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Efficacy of ICT as a Transactional Pedagogical Strategy in Teaching of Science at Secondary Stage

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Abstract

There is a colossal debate about the role and extent of the information and communication technology (ICT) in transforming the science pedagogical practices. Improving Science Education is fundamental, indispensable, crucial as well as essential priority to elevate the levels of scientific literacy. Aiming at the improvement of quality and effectiveness of Science education making use of new ICT tools, in-class is clearly proved in different school levels and disciplines. The present study intends to find out efficacy of ICT as a transactional pedagogical strategy in teaching of science at secondary stage. Via conducting experiment and using 2x2x2 factorial design it was divulged that there is significant effect of ICT based transactional pedagogical strategy and physical facilities on the academic achievement of students in science. Moreover the effect of treatment on the achievement of the students in science in relation to intelligence is striking.

Keywords: ICT, science pedagogy, ICT in science pedagogy

The very air we breathe literally buzzes with all kinds of information signals. ICT encompass all the technologies by means of which we can detect these signals, interpret them and exchange information with others. The term ICT is plural, referring to a great many technologies. To sum up, ICT is an all encompassing term that includes the full gamut of electronic tools by means of which we gather record and store information, and by means of which we exchange and distribute information to others.

Information and communication technology (ICT) enabled science teaching-learning encompasses array of techniques, tools, content and resources aimed at perking up the eminence and efficiency of the teaching-learning process. There are varieties of choices accessible to the science teacher to employ assorted modes of ICT tools for effective pedagogy. So with the introduction of ICT in the science classroom, the techniques, processes and approaches to science learning are larger especially to inculcate scientific skills, knowledge and application as it can provide an environment for learning that is self paced, learner controlled and oozes dynamism.

It is very true that appropriate educational technologies have the potential to make scientific concepts more accessible through visualization, modeling, and multiple representations (Bearer, 1991; Gardner *et al*., 1994). Analysis of studies unveiled that students with computer-based teaching scored better in final examinations than the students in conventionally taught classes (Kulik, Banger, and Williams, 1983). In science, visual aids, such as practical or video demonstrations, have always been used to explore difficult concepts and ICT can, especially in the form of simulations and models, greatly enhance the learning experience (NCET, 1994). It was established that students using a computerized integrated learning system (ILS) in both laboratory and classroom settings were more actively engaged in learning tasks than students in the non-ILS classrooms (Worthier, Duson, and Sailor, 1994).It was revealed that the video lesson has been found to be more effective than printed lesson (Muchal, 2001). Some experimental studies have confirmed that computer simulations can be as effective as the real activity in teaching science concepts and improving scientific understanding across a variety of topics (Huppert, Lazarowitz, Fiolhais, and Almeida, 2002).

ICT boost learner's knowledge when it involves the synergy of multiple senses. Learners were found to retain new knowledge better when the curriculum was presented with a combination of formats of text, sound, graphics and video (Bergman and Cheney, 1996). It was also reported that on work done in exploring the effects of software in a range of school subjects, including science established benefits in terms of understanding (Collins *et al*., 1997). Research has suggested that using computer modeling and simulation allows learners to understand and investigate far more complex models and processes than they can in a school laboratory setting (reviewed by Millar *et al*., 1994; Linn 1999; Cox, 2000).

Pupils receiving traditional instructions supplemented with computer-assisted instruction attained higher academic achievement than those who are receiving only traditional instructions and the effects on achievement were greater in science than in other subjects (Chrisman *et al*., 1997).

ICT can help to deepen students' content knowledge, engage them in constructing their own knowledge, and support the development of complex thinking skills (Kulik, 2003; Webb and Cox, 2004; Kozma, 2005). ICTs can be very helpful in communicating and representing ideas in science (Whitelock, and Littleton , 2010).

To ensure quality science education the essential facilities like text book, teacher, teaching aids, library, laboratory , co-scholastic activities and above all Information and Communication Technologies (ICTs) are required. In India, various ICTs have been employed over the years to promote primary and secondary education. These include radio, satellite based, one-way and interactive television, and the Internet. Scholars (Wilcockson 1994, Lawal 1995, Ajayi 1996) have identified the significance of facilities in teaching learning spheres and concluded that absence or poor (and or deteriorating) quality of educational facilities can affect academic performance.

It is not appropriate to simply assume that the introduction of learning technologies in schools necessarily transforms the science education (Osborne and Hennessy, 2004). In the classroom, where learning objects are encountered in a social and discursive environment, digital resources can assist teachers and students to slow down and focus on the intermediate cognitive processes of observing, predicting and explaining that are central to science inquiry and understanding (Polman and Pea, 2007).

The effective use of ICT in science places considerable pedagogical demands on teachers. Teachers need to be clear on how a particular application will meet learning objectives (Thomas, 2001) and should be aware of its implications. Further it was proclaimed that, "With the aid of technology, many science teachers can take students beyond traditional curriculum limits, creating virtual environments for experimentation and exploration" (Hama and Alhalabi, 1990).

From the exceeding, it is apparent that ICT mediated instructional strategy is superior to traditional instructional method.

Objectives

The study was designed to achieve the following objectives:

1. to study the effectiveness of treatment on the achievement of the students in science in relation to intelligence.
2. to study the effectiveness of treatment on the achievement of the students in science in relation to Physical facilities.

Hypotheses

The present study intended to test the following hypotheses:

1. There is no significant difference in the achievement of the students with ICT and without ICT mediated classroom instructional strategies.
2. There is no significant difference in the achievement of the students with high intelligence and low intelligence in the subject.
3. There is no significant difference in the achievement of the students with rich and poor physical facilities.
4. With ICT and without ICT mediated classroom instructions, achievement in science is equal in case of high intelligent and low intelligent groups.
5. With ICT and without ICT mediated classroom instructions, achievement in science is comparable at the two levels of physical facilities.
6. There is no significant difference in the achievement of high and low intelligent students at both the levels of physical facilities.
7. With ICT and without ICT mediated classroom instructions achievement scores are equal for high intelligent and low intelligent students at both levels of physical facilities.

Methods

The present study is of experimental type. A pre and post-test experimental design has been used to determine the effectiveness of instructions with and without information and communication technology in science subject at secondary stage.

Sample selection: Simple random sampling was employed. The sample of the study comprised thirteen public schools affiliated to Central Board of Secondary Education board from Gurdaspur district of Punjab. Afterward rating scale of physical facilities was administered. On the basis of the scores, the top 3 schools represented rich physical facilities, and bottom 3 schools represented poor physical facilities were selected. In total, 608 students of IX class were taken as the sample for the study. Intelligence test of Standard Progressive Matrices set by Raven (1998) for testing intelligence was administered. The obtained scores were arranged in descending order of their magnitude. On the basis of intelligence scores, students were classified into high intelligent and low intelligent groups by taking 30% top and 30% bottom students.

Equal number of students was assigned to two groups viz., ICT mediated instructions and without ICT mediated instructions. Thus, the groups of subjects selected, represented the eight groups in each of the selected schools. Each sub group consisted of 45 students. In total the sample of the study comprised 360 students.

Design of the Study

2 x 2 x 2 factorial design was employed on the achievement gain scores in science with ICT and without ICT mediated classroom instructions in relation to intelligence and physical facilities. In the present design, gain in achievement was studied as dependent variable. Intelligence and physical facilities were studied as independent variables and were further studied at high and low; rich and poor level respectively.

Tool used

Tools namely Standard Progressive Matrices by Raven (1998) for testing intelligence, rating scale for physical facilities adapted from Sikand, (1995), achievement test in science prepared by the investigator and ICT based instructional plans prepared by the investigator were used for data collection.

After the selection of the sample, the pre achievement test of science was administered. One group was taught through ICT mediated instructional system and the second group was assigned to teacher directed instructional system. After the completion of the treatment of 34 working days, post test of achievement in science was administered to obtain the gain achievement score in science.

Analysis of Data

In order to analyze the achievement gain scores in science, the computed mean and SDs of different subgroups i.e. experimental and control groups with respect to two levels of intelligence and physical facilities is given in the Table 1.

Analysis of Variance of gain scores of Achievement in Science

In the present experimental study, the 2x2x2 factorial design was employed. The effect of the three independent variables on the achievement gain scores in science of subjects was studied along with their interaction effects. In order to analyze the achievement gain scores in science, the F-ratios for the main and the interaction effects were computed and same is given in the Table 1.

Main Effects

Treatment (A)

It may be observed from the Table 1 that the F- ratio for the difference in achievement gain scores in science between control and experimental groups has been found to be significant at the 0.05 level of confidence. The examination of the corresponding means suggests that ICT mediated instruction group yielded higher achievement gain scores in science than the group taught without ICT mediated instructions. Hence, the hypothesis viz. “There is no significant difference in the achievement of the students with ICT and without ICT mediated classroom instructional strategies.” has been rejected.

The evidence from the literature also sustains the findings as Kulik, Bangert, and Williams (1983) unveiled that students with computer-based teaching scored better than did students in conventionally taught classes. Christmann *et al.*, (1997) analysis, indicated students with computer-assisted instruction attained higher academic achievement than did those only receiving traditional instruction.

Table 1: 2X2X2 ANOVA on gain scores of Achievement in Science

Source of Variance	SS	df	MSS	F-Value
Main Effects				
Treatment (A)	16769.025	1	16769.025	245.581**
Intelligence (B)	399.003	1	399.003	5.843*
Physical Facilities (C)	1043.803	1	1043.803	15.286**
Interaction Effects				
Treatment × Intelligence (A × B)	918.403	1	918.403	13.450**
Treatment × Physical Facilities (A × C)	535.336	1	535.336	7.840**
Intelligence × Physical Facilities (B × C)	177.803	1	177.803	2.604
Treatment X Intelligence X Physical Facilities (A × B × C)	3.803	1	3.803	.056
Error (Within)	24035.689	352	68.283	

*significant at the 0.05 level of confidence
**significant at the 0.01 level of confidence

Huppert *et al.*, (1998) the post-test results on academic achievement indicated that pupils in the experimental group achieved significantly higher mean scores than the control group. Sanjna (2001) concluded that both CAI and CMI were found to be contributed significantly towards the achievement of pupils in science. Kara (2008) investigated the retention effect of computer assisted instruction on students' academic achievemen. Muhlis (2009) found that in the science subject experimental group taught with ICT has higher achievement than control group.Mustafa and Turgay (2011) examined that the students on whom CAI method was applied came out more successful than control group on whom traditional method was applied.

Intelligence (B)

Table 1 indicates that F- ratio for the difference between means of achievement gain scores in science between high and low level of intelligence groups have been found to be significant at the 0.01 level of confidence. It specifies that two groups differ significantly in achievement gain scores in science. Further, the observation of the respective groups mean suggests that low intelligent group was found to be superior to high intelligent group with respect to achievement gain score in science. Hence, the hypothesis viz., "There is no significant difference in the achievement in science of the students with high intelligence and low intelligence group" has been rejected. The finding suggests that the gain in achievement in Science is higher in Low intelligence group than high intelligence Group.

It was found that intelligence is a major factor in influencing the academic achievement (Briggs 1962, Mitchell 1963, Keller and Rawley 1964). More intelligent children with more capabilities are likely to accomplish more on academic tasks (Torrance 1965). Exceptionally high achievement in final high school examinations correlated significantly with high I.Q (Berman, 1970). More intelligent children tend to get better grades in school, remain in school longer and have more positive attitude towards instructional media (Tyler 1974).

All the exceeding studies are incongruous to the finding as the low intelligent group was found to be performing better in terms of gain in academic achievement in science than to high intelligent group. Probably most of the studies are in terms of how intelligence effects achievement. In this very investigation the finding is in terms of gain in achievement. High Intelligent group normally performs better at Pre-Test Level in comparison to low intelligent group. After treatment the extent of improvement in Low Intelligent Group was higher as the scope of improvement was higher. Finding also lends credence to the submission of Niedderer *et. al.,* (1991) as it was established that when pupils are given autonomy to use ICT their own ideas and understanding, their ways of learning change, and there is improvement in their understanding and achievement.

Other finding also corroborate to the submission of Webb (1992) results which inferred that students were able to learn logical strategies for categorizing scientific processes and could construct relevant and reliable models successfully with the usage of scientific softwares. Boohan (1994) also furnished that by using ICT in science, pupils develop novel strategies for problem solving by building models and creating new rules. Mellar *et al.*, (1994) inferred that new technologies has affected learners' mental models, showing that learners develop new ways of reasoning and hypothesizing their own and new knowledge. Worthen, Dusen, and Sailor (1994) accomplished that students using a computerized integrated learning system (ILS) in both laboratory and classroom settings were more actively engaged in learning tasks than students in the non-ILS classrooms. Williamson and Abraham (1995) found that the simulations increased conceptual understanding by helping students from their own dynamic mental models. Berson (1996) concluded that by using internet, students can gain access to expansive knowledge links and broaden their exposure to diverse people and perspectives.

Collins *et al.*,(1997) reported on work done in exploring the effects of software in a range of school subjects, including science and established benefits in terms of understanding. Taylor *et al.*, (1997) divulged that modeling was used to build an understanding of pupils' misconceptions and has been shown to enhance pupils' cognitive skills. Hennessy (1999) exposed that the use of ICT changes the relative emphasis of scientific skills and thinking. Davelsbergh *et al.*, Henderson *et al.*, (2000) investigated that simulation helps in improvement in the thinking skills and strategies, from basic recall to higher level skills. Cox (2000) unveiled that pupils' understanding of science through the acquisition of investigative skills and improved understanding of some scientific concepts and processes was due o usage of multimedia.

Linn and Hsi, (2000) concluded that there were substantial improvements in understanding, problem-solving and inquiry skills. Chang (2000) inferred that CAI is superior in promoting students' learning of earth science concepts, especially knowledge and comprehension levels of Bloom's cognitive taxonomy. Desai (2001) found that programmed learning approach proved better than the lecture method in the study of physics and pupils scoring high on the intelligence test also scored high in the post test and pre test and those having low scores on the intelligence test scored low on the post test. Alev (2007) found that computer assisted instruction is more feasible than the traditional approach in terms of cognitive and affective behaviors. Ferguson, Whitelock, and Littleton (2010) divulged that ICTs can be very helpful in communicating and representing ideas in science.So, ICT mediated instructions in science can increase the level of achievement of low intelligent students substantially.

Physical Facilities (C)

It is experiential from the Table 1 that the F- ratio for the difference for means of achievement gain scores in science between rich and poor physical facilities has been found to be significant at the 0.05 level of confidence. Further, the observation of the respective means suggests that students belonging to rich physical facilities group were found to gain higher than poor physical facilities group with respect to their achievement gain scores in science. Hence, the hypothesis viz., "There is no significant difference on the achievement of the students with rich physical facilities and poor physical facilities" has been rejected.

This finding is in parallel with Adesina (1990) that adequate provision of school facilities in relation to the students' population is important because the quality of education that our children receive is affected by the availability or non-availability of physical facilities. Kovol (1991) examined the relationship of classroom physical features to the learning environment and found significance for every factor examined.

The most extensive meta-analysis conducted on school learning (Wang, Haertel, and Walber, 1993) pointed out that the positive relationship between the learner and the environment was the most critical factor. Olubor (1998) revealed that lack of adequate facilities such as textbooks, ill-equipped classrooms, laboratories, workshops and library are among the probable causes of student's poor performance in examinations.

Becta (2001) resulted that consistent positive differences were found in science attainment between those schools with good levels of ICT resources and those with poor levels of ICT resources. Dwyer, *et al.*, (2005) divulged that the use of computers and Internet can deliberately provide learning outcomes to their students. Edyburn (2006) disclosed that the collaboration of technology and teaching among the schools can be a good start in academic performance. Kang, (2007) unveiled that in addition to the educational investments such as providing facilities can strongly contribute to increase the academic performance of the students. So the physical facilities have a positive effect on the academic achievement of science students.

Two Order Interaction

(i)Treatment and Intelligence (A x B)

It may be observed from the Table 1 that the F-Ratio for interaction between treatment and intelligence has been found to be significant at the 0.01 level of confidence. Hence, the data provide sufficient evidence to reject the hypothesis (Beare,1991) viz., "With and without ICT mediated classroom instructions, achievement gain scores in science is equal in case of high intelligent and low intelligent groups" has been rejected. It suggests that the effect of teaching with ICT on the achievement gain scores in science is not independent of their respective levels of Intelligence.Further, in order to examine the interaction between the pairs of sub groups, t-values have been calculated and are presented in the Table 2.

It may be observed from the Table 2 that the differences between means of M_9-M_{11}, M_9- M_{10}, M_9- M_{12}, M_{11}- M_{10} and M_{11}- M_{12} groups have been found to be significant at the 0.01 level of confidence whereas the difference between the means of M_{10}-M_{12}group is not found to be significant even at the 0.05 level of confidence. The analysis of means Table 3 reveals that

Table 2: Summary of t-values of gain scores of achievement in science for treatment and intelligence

Two order interaction		D	SE	t- values
Treatment group x Intelligence	M_9-M_{11}	5.3	1.48	3.57**
	M_9- M_{10}	10.46	1.33	7.86**
	M_9- M_{12}	11.55	1.18	9.80**
	M_{11}- M_{10}	15.76	1.35	11.64**
	M_{11}- M_{12}	16.85	1.21	13.98**
	M_{10}- M_{12}	1.09	1.01	1.07

** Significant at the 0.01 level of confidence

- When both high and low intelligent groups are exposed to ICT mediated instructions in science, the achievement gain scores of low intelligent group is significantly higher than that of high intelligent group (M_9-M_{11}).
- When high intelligent group is exposed to ICT mediated instructions in science, their achievement gain score is significantly higher than those of high as well as low intelligent groups who are not exposed to ICT mediated instructions in science (M_9- M_{10} and M_9-M_{12}).
- When low intelligent group is exposed to ICT mediated instructions in science their achievement gain score is significantly higher than those high as well as low intelligent groups who are not exposed to ICT mediated instructions in science (M_{11}- M_{10} and M_{11}-M_{12}).
- When both high and low intelligent groups are not exposed to ICT mediated instructions in science then there is no

difference in the achievement gain score of both the low and high intelligent groups ($_{M10-M12}$).

(ii)Treatment and Physical Facilities (A x C)

It may be observed from the Table 1 that the F-Ratio for interaction between treatment and physical facilities has been found to be significant at the 0.05 level of confidence. Hence, the data provide sufficient evidence to reject the hypothesis (Becta 2001) viz., "With ICT and without ICT mediated classroom instruction, achievement in science is comparable at the two levels of physical facilities" has been rejected. It suggests that the effect of teaching with ICT on the achievement gain scores in science is not independent of their respective physical facilities.

It may be observed from the Table 3 that the differences between means of $M_{E\text{-}RPF}$-$M_{E\text{-}PPF}$, $M_{E\text{-}RPF}$ – $M_{C\text{-}RPF}$, $M_{E\text{-}RPF}$ – $M_{C\text{-}PPF}$, $M_{E\text{-}PPF}$ - $M_{C\text{-}RPF}$, and $M_{C\text{-}RPF}$ - $M_{C\text{-}PPF}$ groups have been found to be significant at the 0.01 level of confidence. Further analysis of Means in Table 1 reveals that

When both rich and poor physical facilities groups are exposed to ICT mediated instructions in science, the achievement gain scores of rich physical facilities group is significantly higher than that of poor physical facilities group ($M_{E\text{-}RPF}$-$M_{E\text{-}PPF}$).

When rich physical facilities group is exposed to ICT mediated instructions in science their achievement gain score is significantly higher than those of rich as well as poor physical facilities groups who are not exposed to ICT mediated instructions in science ($M_{E\text{-}RPF}$ – $M_{C\text{-}RPF}$) and ($M_{E\text{-}RPF}$-$M_{C\text{-}PPF}$).

When poor physical facilities group is exposed to ICT mediated instructions in science their achievement gain score is significantly higher than rich as well as poor physical facilities groups who are not exposed to ICT mediated instructions in science ($M_{E\text{-}PPF}$ - $M_{C\text{-}RPF}$).and ($M_{E\text{-}PPF}$ - $M_{C\text{-}RPF}$).

When both rich and poor physical facilities groups are not exposed to ICT mediated instructions in science, the achievement gain scores of rich physical facilities group is significantly higher than that of poor physical facilities group ($M_{C\text{-}RPF}$ - $M_{C\text{-}PPF}$).

(iii)Intelligence and Physical Facilities (B × C)

It may be observed from the Table 1 that the F-Ratio for interaction between Intelligence and physical facilities has not been found to be significant even at 0.05 level of confidence. Hence, the data did not provide sufficient evidence to reject the hypothesis (Becta, 2003) viz., "There is no significant difference in the achievement of high and low intelligent students at both the levels of physical facilities" has not been rejected. It suggests that the intelligence is independent at both the levels of physical facilities.

Three Order Interaction

Treatment, Intelligence and Physical Facilities (A x B x C)

It may be observed from the Table no.1 that the F-Ratio for interaction between treatment, Intelligence and physical facilities has been found to not be significant even at 0.05 level of confidence. Hence, the data did not provide sufficient evidence to reject the hypothesis (7) viz., "With ICT and without ICT mediated classroom instruction achievement scores are equal for high intelligent and low intelligent students at both the levels of physical facilities" has not been rejected. It suggests that the effect of teaching with ICT on the achievement gain scores in science is independent of their respective levels of Intelligence at both the levels of physical facilities.

Discussions

It is evident from the results of this study that ICT mediated instructions capitulated higher mean attainment gain scores in science than teacher directed instructions. ICT mediated instructions has been found as a sole aspect to influence the performance strikingly. Students gained approximately as much as twice the attainment, when taught via ICT mediated instructions as compared to those taught by teacher directed instructions. Statistically significant positive associations between the level of ICT use and pupils' attainment were found for science.

This finding is parallel to the findings of Barnea and Dori (1999) submitting about the considerable gains in the understanding by pupils who were given access to three-dimensional modeling

Table 3: Summary of t-Values o Gain Scores of Achievement in Science for Treatment and Physical Facilities

Source of variance		D	SE	t- values
Treatment x Physical facilities	$M_{E\text{-}RPF}$-$M_{E\text{-}PPF}$	0.97	1.53	0.63**
	$M_{E\text{-}RPF}$ – $M_{C\text{-}RPF}$	11.21	1.31	8.57**
	$M_{E\text{-}RPF}$ – $M_{C\text{-}PPF}$	17.06	1.20	14.16**
	$M_{E\text{-}PPF}$ - $M_{C\text{-}PPF}$	16.09	1.22	13.23**
	$M_{E\text{-}PPF}$ - $M_{C\text{-}RPF}$	10.24	1.32	7.77**
	$M_{C\text{-}RPF}$ - $M_{C\text{-}PPF}$	5.85	0.91	6.35**

** Significant at the 0.01 level of confidence software in Impact project. Harrison *et al*., (2002) also furnished that statistically significant positive associations between the level of ICT use and pupils' attainment found of science. It was delineated that ICT can help to deepen students' content knowledge, engage them in constructing their own knowledge, and support the development of complex thinking skills (Kulik, 2003; Webb and Cox, 2004; Kozma, 2005).

Low intelligent group was found to be better than high intelligent group with respect to achievement gain scores in science. The effect of teaching with ICT on the achievement in science is not independent of their respective levels of Intelligence.The mean achievement scores of students among rich and poor physical facilities diverge extensively. The difference of the performance through ICT mediated instructions and teacher directed instruction is qualified at both the levels of physical facilities. These findings are in conformity with the findings of (Becta, 2001) which, established that a consistent positive difference was found in science attainment between those schools with good levels of ICT resources and those with poor levels of ICT resources.

Conclusion

Overall, outcomes of this study are encouraging and divulge that students perform better in ICT-based instructional strategy than the students in a conventional, lecture-based instructional strategy. ICT-based instructional strategy seems to improve the academic achievements of 9th grade students in basic general science learning. In the short term, both high and low intelligent students when taught through ICT-based and conventional, lecture-based instructional strategy showed significant difference in their academic achievement, further it was also pertinent from the analysis that low intelligent students gained more as compared to high intelligent students when taught via ICT. This improvement was statistically significant in the post-test academic achievement and besides that it is probable that ICT mediated instructional strategies lead students to acquire knowledge in different ways, at different rates. The positive differences were found in science attainment between those schools with good levels of ICT resources and those with poor levels of ICT resources. It is also clear that the availability of physical facilities in a school had a significance impact on students' performance

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