TEACHING PHYSICAL SCIENCE: SHOULD WE IMPLEMENT TEACHER-CENTERED CAI OR STUDENT-CENTERED CAI AT SECONDARY SCHOOL LEVEL IN INDIA?

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Abstract

This study investigated the effects of traditional instruction, teacher-centered computer assisted instruction (CAI) and student-centered computer assisted instruction on secondary school students' achievement in Physical Science. A total of 120 tenth-grade secondary school students participated in this randomized pretest-posttest control group experimental study. These students were randomly divided into three groups, namely, control group (n = 40), Teacher-centered CAI experimental group (n = 40) and Student-centered CAI experimental group (n = 40). During a period of 5 weeks, control group was taught by traditional instruction, whereas Teacher-centered CAI and Student-centered CAI experimental groups were subjected to teacher-centered CAI and student-centered CAI methods respectively. An analysis of covariance on the Physical Science Achievement Test posttest scores with students' pretest scores as the covariate showed that the teacher-centered CAI approach was more effective in enhancing the students' achievement in Physical Science than traditional instruction and student-centered CAI method. It is, therefore, suggested teacher-centered CAI method is a good alternative for teaching Physical Science at secondary school level in India.

Keywords: Traditional instruction, teacher-centered computer assisted instruction, student-centered computer assisted instruction, secondary school students, physical science

Introduction

A growing body of research is beginning to illuminate how people learn science and how best to support that learning (National Research Council, 2005, 2007). This research indicates that developing proficiency in science is much more than knowing facts. Students need to learn how facts and ideas are related to each other within conceptual frameworks. Although good teaching can facilitate this process, developing conceptual understanding of science is difficult and takes time. Engaging students in the processes of science - including talk and argument, modeling and representation, and learning from investigations - aids development of proficiency. These science processes (often called a science inquiry) motivate students by fostering their natural curiosity about the world around them, encouraging them to persist through difficulty to master complex science concepts. New science teaching approaches that carefully integrate scientific processes with other forms of instruction and target clear learning goals have been shown to increase interest in science, enhance scientific reasoning, and increase mastery of the targeted concepts (National Research Council, 2005). Computer assisted instruction and its various modes such as computer simulations and games can support the new, inquiry-based approaches to science instruction, providing virtual laboratories or field learning experiences that overcome practical and logistical constraints to student investigations. They can allow learners to visualize, explore, and formulate scientific explanations for scientific phenomena that would otherwise be impossible to observe and manipulate. They can help learners mentally link abstract representations of a scientific phenomenon (for example, equations) with the invisible processes underlying the phenomenon and the learner's own observations (Linn et al., 2010).

A number of meta-analysis studies have consistently demonstrated the effectiveness of CAI in the mainstream classroom (Bangert-Drowns *et al.*, 1985, Kulik and Kulik, 1986, 1991, Kulik & Kulik, 1987). Fletcherflinn and Gravatt (1995) showed a learning advantage for CAI with the mean effect size of 0.24 for studies in the years 1987–1992 and 0.33 for more recent studies. However, they also cautioned that only well designed CAI instruction and materials accounted for the typical learning benefits of CAI to students. Christmann *et al.* (1997) reported a meta-analysis, comparing traditional instruction versus traditional instruction supplemented with CAI effects on the academic achievement of sixth graders through to twelfth graders across eight curricular areas. Again, higher academic achievement among students receiving traditional instruction supplemented with CAI was found with an overall mean effect size of 0.209 reported. Effect sizes were larger for science (0.639).

Despite constant support for implementing CAI in the secondary schools, confounding research findings on the comparative efficacy of CAI versus traditional instruction are present in the science education literature. Some studies report that students' learning outcomes favor the CAI over those strategies reflected in the traditional science classrooms (Chang, 2000, 2001; Davis, Storch, & Strawser, 1987; Ferguson & Chapman, 1993; Gardner, Simmons, & Simpson, 1992; Hughes, 1974; Levine, 1994; Lu, Voss, & Kleinsmith, 1997; Whiting, 1985; Yalcinalp, Geban, & Ozkan, 1995). Conversely, a number of studies report that the CAI approach has no significant effects on achievement in science (Morrell, 1992; Olugbemiro, 1991; Summerlin & Gardner, 1973; Wainwright, 1989).

Furthermore, while a number of previous studies and meta-analyses have primarily focused on the comparative efficacy of computer assisted instruction versus traditional instruction in the area of science education, there are relatively few studies (Chang, 2002, 2003, 2005) exploring how various teaching formats of CAI (namely, Teacher-centered CAI and Student-centered CAI) influence students' science learning outcomes at the secondary school level. The authors are not aware of any studies that have been done in India to determine the effects of using different teaching formats of CAI on students' achievement in Physical Science. Therefore, this study was undertaken to compare the effects of teacher-centered CAI and student-centered CAI with traditional instruction on secondary school students' achievement in Physical Science. Therefore, this study took further steps and attempted to evaluate the impact of different computer-assisted teaching formats on students' science learning with the aims at improving science instruction at the secondary school level in India.

Purpose of the Study

The main purpose of this study was to investigate the comparative effects of traditional teaching, teacher-centered CAI and student-centered CAI on secondary school students' achievement in Physical Science.

In order to suitably address the above mentioned purpose, the following null hypotheses were formulated:

H_0 1: There is no significant difference between the mean pretest and posttest Physical Science achievement scores for students in the control group.

H_0 2: There is no significant difference between the mean pretest and posttest Physical Science achievement scores for students in the teacher-centered CAI experimental group.

H_0 3: There is no significant difference between the mean pretest and posttest Physical Science achievement scores for students in the student-centered CAI experimental group.

H_0 4: There is no significant difference between the mean posttest scores for students in the control group, teacher-centered CAI experimental group, and student-centered CAI experimental group, after controlling for the effect of pretest scores.

Method

Participants

The participants included 120 secondary school students enrolled in tenth-grade in a senior secondary school in Aligarh, Uttar Pradesh, India. These students were randomly divided into six sections of 20 students each. Each of the six sections was randomly assigned to either traditional teaching (two sections with a total of 40 students), teacher-centered CAI (two sections with a total of 40 students), or student-centered CAI (two sections with a total of 40 students). In other words, 2 sections, subjected to traditional instruction, were considered as Control group and the remaining 4 sections, subjected to CAI, were considered as experimental groups: 2 sections as Teacher-centered CAI experimental group and the remaining 2 sections as Student-centered CAI experimental group. The two teachers also participated in this study. Both of them held an equivalent Masters degree and had 6 years experience of teaching Physical Science at secondary school level. The three teaching approaches used were randomly assigned to these two teachers so that each teacher had three groups to teach. This was done to minimize teacher differences.

Research Design

In this study, a randomized pretest-posttest control group design (Campbell and Stanley, 1966) was used. This design permitted an investigation of the effectiveness of CAI on students' achievement in Physical Science. This experimental design can be represented as:

	Pretest	Treatment	Posttest
CG	T	X_a	T
TCCAI	T	X_b	T
SCCAI	T	X_c	T

Where, CG represents the control group, using the traditional teaching approach (X_a); TCCAI represents Experimental Group 1, using the Teacher-centered CAI approach (X_b); and SCCAI represents Experimental Group 2, using the Student-centered CAI approach (X_c). T represents the Physical Science Achievement Test. Physical Science Achievement Test was given as pre- and post-tests to students in all the three groups at the beginning and end of the treatment to measure students' achievement in Physical Science.

Measuring Instrument

Students' achievement in Physical Science was measured using the Physical Science Achievement Test (PSAT) developed by the researcher. The instrument, containing 50 four-option, multiple-choice questions, was developed by the researcher. Two chapters from the textbook Science for class X, published by NCERT, New Delhi, were selected for this study. The test was based on these two chapters: Light - Reflection and Refraction (Physics) and Metals and Nonmetals (Chemistry). The test was intended to determine the knowledge and comprehension levels of students related to the fundamental concepts, and their skills in recalling the relationships between concepts, and applying them to problems. Cronbach's alpha reliability coefficient of the test was 0.92.

Software and Instructional Methods

Multimedia CAI software was prepared for the study by a computer expert in consultation with the authors using Microsoft PowerPoint, Flash and Adobe Photoshop 7.0. It included detailed study materials, figures, graphs, three-dimensional animations, and self-assessment exercises to enrich the theoretical content knowledge.

The control group was subjected to traditional teaching without any exposure to multimedia CAI software. This teaching approach emphasized direct lectures given by teachers, interactive discussions between the teacher and students, use of textbook materials, and clear explanation of important concepts to students, but no use of multimedia CAI software was done.

The teacher-centered CAI (TCCAI) scheme in the current study was a mixture of whole-class presentation, interactive discussions between the teacher and students, and classroom activities using the multimedia CAI software. The whole-class presentation was implemented using a combination of a laptop computer and a projector to display the contents of the multimedia CAI software on a large screen in front of a whole class.

The student-centered CAI (SCCAI) approach stressed students' self-paced learning using the multimedia CAI software with their own individual computers (PCs) in a modern computer lab. In this approach, the teacher made use of mini lectures to introduce the key concepts about Physical Science and simply presented the contents in the beginning of a class period after which the students were left to work alone, with minimal interference from the teacher who was present only either to respond to the doubts and questions raised by individual students or to provide support and guidance to those who asked for help.

All the groups were subjected to their respective instructional method for 5 weeks. They attended six periods per week (4 hours per week). Each period was of 40 minutes duration. Six periods were allotted to these groups for learning Physical Science; three periods each for Physics and Chemistry on alternate days of the week. All the groups followed the same instruction sequence and had the same learning objectives. Thus, care was taken to ensure that an appropriate comparison was attained among the three instructional approaches.

Data Analysis

The data from the Physical Science Achievement Test were analyzed using SPSS 16.0. Means (M) and standard deviations (SD) were calculated. A paired t-test was used to determine if there was a statistically significant difference between the pre- and post-test achievement scores in Physical Science for each of the three groups. Analysis of Covariance (ANCOVA) was used to determine whether a significant difference between group means of achievement in Physical Science for the control and experimental groups when differences in pretest scores were controlled. An alpha level of 0.05 was used for all statistical tests.

Results

In order to evaluate the impact of the intervention on control group students' achievement in Physical Science, descriptive statistics were calculated first for their Pretest and Posttest scores on the Physical Science Achievement Test (PSAT). The Pretest and Posttest means and standard deviations for the control group have been reported in Table 1.

Table 1: Descriptive Statistics for Control Group

Achievement in Physical Science	N	Mean	SD
Pretest	40	27.70	6.40
Posttest	40	36.95	8.04

Then, a paired-samples t test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the control group. The results in Table 2 indicated that there was a significant difference between the Pretest and Posttest scores, $t(39) = -11.24$, $p < .05$. The control group scored significantly greater on the Posttest ($M = 36.95$, $SD = 8.04$) than on the Pretest ($M = 27.70$, $SD = 6.40$). Therefore, the null hypothesis, that there is no significant difference between the mean Pretest and Posttest scores for students in the control group, was rejected.

Table 2: Paired-Samples *t*-test for Control Group

	Paired Differences				t	df	Sig.
	Mean	SD	95% Confidence Interval of the Difference				
			Lower	Upper			
Pretest - Posttest	-9.25	5.20	-10.91	-7.58	-11.24	39	.000*

* Significant at .05 level

In order to evaluate the impact of the intervention on teacher-centered CAI experimental group students' achievement in Physical Science, descriptive statistics were calculated first for their Pretest and Posttest scores on the Physical Science Achievement Test (PSAT). The Pretest and Posttest means and standard deviations for the teacher-centered CAI experimental group have been reported in Table 3.

Table 3: Descriptive Statistics for Teacher-centered CAI Experimental Group

Achievement in Physical Science	N	Mean	SD
Pretest	40	25.68	7.31
Posttest	40	41.58	7.48

Then, a paired-samples t test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the teacher-centered CAI experimental group. The results in Table 4 indicated that there was a significant difference between the Pretest and Posttest scores, t (67) = -18.75, p < .05. The teacher-centered CAI experimental group scored significantly greater on the Posttest (M = 41.58, SD = 7.48) than on the Pretest (M = 25.68, SD = 7.31). Therefore, the null hypothesis, that there is no significant difference between the mean Pretest and Posttest scores for students in the teacher-centered CAI experimental group, was rejected.

Table 4: Paired-Samples *t*-test for Teacher-centered CAI Experimental Group

	Paired Differences				t	df	Sig.
	Mean	SD	95% Confidence Interval of the Difference				
			Lower	Upper			
Pretest - Posttest	-15.90	5.36	-17.61	-14.18	-18.75	39	.000*

* Significant at .05 level

In order to evaluate the impact of the intervention on student-centered CAI experimental group students' achievement in Physical Science, descriptive statistics were calculated first for their Pretest and Posttest scores on the Physical Science Achievement Test (PSAT). The Pretest and Posttest means and standard deviations for the control group have been reported in Table 5.

Table 5: Descriptive Statistics for Student-centered CAI Experimental Group

Achievement in Physical Science	N	Mean	SD
Pretest	40	27.15	6.93
Posttest	40	39.25	8.63

Then, a paired-samples t test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the student-centered CAI experimental group. The results in Table 6 indicated that there was a significant difference between the Pretest and Posttest scores, t (67) = -17.23, p < .05. The student-centered CAI experimental group scored significantly greater on the Posttest (M = 39.25, SD = 8.63) than on the Pretest (M = 27.15, SD = 6.93). Therefore, the null hypothesis, that there is no significant difference between the mean Pretest and Posttest scores for students in the student-centered CAI experimental group, was rejected.

Table 6: Paired-Samples *t*-test for Student-centered CAI Experimental Group

	Paired Differences				t	df	Sig.
	Mean	SD	95% Confidence Interval of the Difference				
			Lower	Upper			
Pretest - Posttest	-12.10	4.44	-13.52	-10.68	-17.23	39	.000*

* Significant at .05 level

In order to test hypothesis 4, a one-way analysis of covariance was conducted to evaluate the effects on secondary school students' achievement in Physical Science. The independent variable was an instructional method (traditional teaching, teacher-centered CAI, and student-centered CAI). The dependent variable was scores on the Physical Science Achievement Test (PSAT), administered following completion of the instructional period. Scores on the PSAT administered prior to the commencement of the instructional period were used as a covariate to control for individual differences. Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. The means and standard deviations for the pretest, posttest and adjusted posttest scores have been reported in Table 7.

Table 7: Descriptive Statistics of Achievement Scores by Instructional Group

		Pretest		Posttest		Adjusted Posttest	
Group	**N**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Control	40	27.70	6.40	36.95	8.04	36.16	0.79
Teacher-centered CAI	40	25.68	7.31	41.58	7.48	42.65	0.80
Student-centered CAI	40	27.15	6.93	39.25	8.63	38.97	0.79

Table 8: ANCOVA Summary for Achievement by Instructional Group

Source	SS	df	MS	F	Sig.	Partial Eta Squared
Pretest	4699.96	1	4699.96	187.27	.000*	.618
Group	834.27	2	417.14	16.62	.000*	.223
Error	2911.21	116	25.09			
Corrected Total	8038.99	119				

Results in Table 8 show that the ANCOVA yielded a significant effect of the covariate, F (1, 119) = 187.27, $p < .05$, and a significant main effect of the instructional method, F (2, 119) = 16.62, $p < .05$, *partial* $\eta^2 = .223$; this latter effect accounted for 22.3 percent of the total variance in Physical Science Achievement, after controlling for the effect of Pretest scores. Since the results of ANCOVA indicate that there was a statistically significant difference for the adjusted Posttest means between the groups, therefore the null hypothesis stating that, there is no significant difference between the mean posttest scores for students in the control group, teacher-centered CAI experimental group, and student-centered CAI experimental group, was rejected.

Follow-up analyses of the significant main effect of instructional method were conducted to determine which instructional method was more effective. The follow-up tests consisted of all pairwise comparisons among the three types of instructional methods. For this, the Posttest means adjusted for initial differences were ordered as shown in Table 9. The teacher-centered CAI group had the largest adjusted mean (M = 42.65), the student-centered CAI group had a smaller adjusted mean (M = 38.97), and the control group had the smallest adjusted mean (M = 36.16). Post hoc follow-up tests were conducted to evaluate pair-wise differences among the adjusted means for achievement in Physical Science. The Bonferroni procedure was used to control for Type I error across the three pairwise comparisons ($\alpha' = .05/3 = .0167$). The results in Table 9 show that the adjusted Posttest mean for the teacher-centered CAI group differed significantly from both the student-centered CAI group and control group. Also, the adjusted Posttest mean for the student-centered CAI group differed significantly from the control group. Overall, the pairwise comparisons indicate superiority for the teacher-centered CAI method.

Table 9: Pairwise Comparisons among the adjusted means for Achievement

Instructional Group (I)	**Instructional Group (J)**	**Mean Difference (I-J)**	**(p-value) Sig.[a]**
Teacher-centered CAI	Student-centered CAI	3.68*	.004
	Control	6.49*	.000
Student-centered CAI	Teacher-centered CAI	-3.68*	.004
	Control	2.81*	.041
Control	Teacher-centered CAI	-6.49*	.000
	Student-centered CAI	-2.81*	.041

* The mean difference is significant at .05 level.

a. Adjustment for multiple comparisons: Bonferroni.

Discussion

The primary purpose of this study was to investigate the effects of traditional teaching and computer assisted instruction (Teacher-centered CAI and Student-centered CAI) on secondary school students' achievement in Physical Science. The results indicated that computer assisted instruction had a better learning impact on students' achievement in Physical Science than traditional teaching. Consistent with the results of many studies on the positive effects of computer assisted instruction on achievement in Science (Ardac & Akaygun, 2004; Geban, Askar, & Ozkan, 1992; Chang, 2001; Yalcinalp, Geban, & Ozkan, 1995; Ozmen, 2008; Stern, Barnea & Shauli, 2008; Zacharia, 2007; Zacharia, Olympiou, & Papaevripidou, 2008), this study confirms that computer assisted instruction is a useful tool for learning. However, less conclusive findings on the effects of CAI on achievement were also reported by a few researchers (Chang, 2002; Pol, Harskamp, & Suhre, 2005). A number of researchers found CAI as effective as traditional teaching (Choi & Gennaro, 1987; Wainwright, 1989). Furthermore, the results also showed that Teacher-centered CAI experimental group had shown greater improvement in achievement than Student-centered CAI experimental group. This finding is in accordance with the previous studies (Chang, 2002, 2003, 2005), confirming that Teacher-centered CAI is a useful tool for teaching and learning in Physical Science.

The results of the paired-sample *t*-tests computed for each group indicate that the posttest scores of achievement in Physical Science significantly increased for all groups. The lower pretest scores of all groups were due to the students' insufficient knowledge of the topic prior to instruction. The increase in students' performance from pre-test to post-test in all the three groups was very normal because they received instruction based on two chapters of Physical Science. Although implementations and applications used in TCAI and SCAI experimental groups were different from those used in CG, the CG students also received instruction which included all the concepts related to two chapters of Physical Science. Therefore, an increase in students' performance in all the groups was not surprising. All groups benefited from their respective instructional method, and their posttest results for achievement were consequently higher. The most important factor not to overlook is that TCAI and SCAI groups' performance was significantly greater than the CG on PSAT. This is an indicator of the effectiveness of CAI instruction on students' knowledge and understanding. The reason for this effectiveness is probably due to the detailed explanations and dynamic and interactive character of multimedia CAI software.

However, Teacher-centered CAI group had significantly better achievement scores in Physical Science than did the Student-centered CAI group. It may be because the classroom teacher played a more important role in the Teacher-centered CAI group by integrating human interactions and discussions sensibly within the classroom culture, which could not possibly be fully achieved through individual student's self-paced learning with his or her own computer. The emergence of the role of the teacher as an important factor in computer-aided instruction is perhaps an unsurprising finding. Fraser and Tobin (1989) synthesized some exemplary practice studies and reported that the biggest differences between classes of exemplary and non-exemplary teachers were closely related to classroom variables such as involvement, teacher support, order and organization. Therefore, the interactive and well-organized teaching strategies embedded in the Teacher-centered CAI here might have some possible positive impacts on learners in the current study.

Conclusion and Recommendations

In this study, the teacher-centered CAI led to better achievement in Physical Science for students of Teacher-centered CAI experimental group than those of Student-centered CAI and control groups. This finding calls for a redefinition and restructuring of instruction to include both CAI and traditional teaching. This also suggests the need for understanding how both modes of instruction should be integrated in activity sequences for science teaching and learning. It is essential to expand the empirical base through similar research to test further these perspectives as well as to ground theoretical conjectures regarding a framework for integrating both CAI and traditional teaching within science learning environments. In addition, science teachers should be encouraged to use the CAI because it appears from the data of this study that it is worth trying. Therefore, it is suggested that teachers apply teacher-centered CAI into CAI settings in Science courses. In creating a CAI environment, instructors should be familiar with different CAI approaches (namely, Teacher-centered CAI, Student-centered CAI, and cooperative CAI) and teach students computer and CAI operating skills before administering any of these approaches in their classes. In addition, because of the positive outcomes of learning with CAI, it is suggested that CAI software be suitably designed for individual, cooperative, and group work.

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