Effect of Inquiry-based Learning on Achievement and Retention in Science of Eighth Graders with Different Learning Approaches

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Abstract

The present research aimed to find the effect of inquiry-based learning approach using 5E model on achievement and retention in Science of 157 VIII graders with two learning approaches viz. deep learning approach and surface learning approach. 'Pre-test and post-test control group design with one experimental group" was used. The data collected was analysed with the help of three-way Analysis of Variance. The major findings of the study revealed that, (i) When students were taught through 5E inquiry-based learning approach it resulted in significantly higher mean score on achievement and retention than when students taught through conventional chalk, and talk method. (ii) Students with deep and surface learning approaches performed, and retained comparably in Science. (iii) Through inquiry-based learning, students with deep learning approach performed higher than students with surface learning approach at knowledge category, whereas performance was similar on comprehension and application categories of objectives. (iv) At all categories of objectives, students in inquiry-based learning group with either learning approach performed higher in terms of achievement and retention than the control group.

Keywords: *Inquiry-based learning, 5E learning model, learning approach.*

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Introduction

The primary objective of teaching learning process is achievement in terms of grades, as it is the sole measure of learning in many cases. The teacher should utilise a variety of instructional methods in order to accomplish this goal. In order to teach effectively, the teachers must have sufficient knowledge about the students, in addition to the knowledge about the subject and appropriate methods of teaching. The inquiry-based teaching approach is supported on knowledge about the learning process that has emerged from research (Bransford, Brown, and Cocking, 2000). "In inquiry-based learning approach, students engaged in many of the activities and thinking processes that scientists use to produce new knowledge. Science educators encourage teachers to replace traditional teacher-centered instructional practices, such as emphasis on textbooks, lectures and scientific facts, with inquiry-oriented approaches that (a) engage student interest in science, (b) provide opportunities for students to use appropriate laboratory techniques to collect evidence, (c) require students to solve problems using logic and evidence, (d) encourage students to conduct further study to develop more elaborate explanations, and (e) emphasise the importance of writing scientific explanations on the basis of evidence" (Secker, 2002). "In contrast, the traditional classroom often looks like a one-person show with a largely uninvolved learner. Traditional classes are usually dominated by direct and unilateral instruction. Traditional approach followers assume that there is a fixed body of knowledge that the student must come to know" (Secker, 2002, p.38). Students are expected to blindly accept the information they are given without questioning the instructor. Even in the activities-based subjects, although activities are done in a group they do not encourage discussion or exploration of the concepts involved. This tends to overlook the critical thinking and unifying concepts essential to true Science literacy and appreciation (Yore, 2001).

The majority of the studies included in the existing review of literature reported that instructional strategies that are based on inquiry-based learning are strongly associated to achievement in various subjects, viz., in Science (Marx et al., 2004; Veloo et al., 2013; Abdi, 2014; Koksal and Berberoglu, 2014; Maxwell et al., 2015; Unlu and Dokme, 2020; Wilson, 2020; Alachi and Ifeanyi, 2021; Tekin and Mustu, 2021; Tsering and Yangden, 2021), History (Hemaletha, 2002), Mathematics (Ferguson, 2010; Kalsia, 2018; Yanakit and Kaewsaiha, 2021), Social Science (McCright, 2012; Bailey, 2018), Home Economics (Ifeanyi-Uche and Chima, 2013), Technology Education (Avsec and Kocijancic, 2014), English (Zalloum, 2018), Computer Science (Jacob et al., 2020), Basic Calculus (Santos and Boyon, 2020), college algebra (Khasawneh et al., 2023). Apart from academic achievement, many researchers have also found that inquiry-based learning approach is significantly effective in promoting critical thinking skills (Magnussen et al., 2000; Ramdani, 2020), process skill and attitudes towards Science (Simsek and Kabapinar, 2010), ability to establish relationship with real-world problems (Madhuri et al., 2012), Science literacy skill and confidence, active learning and conceptual understanding (Supasorn and Promarak, 2015), motivation and scientific inquiry ability (Cheng et al., 2016), student's computational thinking skills (Sulistiyo and Wijaya, 2020), metacognitive skills, scientific reasoning skill (Schlatter et al., 2020), learner autonomy and conception of learning among students of various groups (Yildiz-Feyzioglu and Demirci, 2021). Further, studies showed that when inquiry-based learning is incorporated with 5E learning cycle model it promoted achievement in Science (Ebrahim, 2004; Cherry, 2011; Sen and Oskay, 2016; Malik et al., 2017), students inquiry skills (Aryulina, 2009), retention conceptual understanding of scientific phenomena (Supasoran and Promarak, 2015; Laksana et al., 2019), was considered as the best model for designing Physics lesson plans (Sahingoz, 2018) and enhanced team work among learners. When 5E learning model is incorporated with cooperative learning (Pholphuet et al., 2018) and in some comparative studies guided inquiry-based learning, it has been found to be more effective than cooperative instructional strategy (Eziyi et al., 2016) and computer based instruction methods (Ayoola, 2023).

However, in some studies (Bittinger, 2015; Miller, 2014; Maxwell et al., 2015; Jerrim et al., 2020; Mohammadi and Lynch, 2021), it was found that inquiry-based learning approach had no significant effect on achievement in science when compared with traditional teaching method.

The inquiry-based learning strategy is based on the constructivism continuum as its core conceptual foundation. This paradigm states that the learner gains knowledge through interactions with the outside environment. In order to address and then elaborate on the learners' preconceived notions, the instructor makes sure that he or she is aware of them. Constructivism in the classroom entails integrating inquiry, exploration and assessment as key elements of the instructional strategies. The teacher plays the role of a facilitator, assisting learners in acquiring new knowledge and translating information to be learned into a manner suitable for each learner's comprehension level at the time (Khalid and Azeem, 2012).

Rationale of the Study

The traditional approach of education places greater emphasis on memorisation of facts and information, which is not the most essential skill in today's society. According to National Education Policy (NEP) 2020, certain skills related to Science as a subject include; scientific temper, evidence-based thinking, creativity and innovativeness, problem-solving, and logical reasoning, collaboration and teamwork. These skills can be developed only when students are given opportunities to discover or apply ideas by themselves. This is undeniably supported by constructivist teaching approaches like inquiry-based learning. Inquiry-based learning results in a shift from a traditional 'teacher-centric' to a 'student-centric' strategy that leads to active participation among students physically and cognitively. Students establish relation between what they already know, and what they learn in class and from other sources, and determine 'cause and effect' relationship, able to reason out and predict. This results in deeper understanding which students may apply to new situations.

It is possible to implement inquiry-based techniques in the classroom by utilising instructional design template and there are many ways to initiate inquiry in the classroom (Bybee et al., 2006). One tool that works well for instructors as they start to develop inquiry-based lessons is the utilisation of the learning cycle model (Abraham, 1997). The 5E model originated on the 'constructivist theory of learning', which claims that individuals construct knowledge and meaning by their own experiences and observations (Ergin et al., 2008). It is one of the instructional strategies and methods that facilitates inquiry-based learning. Students who were taught using inquiry-based instruction supported by the '5E learning cycle model' achieved greater success than those who were taught using conventional methods as supported by the work of prior scholars (Marek et al., 1990; Behera, 2016; Bevevino et al., 1999; Anderson, 2002; Seyhan and Morgil, 2007; Cardak et al., 2008). "As an instructional paradigm, the 5E learning cycle provides the active learning experiences specified by the National Science Education Standards (National Research Council, 2000) and can be utilised as a foundation for constructing inquiry-based lessons" (Luera et al., 2003, p. 195). It encourages the students to ask questions, explore and construct their own understanding of scientific phenomena (Duran and Duran, 2004; Northern, 2019; Gerges, 2022).

Students can differ not only in their learning ability but also in the ways in which they approach a learning material or how student styles the task of learning. The most common approaches to student learning are 'deep approach and surface approach' (Entwistle and Entwistle, 2003). 'Surface approach' is characterised by lack of reflection and personal connection, more emphasis is on memory, and students attempts to satisfy the necessities of the tasks with minimum effort whereas, 'deep approach' is characterised by reflection on meaning and comprehension, personal connections that leads to more satisfaction, and students take intrinsic responsibility (Justicia et al., 2008). Students' approach to learning are strongly related to both students' ideas and conceptions of learning, and perceptions of their teaching-learning context, and refer to how students go about their learning intentions (motives)—situations that awaken interest among students, why they learn and their methods (strategies)—means that added to the interest of each student allow for the achievement of the product (Biggs, 2003).

Objectives of the Study

- To investigate the effect of two instructional treatments, viz., inquiry-based learning and conventional method on achievement, and retention in Science.
- To find the effect of instructional treatments on achievement, and retention of the students with deep and surface learning approaches.
- To find the effect of two instructional treatments on students with deep and surface learning approaches at knowledge, comprehension and application categories of objectives.

Hypotheses of the Study

H_1 There exists no significant difference between experimental and control groups with respect to:

H_{1a}: mean gain scores on achievement

H_{1b}: retention scores

H_2 There exists no significant difference among students with deep learning approach and surface learning approach with respect to:

H_{2a}: mean gain scores on achievement

H_{2b}: retention scores

H_3 There exists no significant difference at knowledge, comprehension and application categories of objectives with respect to:

H_{3a}: mean gain scores on achievement

H_{3b}: retention scores

H_4 With respect to academic achievement in Science, no significant interaction exists:

H_{4a}: between instructional treatments and learning approaches

H_{4b}: between instructional treatments and categories of objectives

H_{4c}: between categories of objectives and learning approaches

H_{4d}: among three variables, viz.; treatment, learning approaches and categories of objectives

H_5 With respect to retention scores in Science, no significant interaction exists:

H_{5a}: between instructional treatments and learning approaches

H_{5b}: between instructional treatments and categories of objectives

H_{5c}: between categories of objectives and learning approaches

H_{5d}: among three variables, viz.; treatment, learning approaches and categories of objectives

Delimitations of the Study

1. The present work was delimited with respect to class and place, i.e., eighth graders of Government Model Senior School, Sector 37-B and Government Model Senior School, Sector 22-A in Chandigarh.
2. Only six chapters of Class VIII Science textbook by NCERT 2008 were taken.
3. Two types of learning approaches, viz., deep learning approach and surface learning approach were taken. Levels of objectives were studied at knowledge, comprehension and application levels only.

Methodology

Sample

The research was carried out on Class VIII students enroled in CBSE affiliated schools of Chandigarh. The researcher obtained a sample using a simple random sampling technique of probability sampling method. In order to collect data and conduct experiments in government schools of Chandigarh, from the list of 115 schools, the researcher randomly selected 2 schools by lottery method (Alvi, 2016). The schools were given numbers written on the slips of paper and the slips were thoroughly mixed. Then, randomly two slips were drawn out of it, i.e., Government Senior Secondary School, Sector 37-B, acted as experimental group and Government Senior Secondary School, Sector 22-A, Chandigarh, acted as control group. Following the selection of two schools, the permission from District Education Officer (DEO). was sought. Revised Two Factor Study Process Questionnaire (R-SPQ-2F) (Biggs et al., 2001) was administered to 179 students of Class VIII of both the schools. On the basis of the scores obtained by the students on R-SPQ-2F, the students were categorised into deep learning approach and surface learning approach.

Table 1: Sample Distribution

S. No.	Name of the School	Treatment Groups	Deep Learning Approach	Surface Learning Approach	Total
1.	Government Model Sr. Sec. School, Sector 37-B, Chandigarh	Experimental Group (N=78)	37	41	78
2.	Government Model Sr. Sec. School, Sector 22-A, Chandigarh	Control Group (N=79)	36	43	79
				Total	157

Tools used

Following tools were used for the present investigation by the researcher:

1. Inquiry-based learning instructional material and lesson plans (developed and validated by the investigator) were based on the chapters covered from the syllabus of Class VIII Science textbook prescribed by NCERT, New Delhi, 2008.

The chapters included were: 'Combustion and Flame', 'Cell Structure and Function', 'Reproduction in Animal', 'Force and Pressure', 'Friction and Chemical Effect of Current'.

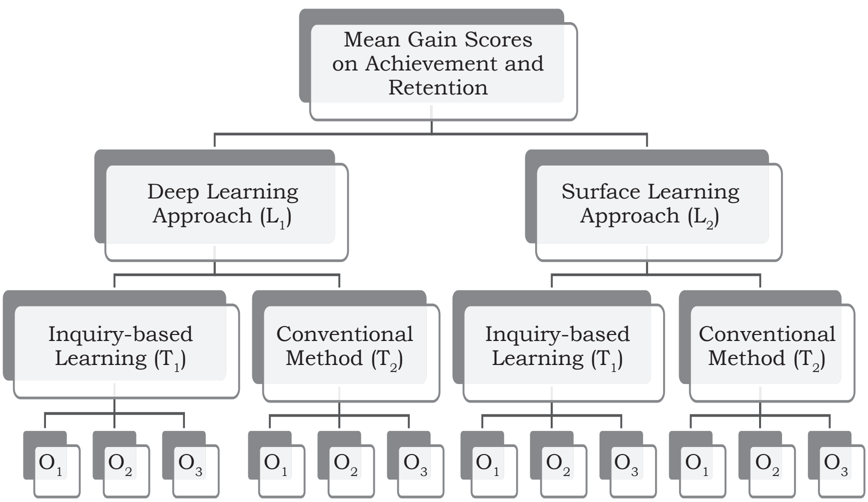
2. Worksheets (developed by investigator)
3. Achievement test in science comprised of 108 items. 37 items were developed at knowledge level, 33 items were developed at comprehension level and 38 items were developed at application level. Reliability of the test was calculated by 'Cronbach's alpha' and 'Guttmann split-half coefficient' and found to be 0.89 and 0.86, respectively.
4. The R-SPQ-2F (Biggs et al., 2001) was used to assess the students' approach to learning. The questionnaire comprised of 20 test items using 5-point Likert scale. There were two main scales, i.e., 'Deep Approach (DA)' and 'Surface Approach (SA)' with four sub-scales, 'Deep Motive', 'Deep Strategy', 'Surface Motive' and 'Surface Strategy'. A 'deep approach' to learning involves concentration on latent meanings of the material to be learned whereas the 'surface approach' involves memorisation and less priority on the material in the presented tasks. For both deep and surface approach scales, the scores were determined separately by summing up the 10 items in each scale. The approach having greater scores represents students' approach to learning.

Research Design

The study was experimental in nature and 'Pre-test and post-test control group design with one experimental group' was employed.

In the present study two schools were randomly assigned as 'experimental and control group'. In the present study, 'extraneous variables' such as, environment, age, subject, the class being taught, and the teacher were kept constant throughout the intervention to assure the internal validity of the research. The extraneous variables, viz., (i) situational variables, i.e., the environmental variables were kept constant as both the government schools have similar set of lab and classroom facilities; (ii) participant variables were controled by categorising students into deep and surface learning groups. On the basis of their achievement both groups were assessed before the treatment and were found to be equivalent; (iii) control related to experimenter bias was employed by randomly assigning the subjects to treatment group and control group; following and implementing the steps of lesson planning on the basis of 5E cycle to experimental group, and traditional method to the control group. Same content was taught to both the groups. In the experimental group, students were instructed using inquiry-based learning, while in the control group students were instructed using traditional method. On the basis of their achievement, both groups were assessed before and after the treatment. The same achievement test was administered to both the groups after the gap of 25 days to obtain the scores on retention. During teaching intervention, students worked in small groups where they were encouraged to share their ideas, discuss their observations and interpret findings of the experiments carried out with the classmates.

The 2×2×3 factorial design with repeated measures ANOVA was employed for the analysis of mean gain scores on academic achievement and retention. The variable of instructional treatment was studied at two levels, viz., experimental group (T_1) was taught through 'inquiry-based learning' and control group (T_2) was taught through 'conventional chalk and talk method'. Learning approach (L) was the classification variable which was studied at two levels, viz., deep learning approach (L_1) and surface learning (L_2) approach. The third variable—'categories of objectives' was studied at three levels: knowledge, comprehension and application levels.



O1=Knowledge category, O2=Comprehension category, O3=Application category

Figure 1: Plan of 2×2×3 Factorial Design for Mean Gains on Achievement and Retention

The categories of objectives were a repeated variable in the above 2×2×3 design. Achievement and retention scores were taken as sum total of items at knowledge (O_1), comprehension (O_2) and application (O_3) categories of objectives. The assumptions for repeated measures were satisfied, viz., 'normality of distribution, independence of observations, homogeneity of variance and sphericity' using SPSS. The given data was further analysed by applying 2×2×3 ANOVA with repeated measures on one factor (categories of objectives) in SPSS to study the main effects and interaction effects.

Procedure

The experiment was conducted in four phases:

Phase 1: Administration of Pre-test

In this phase the achievement test was administered to the students of the experimental and control group. Students were provided separate response sheets to mark their answers. The answer sheets were scored with the help of scoring key.

Phase 2: Carrying out the experiment

For Experimental group

As students were not familiar with inquiry method of learning, investigator decided to introduce them with two demo lessons before conducting the actual instructional programme. The experimental group was taken to the laboratory as per requirement.

Instructional Programme for Inquiry-based Learning

The inquiry-based lessons were prepared by utilising 5E Model. This model includes five stages, viz., engagement phase, exploration phase, explanation phase, elaboration phase and evaluation phase (Bybee et al., 2006; Llewellyn, 2007). The time-duration of 50-minute period was divided according to the requirement of each phase (Bala, 2022) as shown in the Table 2.

Following steps included in planning and presentation of inquiry-based lessons (Bala, 2022).

(a) Introduction of lesson

Engagement phase

Table 2: Division of 50-minute Period

Phases	Activities	Time allotted
Engagement	• Previous knowledge testing	5–7 minutes
Exploration	• Hands-on activities, with guidance to explore the phenomena.	15 minutes
Explanation	• Students in groups sharing their results and explaining what they have understood.	10 minutes
Elaboration	• Students solving application-based questions on worksheet	15 minutes
Evaluation	• Assessing the performance of students	5–7 minutes

"The engagement phase means channelising student's attention and focus" (Llewellyn, 2007). Investigator oriented students towards the new concept by giving a brief introduction about the lesson to be studied. Learners' previous knowledge was assessed by asking questions and performing short activity.

(b) Hands-on activity in the group: For the rest of phases, students were divided into groups of six and one student from each group was assigned as a leader of the group. During lab sessions, students were asked to take necessary precautions. Investigator distributed material related to each experiment such as, common materials available at home as well as equipment and chemicals needed for carrying out activities. Worksheets related to each lesson were distributed on the daily basis for writing observations and other responses.

Exploration phase

Students were required to perform 'hands-on activity' with the given material and write down their observations on the worksheets following instructions on the worksheet. The investigator facilitated the on-going process where students worked without the direct help of the teacher and were most active at this phase. Students could take help of the textbooks and their team mates. Students were supposed to peer-review their group members and help their team mates in understanding the concept.

Explanation phase

Group leader from each group presented their observations and results. The investigator further explained the terms, remaining details, information related to topic after the students' presentations are over, and augmented with the audio-visual resources.

Elaboration phase

This phase was accomplished by engaging students to apply the learned concept in a real-world situation outside the classroom like citing examples, reasoning questions and other application-based problems given on the worksheet.

Evaluation phase

Evaluation was done on the basis of students' performance in observing and recording while performing activities, and solving worksheets by grading their performance of behaviours on the monitoring chart.

(c) Formative tests and rewards: After completing the whole chapter, a formative test (consisting multiple choice questions and constructive response questions, e.g., fill in the blank items, short answer questions) was conducted where students took the test individually. In total, 14 formative tests were administered throughout the experiment. Those students who scored high marks in formative tests were assigned badges like 'junior scientist', 'scholar', 'perfect score', 'master of science'.

(d) Review: The students gave opinions based on self-reflection to the teacher verbally on what worked and what did not work well, as well as what they thought was important about the topic after each lesson.

(e) Re-teaching: Those parts of the lesson that had been poorly understood by the majority of the students were taught again, but with different examples for better comprehension.

In all, 35 lessons were taught covering six chapters.

For Control Group

The control group was also taught same six chapters covering the same content through 'conventional chalk and talk method'.

Phase 3: Administration of the Post-Test

After the instructional treatment was over, the post-test was administered to both the experimental and control groups to assess the effect.

Phase 4: Administration of the Retention Test

To determine how much they have retained, the achievement test was again administered to both the groups (experimental and control groups) after 25 days of post-test.

Analysis of Mean Gain Scores on Achievement and Retention

After scoring, the gain scores as measured by the difference of post-test and pre-test scores on achievement test were computed for each student at knowledge, comprehension, and application levels of objectives. As the number of test items in the three categories of objectives of the achievement test was different, i.e., knowledge objective had 37 items, comprehension objective had 33 items, and application objective had 38 items. So, the actual gain scores were calculated as follows:

$$\textit{Actual gain scores at knowledge level} = \frac{\textit{post-test} - \textit{pre-test}}{37} \times 100$$

$$\textit{Actual gain scores at knowledge level} = \frac{\textit{post-test} - \textit{pre-test}}{33} \times 100$$

$$\textit{Actual gain scores at knowledge level} = \frac{\textit{post-test} - \textit{pre-test}}{38} \times 100$$

Actual retention scores were obtained in the same way as the difference between pre-test and retention test conducted after 25 days.

The obtained mean gain scores on achievement and retention were subjected to 2×2×3 ANOVA with one repeated measure. The data was analysed according to the specifications of Winer (1971), Girden (1992) and Everitt (2001).

Before applying 2×2×3 ANOVA with repeated measures, the necessary assumptions were tested, viz., Normality of distribution tested by Q-Q plot and Shapiro-Wilk test, homogeneity of variance by Levene's test and Mauchly's test of sphericity in SPSS. None of the assumptions was found to be violated.

Main Effect

Table 4 shows, *F-ratio* for the difference in the mean gain scores of the 'two treatment groups' was found to be highly significant at 0.01 level of confidence ($F=42.82; p<0.01$). Hence, H_{1a} is rejected. Further

Table 3: Means and SDs of Sub-samples (Mean Gain Scores on Achievement)

Learning Approach (L)	Categories of Objectives (O)	Experimental group (T_1)	Control group (T_2)
Deep Approach (L_1)	O_1	M=31.08	M=15.20
		N=37	N=36
		SD=19.30	SD=13.02
	O_2	M=29.09	M=17.16
		N=37	N=36
		SD=16.85	SD=13.05
	O_3	M=32.22	M=18.71
		N=37	N=36
		SD=15.81	SD=12.18
Surface Approach (L_2)	O_1	M=22.90	M=17.57
		N=41	N=43
		SD=15.02	SD=13.35
	O_2	M=31.06	M=16.55
		N=41	N=43
		SD=16.73	SD=11.71
	O_3	M=31.32	M=16.65
		N=41	N=43
		SD=20.10	SD=9.52

Table 4: Summary of ANOVA (for Mean Gain Scores on Achievement)

Between-Subjects					
Source	**Sum of Squares**	**df**	**MSS**	**F-value**	**p-value**
Treatment (T)	18711.970	1	18711.970	42.828	0.0001**
Learning Approach (L)	178.709	1	178.709	0.409	0.523
Treatment * Learning Approach (TxL)	150.863	1	150.863	0.345	0.558
Error	66847.136	153	436.909		
Within-Subjects					
Source	**Sum of Squares**	**df**	**MSS**	**F-value**	**p-value**
Objectives (O)	727.282	2	363.641	3.066	0.048*
T x O	257.200	2	128.600	1.084	0.339
L x O	254.786	2	127.393	1.074	0.343
T x L x O	1013.839	2	506.920	4.275	0.015*
Error (Within)	36287.300	306	118.586		

**Significant at 0.05 level of confidence*
***Significant at 0.01 level of confidence*

value of means indicated that the students when taught through 5E inquiry-based learning performed higher on achievement scores as compared to those taught through conventional method.

The F-ratio for the difference in the mean gain scores on achievement at 'learning approach' factor was found to be not significant even at 0.05 level of confidence ($F=0.409$; $p>0.05$). This indicates that students with deep and surface learning approaches performed equably on achievement in Science. Thus, H_{2a} is retained. The F-ratio for the difference in mean gains at the three categories of objectives was found to be slightly significant at 0.05 level of confidence ($F=3.066$; $p\leq0.05$). H_{3a} was rejected. After computing t-ratios, it was found that students performed comparably at knowledge and comprehension ($t=0.96$); at knowledge and application ($t=1.64$); and at comprehension and application categories of objectives ($t=0.65$).

Interaction Effects

Double interaction

The F-ratios for the 'interaction between treatment and learning approach' ($F=0.345$; $p>0.05$) 'between treatment and categories of objectives' ($F=1.084$; $p>0.05$) and 'between learning approach and categories of objectives' ($F=1.074$; $p>0.05$)' were all found to be not significant even at 0.05 level of significance. Hence, H_{4a}, H_{4b}, and H_{4c} were retained.

Triple interaction

The F-ratio for the 'interaction among the three variables, viz., treatment, learning approach and categories of objectives' was found to be significant at 0.05 level of confidence ($F=4.275$; $p<0.05$), leading to the rejection of H_{4d}. This has been shown by the graphical representations in Figure 2.

For the experimental group (Figure 2), students with deep learning approach displayed higher scores at application, followed then at knowledge and comprehension categories. But, students with surface learning approach displayed highest performance at application category, then at comprehension and knowledge categories of objectives. For the control group, performance for students with deep learning approach was highest at application category of objectives, then at comprehension and knowledge categories; whereas performance for students with surface learning approach was higher at knowledge category but

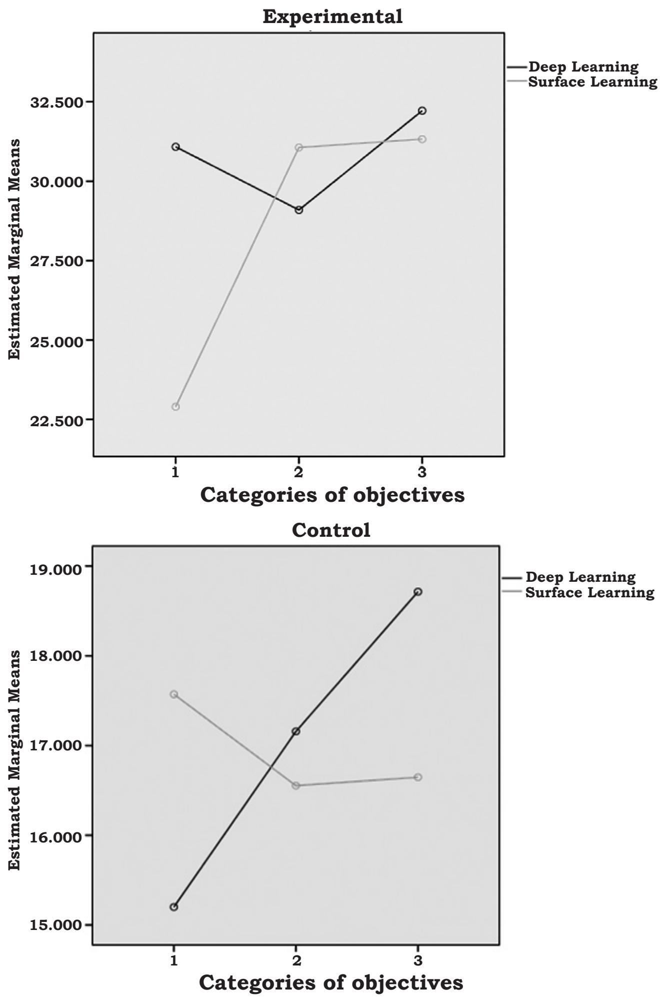


Figure 2: Interaction effect among treatment, learning approach, and categories of objectives pertaining to achievement in experimental group and control group

equivalent at application and comprehension categories.

For further investigation among various combination of groups, the t-ratios were computed as a result of significant triple interaction. The major findings:

- At knowledge category of objective, students with deep learning approach performed higher (t=4.13**) when taught through inquiry-based learning than conventional method whereas, students with surface learning approach performed comparably (t=1.72) when taught through inquiry-based learning and conventional method. At comprehension category of objective, students with deep learning approach (t=3.39*) as well as surface learning approach (t=4.42**) performed better when taught through inquiry-based learning than conventional method. At application category of objective, students with deep learning approach (t=4.10**) as well as surface learning approach (t=4.24**) performed better when taught through inquiry-based learning than conventional method.

- For experimental group, through inquiry-based learning, performance of students with deep learning approach is similar at knowledge and comprehension categories of objectives (t=0.47), at knowledge and application categories of objectives (t=0.05), at comprehension and application categories of objectives (t=0.82). Whereas, students with surface learning approach performed significantly higher at comprehension level than at knowledge level (t=2.32*), higher at application level than at knowledge level (t=2.15*), but equivalent at comprehension and application categories of objectives (t=0.06). Students with deep learning approach performed better than students with surface learning approach at knowledge level (t=2.07*), whereas no difference was found among students with deep or surface learning approach at comprehension level of objectives (t=0.52), and at application category of objective, (t=0.22).
- For control group in conventional settings, performance of students with deep learning approach is equivalent at knowledge and comprehension categories of objectives (t=0.64), at knowledge and application categories of objectives (t=1.18), at comprehension and application categories of objectives (t=0.52). Students with surface learning approach performed comparably at knowledge and comprehension categories of objectives (t=0.38), at knowledge and application categories of objectives (t=0.37), at comprehension and application categories of objectives (t=0.04). No difference was found on the mean scores of students with of either deep or surface learning approaches at knowledge category of objectives (t=0.76) at comprehension category of objectives (t=0.21), at application category of objectives (t=0.83).

Table 5: Means and SDs of Sub-Samples (Retention Scores)

S. No.	Learning Approach (L)	Categories of Objectives (O)	Experimental Group (T1)	Control Group (T2)
1.	L_1	O_1	M=38.06	M=19.29
			N=37	N=36
			SD=19.53	SD=12.49
		O_2	M=35.53	M=19.04
			N=37	N=36
			SD=18.31	SD=12.70
		O_3	M=37.34	M=21.78
			N=37	N=36
			SD=16.14	SD=12.99
2.	L_2	O_1	M=30.56	M=24.55
			N=41	N=43
			SD=15.82	SD=15.84
		O_2	M=37.66	M=22.71
			N=41	N=43
			SD=19.55	SD=15.84
		O_3	M=37.16	M=21.72
			N=41	N=43
			SD=19.63	SD=12.40

Again, assumptions of 'normality, homogeneity of variance and sphericity' were tested in SPSS. None of the assumptions were violated.

Main Effect

Table 6 shows, F-ratio for the difference in the mean gain retention scores of the two treatment groups was found to be highly significant at 0.01 level of confidence (F=46.168; p<0.01). Further, means indicated that students in inquiry-based learning settings displayed higher retention as compared to those when taught through conventional chalk and talk method. H_{1b} is rejected.

F-ratio for the difference in retention scores between deep and surface learning groups was found to be not significant even at 0.05 level of confidence (F=0.067; p>0.05). This indicates that amount of retention in Science among students with either of the learning approach was similar. H_{2b} is retained.

Table 6: ANOVA Summary for Retention Scores

Source of variation	Sum of Squares	Df	MSS	F-value	p-value
Treatment (T)	24755.229	1	24755.229	46.168	0.0001**
Learning approach (L)	35.699	1	35.699	0.067	0.797
Treatment x Learning approach (T x L)	677.440	1	677.440	1.263	0.263
Error (between)	82038.532	153	536.200		
Within Subjects					
Source	**Sum of Squares**	**Df**	**MSS**	**F-value**	**p-value**
Objectives (O)	151.188	2	75.594	0.602	0.548
Treatment x Objectives (T x O)	271.132	2	135.566	1.080	0.341
Learning approach x Objectives (L x O)	342.675	2	171.338	1.365	0.257
Treatment x Learning approach x Objectives (T x L x O)	936.669	2	468.334	3.731	0.025*
Error (within)	38410.596	306	125.525		

**Significant at 0.05 level of confidence*
***Significant at 0.01 level of confidence*

F-ratio for the difference in mean gain at three categories of objectives was found to be not significant even at 0.05 level of confidence (F=0.602; p>0.05). This implies that the students retained similarly at knowledge, comprehension and application categories of objectives. H_{1c} is retained.

Interaction Effects

Double interaction

The F-ratios for the interaction between treatment and learning approach (F=1.263; p>0.05); treatment and categories of objectives (F=1.080; p>0.05), and between learning approach and categories of objectives (F=1.365; p>0.05) were all found to be not significant even at 0.05 level of confidence. $H_{5a,}$ H_{5b} and H_{5c} were retained.

Triple interaction

The F-ratio for the interaction among the three variables, viz., treatment, learning approach and categories of objectives was found to be significant at 0.05 level of confidence ($F=3.731$; $p<0.05$). Hence, H_{5d} is rejected.

The Figure 3 shows that in the experimental group retention for the students with deep learning approach was highest at knowledge category, then at application and comprehension categories. But students with surface learning approach attained highest score at the comprehension category followed by application and knowledge

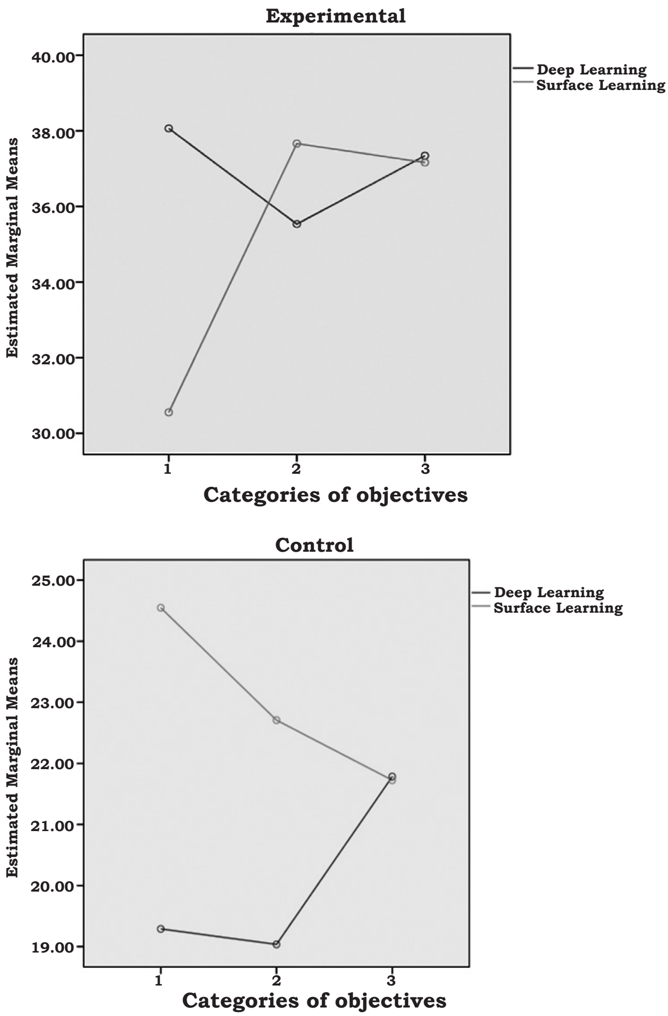


Figure 3: Interaction among treatment, learning approach, and categories of objectives pertaining to retention for experimental and control group

categories. In control group, retention for the students with surface learning approach was highest at knowledge category, then at comprehension and application categories. Similarly, retention for students with deep learning approach was highest at application category, followed by knowledge and comprehension categories of objectives.

The t-ratios were computed to see the difference among various group combinations. The major findings were:

- At knowledge category, students with deep learning approach (t=4.91**) and surface learning approach (t=3.36**) retained higher when taught through inquiry-based learning than conventional method. At comprehension category of objective, students with both learning approaches, viz., deep learning approach (t=4.48**) and surface learning approach (t=3.84**) retained better when taught through inquiry-based learning than conventional method. At application level also, students with deep learning approach (t=4.54**) retained better as well as students with surface learning approach (t=4.29**) when taught through inquiry-based learning than conventional method.
- In the experimental group, students with deep learning approach yielded equivalent retention scores at knowledge and comprehension categories of objectives (t=0.57), at knowledge and application categories of objectives (t=0.17), at comprehension and application categories of objectives (t=0.45). Students with surface learning approach retained in an equal manner at knowledge and comprehension categories of objectives (t=1.81), at knowledge and application categories of objectives (t=1.68), and at comprehension and application categories of objectives (t=0.12). Students with deep and surface learning approaches retained likewise at knowledge category (t=1.85), at comprehension (t=0.5), at application category (t=0.04).
- In the control group, students with deep learning approach retained equally at knowledge and comprehension categories (t=0.08), at knowledge and application categories (t=0.83), and at comprehension and application categories of objectives (t=0.9), students with surface learning approach too retained similarly at knowledge and comprehension categories of objectives (t=0.54), at knowledge and application categories

of objectives (t=0.92), at comprehension and application categories of objectives (t=0.32). Students with deep and surface learning approaches retained likewise at knowledge category of objectives (t=1.65), at comprehension category of objectives (t=1.14), at application category of objectives (t=0.02).

Discussion of Results

According to the findings of the present study it can be concluded that academic achievement and retention of students in Science is greater when taught through an inquiry-based learning approach than those taught through the traditional chalk-and-talk method. The results are in consonance with the earlier studies (Ebrahim, 2004; Marx et al., 2004; Cherry, 2011; Veloo et al., 2013; Abdi, 2014; Koksal and Berberoglu, 2014; Maxwell et al., 2015; Sen and Oskay, 2016; Malik et al., 2017; Unlu and Dokme, 2020; Wilson, 2020; Alachi and Ifeanyi, 2021; Tekin and Mustu, 2021; Tsering and Yangden, 2021; and Ayoola, 2023). The study has shed light on a number of significant aspects such as how different methods of instruction and learning approach impact students' academic achievement. It emerged that students' achievement and retention in science was similar whether they adopted a surface learning approach or a deep learning approach.

The study also found that students performed in a similar manner across knowledge, comprehension and application level of objectives, regardless of inquiry-based learning approach or traditional chalk and talk method. Both deep and surface learners showed similar performance across different learning objectives indicating that the learning approach does not significantly affect student's achievement in different categories of objectives. Interestingly, significant differences were found when the combined interaction of three variables, viz., instructional methods, learning approaches and objective categories was studied. Students using a deep learning approach who were taught through inquiry-based learning performed better on application level than knowledge and comprehension level. Surface learners scored better in understanding and application level than in knowledge level. For delayed retention, students with either of learning approach; deep or surface learning approach in inquiry-based learning retained significantly higher than in conventional settings on all categories of objectives. Students who were taught through inquiry-based learning displayed equivalent retention irrespective of the learning approach adopted by them. The results indicated that 5E model as an inquiry-based learning approach is effective in boosting achievement and retention for a longer period of time irrespective of the kind of approach students adopt in interacting with the instructional material.

Educational Implications

- The impact of inquiry-based learning approach on student academic achievement and retention occurs because learners were engaged in performing activities, observing and drawing out conclusions by making connections between their explored knowledge, and existing knowledge. Additionally, group activities encourage students to participate and motivate each other to learn.
- The various stages of 5E learning cycle, viz., engagement, exploration, explanation, and elaboration involves learners in working in groups, collaborative learning, co-operative learning, group discussion, experiment, observations to record, and interpretation to write were incorporated and this helped students to build a strong foundation of knowledge through active participation. All activities were of reasonable difficulty level. By fostering curiosity, and exploration, 5E model contributes to a deeper understanding of concepts in science and in turn, enhances academic achievement.
- The inquiry-based learning is adaptable to the pace of both categories: students with deep learning approach and student with surface learning approach. This enables it to cater to the specific needs of each student by developing cognitive abilities like reasoning, exploration, observation, questioning, and the ability to make associations among other things.

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