Research Paper EDUCATION

Effectiveness of 5E Instructional Model of Constructivist Approach on Ninth-Grade Students' Conceptual Understanding of Solutions

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ABSTRACT

This paper investigated the effects of teaching one of the most fundamental concepts of Chemistry 'Solutions' using Traditional Instruction (TI) and 5E Instructional Model of Constructivist Approach (IMCA) on students' achievement in Chemistry. A total of 60 ninth-grade students participated in this pretest-posttest control group quasi-experimental study. Control Group (n = 30) was taught by TI, whereas the two Experimental Groups EG (n = 30) was subjected to IMCA. An analysis of covariance on Chemistry achievement posttest scores with students' pretest scores as the covariate showed that IMCA was more effective in enhancing the students' achievement in Chemistry than TI. It is, therefore, suggested 5E model is a good method of teaching Chemistry.

KEYWORDS Chemistry, Solutions, Traditional Instruction, Constructivist Approach, 5E Instructional Model, Achievement.

INTRODUCTION

According to constructivist learning theory, knowledge is constructed as students integrate new information with their pre-existing knowledge base (Bodner, 1986). Proponents of constructivism suggest that students learn science best when they are actively engaged in doing science or in performing activities that allow them to think like scientists. The 5E instructional model (Bybee, 1993) is designed to incorporate all aspects of inquiry learning environments by engaging students and allowing students to explore the concepts being introduced, discover explanations for the concepts they are learning, and elaborate on what they have learned by applying their knowledge to new situations. Throughout the process the model offers multiple opportunities for evaluation of students' understanding. Thus, the 5E instructional model consists of the following phases (Bybee, 1993):

Engage: The goal of the first phase of the 5E model is to give students an opportunity to become motivated or excited about the information they will learn. Engagement is designed to tap into students' previous knowledge and identify misconceptions before proceeding with the learning process. Typically, this is done with questions, activities, demonstrations, or stories that grab students' attention and help them make connections between the new information and the world they know.

Explore: In the exploration phase, students interact directly with the material, concepts, or phenomenon. Usually, the teacher provides a focused activity to direct students' interactions. The teacher, although intricately involved in the process, acts as a facilitator rather than giving direct instruction to students.

Explain: Most teachers recognize the explain phase as "lecturing" or interactive discussion, where teachers give students information they may not be able to glean on their own. At this point in the 5E model, teachers help students understand scientific explanations and introduce terminology to provide students with a common language about the content.

Elaborate: The elaboration phase of the 5E model allows students to apply knowledge they have gained to new situations so they can expand their understanding.

Evaluate: Although evaluation is the final stage of the 5E model, it can and should occur at each phase. Evaluation of student understanding need not be formal. It can be a quick question from the teacher as students exit the class or it can be a unit test and summative assessment on specific information.

PURPOSE OF THE STUDY

The main purpose of this study was to investigate the comparative effects of Traditional Instruction (TI) and 5E Instructional Model of Constructivist Approach (IMCA) respectively on ninth-grade students' conceptual understanding of solutions.

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 Chemistry achievement scores for students in the Control Group (CG) subjected to Traditional Instruction.

H_0 2: There is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Experimental Group (EG) subjected to 5E Instructional Model of Constructivist Approach.

H_0 3: There is no significant difference between the mean posttest Chemistry achievement scores for students in the Control Group and Experimental Group (CG and EG), after controlling for the effect of pretest scores.

METHOD

Research Design and Participants

In this study, a pretest-posttest control group quasi-experimental design (Campbell and Stanley, 1966) was used. The participants included 60 students, who were enrolled in ninth-grade and belonged to two different sections during the session 2014-15, in a secondary school in Kishanganj, Bihar, India. These two sections were randomly assigned to Traditional Instruction (TI) and 5E Instructional Model of Constructivist Approach (IMCA) respectively. In other words, one section, subjected to TI, was considered as Control Group, namely CG (n = 30) and the other section, subjected to IMCA, was considered as Experimental Group, namely EG (n = 30). The two B.Ed. trainees 'A' and 'B' (who were enrolled in B.Ed. course during the session 2014-15, at Department of Education, A.M.U. Centre, Kishanganj, Bihar) also participated in this study. Both of them were male, held an equivalent Bachelor's degree in Chemistry and had no experience of teaching Chemistry at secondary school level. The trainees were also randomly assigned to these two groups. Trainees 'A' and 'B' taught CG and EG respectively.

Measuring Instrument
Students' achievement in Chemistry was measured using the Chemistry Achievement Test (CAT) based on 'Solutions'. The test, containing 20 four-option, multiple-choice questions, was developed by the author. The test was intended to determine the knowledge, comprehension and application levels of students related to the fundamental concepts. Its content validity was established by subject experts. Cronbach's alpha reliability coefficient of the test was 0.85.

Instructional Materials and Methods
The topics covered in the instructional materials were:

- Definition and properties of a solution (such as, nature, stability, size of solute particles, separation of solute particles by filtration, scattering of light by solute particles)
- Types of Solutions (Solution of Solid in a Solid; Solution of Solid in a Liquid; Solution of Liquid in a Liquid; Solution of Gas in a Liquid; Solution of Gas in a Gas) and their respective examples
- The following experimental activities were also included in order to study the properties of solutions:
- Prepare sugar solution in a beaker by dissolving sugar in water.
- Keep sugar solution undisturbed for quite some time in order to check its stability (whether sugar particles will separate out and settle down at the bottom of the beaker or not).
- Observe a drop of sugar solution under a microscope in order to check whether sugar particles will be visible or not.
- Allow the sugar solution to pass through the filter paper to check whether the whole solution will pass through the paper without leaving any residue or not.
- Put a beam of light on the sugar solution kept in a beaker in a dark room in order to check whether the path of light beam will be visible inside the solution or not when seen from the side.

The Control Group was subjected to Traditional Instruction. This instructional approach emphasized direct lectures given by teachers, interactive discussions between the teacher and students, use of textbook materials and charts, and clear explanation of important concepts to students. After explaining the concepts, the teacher demonstrated experimental activities related with 'Solutions' given in the textbook. The teacher's demonstrations exactly followed the procedure given in the Chemistry textbook. The students did not actively participate in demonstrations. They observed the teacher silently and asked questions. At the end of the lesson, the teacher asked several questions related to the demonstrations, received students' responses, and explained the observations and the corresponding results.

The Experimental Group was subjected to 5E Instructional Model of Constructivist Approach. In the Engagement phase, the teacher used "brain storming technique" in order to explore students' existing conceptions about solutions by asking questions (such as: (i) Give some examples of the solutions we commonly use in our daily life. (ii) Is sea water an example of a solution? Give a suitable reason for your answer.). During the Exploration phase, the students performed the experimental activities in order to explore the properties of solutions, wrote down their observations and discussed their results to reach a joint decision. In the Explanation phase, the students shared and discussed the results with one another. The teacher helped students connect their explanations to experiences and observations they had in the engagement and exploration phases so as to enable them derive the conclusions regarding the properties of solutions. Then, the teacher gave new examples of different types of solutions to students from their daily life. During the Elaboration phase, the students tried to identify the components (solute and solvent) of different types of solutions and explain the reasons for their choice. They also made connection between their discussions and experiments as they did in the explore phase in order to understand different types clearly. In the Evaluation phase, the questions were asked to determine whether or not the students learned the concepts related to solutions and their properties and types.

Both the groups were subjected to their respective instructional method for one week. They attended six periods per week. Each period was of 35 minutes duration. These groups followed the same instructional sequence and had the same learning objectives. Thus, care was taken to ensure that an appropriate comparison was attained among these instructional approaches. The content validity of all the lesson plans was established by the author and subject experts. The author supervised the lesson plans of both the B.Ed. trainees throughout the length of all the periods consumed for teaching the concepts. CAT was given as pre- and post-tests to students in both the groups at the beginning and end of the instructional period to measure students' achievement in Chemistry.

DATA ANALYSIS
The data from the Chemistry Achievement Test (CAT) were analyzed using SPSS 16.0. Means (M) and standard deviations (SD) were calculated. A paired samples t-test was used to determine if there was a statistically significant difference between the pre- and posttest achievement scores in Chemistry for each of the three groups. Analysis of Covariance (ANCOVA) was used to determine whether there was a significant difference between group means of achievement in Chemistry 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
The Pretest and Posttest means and standard deviations for the Control Group are reported in Table 1.

Table 1: *Descriptive Statistics of Chemistry Achievement Scores for the Control Group (CG)*

Achievement in Chemistry	N	Mean	SD
Pretest	30	4.63	3.06
Posttest	30	16.40	1.88

In order to test null hypothesis $H_0 1$, a paired-samples ***t***-test was conducted. The results in Table 2 indicate that there was a significant difference between the Pretest and Posttest scores, ***t*** (29) = - 33.18, $p < .05$. The Control Group scored significantly greater on the Posttest (M = 16.40, SD = 1.88) than on the Pretest (M = 4.63, SD = 3.06). Therefore, the hypothesis $H_0 1$ was rejected at 0.05 level of significance.

Table 2: *Paired-Samples t-test for Chemistry Achievement for the Control Group (CG)*

	Paired Differences					t	df	Sig. (*p*)
	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest – Posttest	- 11.77	1.94	0.35	-12.49	- 11.04	- 33.18*	29	.000

***p < .05**

The Pretest and Posttest means and standard deviations for the Experimental Group (EG) are reported in Table 3.

Table 3: *Descriptive Statistics of Chemistry Achievement Scores for the Experimental Group (EG)*

Achievement in Chemistry	N	Mean	SD
Pretest	30	4.93	2.81
Posttest	30	18.63	1.50

In order to test null hypothesis H02, a paired-samples t-test was conducted. The results in Table 4 indicate that there was a significant difference between the Pretest and Posttest scores, t (29) = - 23.96, $p < .05$. The Experimental Group (EG) scored significantly greater on the Posttest (M = 18.63, SD = 1.50) than on the Pretest (M = 4.93, SD = 2.81). Therefore, the hypothesis H0 2 was rejected at 0.05 level of significance.

Table 4: *Paired-Samples t-test for Chemistry Achievement for the Experimental Group (EG)*

	Paired Differences					t	df	Sig. (*p*)
	Mean	SD	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest – Posttest	- 13.70	3.13	0.57	- 14.86	- 12.53	- 23.96*	29	.000

***p* < .05**

In order to test hypothesis H_0 3, a one-way analysis of covariance was conducted to evaluate the effects of instructional methods on secondary school students' achievement in Chemistry. The independent variable was instructional method (TI and IMCA). The dependent variable was scores on CAT, administered at posttest stage after the completion of the instructional period. Pretest scores on the CAT administered prior to the commencement of the instructional period were used as a covariate to control for individual differences. The means and standard deviations for the pretest, posttest and adjusted posttest scores are presented in Table 5.

Table 5: *Descriptive Statistics for Achievement Scores on CAT by Instructional Group*

Instructional Group	N	Pretest		Posttest		Adjusted Posttest[a]	
		Mean	SD	Mean	SD	Mean	SE
CG	30	4.63	3.06	16.40	1.88	16.44	0.27
EG	30	4.93	2.81	18.63	1.50	18.59	0.27

a. Adjustments based on the mean of Pretest (covariate) =4.78

Results in Table 6 show that the ANCOVA yielded a significant effect for the covariate, F (1, 57) = 16.77, p < .05, partial $\eta 2$ = 0.227 and a significant main effect for the instructional method, F (1, 57) = 30.35, p < .05, partial $\eta 2$ = 0.347; this latter effect accounted for 34.7 % of the total variance in posttest scores on CAT, after controlling for the effect of pretest scores used as a covariate. The covariate (Pretest) accounted for 22.7 % of the total variance in achievement on CAT. Since the results of ANCOVA indicate that there was a statistically significant difference for the adjusted Posttest means between the groups and the adjusted Posttest mean of the experimental group was significantly higher than that of the control group indicating the superiority of 5E model over traditional instruction, therefore the null hypothesis H03 was rejected at 0.05 level of significance.

Table 6: *ANCOVA Summary for Posttest Achievement Scores on CAT by Instructional Group*

Source	Sum of Squares	df	Mean Square	F	Sig. (*p*)	Partial Eta Squared, η^2
Pretest	38.24	1	38.24	16.77*	.000	.227
Group	69.19	1	69.19	30.35*	.000	.347
Error	129.92	57	2.28			
Total	18653.00	60				

***p* < .05**

Note. Pretest (used as covariate) represents pretest scores on CAT.

DISCUSSION

The results indicate that 5E Instructional Model of Constructivist Approach had a better impact on ninth-grade students' conceptual understanding of solutions than TT. Consistent with the results of many studies on the positive effects of 5E Instructional Model on achievement in Chemistry (Adams, Bevevino, & Dengel, 1999; Boddy, Watson, & Aubusson, 2003; Caprio, 1994; Cho, 2002; Demircioğlu, Özmen, & Demircioğlu, 2004; Diakidoy & Kendeou, 2001; Ebenezer & Erickson, 1996; Lord, 1997, 1999; Marek, Eubanks, & Gallaher, 1990; Niaz 2002; Panizzon, 2003; Seyhan & Morgil, 2007; Sungur, Tekkaya & Geban, 2001; Treagust, Duit, & Fraser, 1996; Tural, Akdeniz, & Alev, 2010; Yadigaroğlu & Demircioğlu, 2012), this study confirms the effectiveness of this model in teaching-learning process.

ANCOVA results clearly show that the experimental group exhibited better performance than the control group on CAT. This is an indication of the benefits of 5E Instructional Model of Constructivist Approach over Traditional Instruction on students' knowledge and understanding. During the intervention period, the researcher observed the students' involvement in using IMCA and monitored their behaviors. Generally, the students seemed to be happy and eager to discover and learn on their own during the laboratory sessions. Their behaviours indicated that the IMCA provided them with interesting and enjoyable learning experiences through which they were able to understand the topics easily and in a better way. But unlike 5E model, teacher-centered and textbook-oriented traditional instruction fail to improve students' conceptual understanding and leave many misconceptions unchanged.

CONCLUSION AND RECOMMENDATIONS

The results of the present study showed positive outcomes on the ninth-grade students' achievement in Chemistry. This study suggests that 5E Instructional Model of Constructivist Approach is a good supplementary method for traditional instruction in Chemistry at secondary school level in India. This study can be seen as field testing the effectiveness of using 5E Instructional Model of Constructivist Approach in Chemistry teaching and learning. Based on the findings revealed from the study, recommendations for future research on this topic are as follows: Future studies should be carried out for different grade levels, topics, and school types to investigate the effectiveness of 5E Instructional Model of Constructivist Approach in Science education. Further research studies should be conducted to investigate teacher's readiness for, attitudes toward and knowledge about constructivist teaching in India.

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