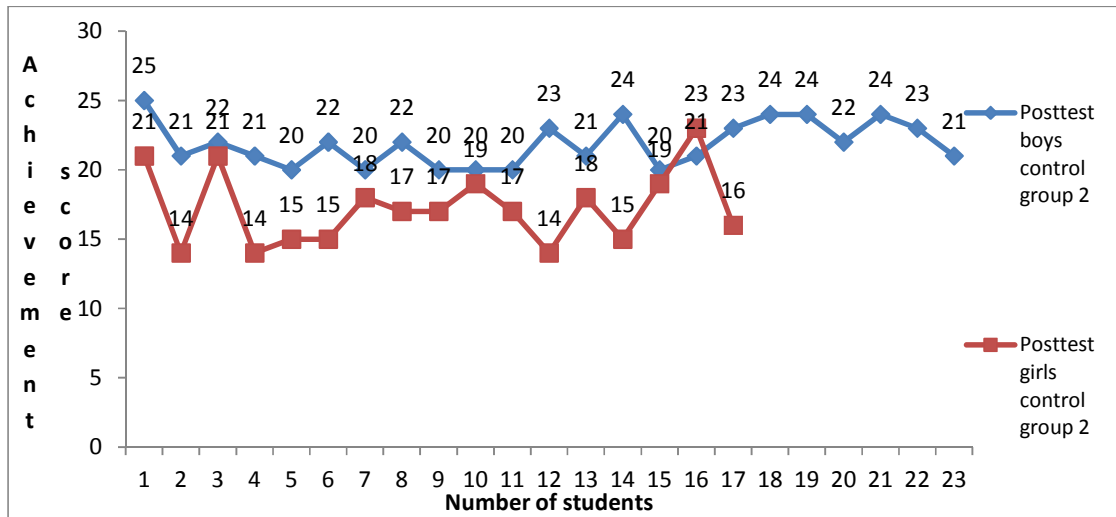


Fig. 13. Comparison of post test scores of boys with girls of control group 2

4. CONCLUSION

In sum, the findings of this study are indicative of the fact that ICT (computer animation graphics, PPT etc) has the capability of motivating children to higher performance by bringing about higher gains in achievement when compared to conventional chalk and talk method. Adequate motivation of teachers is very important as it would allow them to put more effort, spend extra time to gather material and give them sense of belonging in the society to equate with their counterparts in other professions.

CONSENT AND ETHICAL APPROVAL

As per international standard or university standard guideline participant consent and ethical approval has been collected and preserved by the authors.

ACKNOWLEDGEMENT

The investigators are grateful to Prof. P. C. Agrawal, Principal, Regional Institute of Education for constant encouragement and Principals of Navodaya Vidyalayas for providing facilities to carryout the study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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