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Study of Effectiveness of Pattern-Based Teaching Method on Students' Long-Term Retention of Contents in Organic Chemistry

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ABSTRACT: Organic chemistry is a subject which seems difficult to students because of complex reactions and mechanisms involved. The main aim of this study was to study the students' understanding of the concepts of organic chemistry by pattern-based teaching method (PBT). Pattern Based Teaching is a systematic approach in teaching chemistry where the reactions and mechanisms are systematized into a particular pattern for different functional groups. The students are made to understand the basic concepts how to introduce a particular functional group and how functional groups give reactions with different type of reagents. The present paper reports the effect of this innovative teaching method on students' long-term retention of organic chemistry course material. Long term retention of contents was examined by conducting two tests- pre-test (based on traditional lecture teaching) and a post-test (conducted after PBT). Students of first year undergraduate class of two different colleges of Kishangarh city of Ajmer district of Rajasthan were used for the study. These students were divided into six groups and two of them (experimental groups) were taught by PBT method. The rest four groups were control groups which were not given learning by the PBT method. Students' performance after PBT method was compared to that in a traditional lecture-based teaching method. Our analysis showed that the out of the six sample groups of students used in our study, the highest mean scores (10.46 and 13.36) were of the two experimental groups. The four control groups had mean scores in the range 7-10. This investigation thus suggests that pattern-based teaching in organic chemistry is a powerful and systematic approach which facilitates students' long-term retention of contents of the subject. It promotes active learning and creates students' interest in the subject.

Keywords: pattern-based teaching, CBZ, PCM, graduate, pre- and post-test

INTRODUCTION

Organic chemistry is a branch of chemistry which involves study of diverse organic compounds, their structure, syntheses, reactions and mechanisms of reactions [1]. Organic chemistry has a reputation as a challenging course [2,3]. Undergraduate students often lack the metacognitive skills and self-efficacy to be successful in organic chemistry [4]. This paper is based on pattern-based teaching method in Organic Chemistry which improves the metacognitive skills of students as it involves set and organized systematic patterns of reactions in organic chemistry which are otherwise hard to remember. This pattern-based approach provides a step-by-step guide to the students about the reactions, develops their thinking skills and enhances their learning outcomes.

It is a general trend that students find this subject difficult and challenging which may be attributed to the complexity of organic compounds and difficulty in learning and understanding the reactions. Students view organic chemistry synthesis as challenging because of their reliance on memorization of a large number of reactions, reagents and rules, poor conceptual understanding of the topics, ineffective teaching methods which lack active learning and student engagement. Memorization and Rote learning play an important role in the learning of multi-step organic synthesis which might cause a hindrance to process of

learning and can impede students' problem-solving ability [5].

Hence there is a compelling need for a systematic approach towards the subject which enables the students to deeply understand the basic concepts and reactions and makes the subject more interesting for them. Effective teaching and learning of organic chemistry is a challenge for instructors. Traditional ways of teaching do not foster students' active involvement. Hence students' logical thinking and understanding is not facilitated in this method. In order to study organic chemistry one must have an analytical mind, a logical approach, deep understanding of basic concepts and a grasp of technical terms. Introduction of multiple teaching methods in organic chemistry promotes active learning and students' involvement and may include reading worksheets, in-class worksheets, interactive lecturing, audio-visual instruction demonstration methods, discussions, activity method and team-teaching method. All of these helps to develop thinking skills of students [6]

In undergraduate programs, organic chemistry syllabus covers different types of functional groups, their synthesis, and reactions. It involves too many reactions and mechanisms which are difficult to memorize and students often get confused and are compelled to do rote memorization. Hence there is a need for a systematic method of instruction which makes the students better understand these reactions and facilitates them in learning these reactions. Since each functional group gives specific types of reactions, there is a particular and unique pattern of reactions for each type of functional group. So, if a student understands this pattern followed in synthesis and reactions of various functional groups, it becomes easier for them to learn these reactions. The pattern-based teaching developed by us for CBZ (Chemistry, Botany and Zoology) and PCM (Physics, Chemistry and Mathematics) groups of first year graduate level helps the students to understand these patterns. If the basic concepts like how a particular functional group compound is synthesized, which functional group moiety gives which type of reactions, are clear to the students there is no need of rote memorization.

For effective learning lectures should be interactive, discussion based and the instructor should not just only deliver the content but should act as a mentor who is concerned with guiding the students' ways to become proficient [7]. Some of the innovative teaching technologies used are:

- Student-Directed Learning (SDL): This technique fosters self-confidence and awareness of students' role in teaching, learning process. Traditional lecture class session is transformed into a continuous dialogue between teachers and learners [8].
- Collaborative and Problem Based Learning (PBL): This helps students take a deep approach in learning, promotes content acquisition and intellectual development of students [9].
- Team Learning method: Here small groups or teams of learners are made to improve understanding of organic chemistry [10].
- Theme-based Learning method: This refers to the ways to explore associated and related concepts, ideas, knowledge, learning contents and themes. It is for students to work more on their own to find out new knowledge and then apply it into real-life situations [11].
- Flipped Class Room Approach: In this approach students are made to watch educational videos before each class and during the class time they are made to work on problems focused on applying the concepts explained in the videos [12-14].
- Combining Cooperative learning and Multimedia: Using more visuals in class helps to improve the students' observational skills and proficiency in visualizing chemical principles. Combination of lecture, multimedia and cooperative learning creates a productive learning environment [15].
- New information technologies such as Massive open on-line courses (MOOCs) [16]: and on-line homework and clickers [17] are also revolutionizing the ways to access information.
- Project-based learning model creates significant differences in students' learning achievement and collaborative skills [18].

All the above innovative technologies and their integration into instruction have been found to be promising strategies to enhance student learning. However organic chemistry is a subject that is best taught by pattern recognition. First of all, a foundation of basic chemical concepts has to be built by the instructor. Mechanisms, being the heart of the reaction help to breakdown the reaction into simpler steps. Hence teaching mechanisms leads to develop a better understanding. Chemical reactions follow patterns and these patterns allow a student to predict the behavior of a chemical. Thus understanding of basic concepts of chemistry and mechanisms along with pattern recognition facilitates students' learning and

creates interest in the subject.

MATERIAL AND METHODS

In traditional lecture-based teaching method, students are not able to understand the basic concepts of organic chemistry, They often get confused and are not able to memorize so many reactions. Although the students used in the present study were all above average (admission criteria based on the percentage of marks in XII standard), we could see their low retention of Organic Chemistry contents by taking a sample test of few students (a sample sheet is enclosed*). Their answers were vague which suggested their lack of understanding of the concepts of Organic Chemistry. Although there is a repetition of chapters of Organic Chemistry in XII standard and first year undergraduate class and most of the reactions are similar, still it is seen that retention power of these students of Organic Chemistry is quite low.

We developed an innovative teaching method which we called Pattern Based Teaching method in Organic Chemistry for first year undergraduate students. In this method we planned to teach the reactions in a systematic and particular pattern so as to make a clear picture in the minds of learners. We proceeded from simpler to hard reactions. To enhance their retention capability, we emphasized on revision of the previous reactions before moving on to the new reaction following the pattern created. Learning reactions in a patterned way not only enhanced their ability to memorize and understand but also developed students' creative thinking capacity and problem-solving ability. This effectiveness of PBT on long term retention of contents in Organic Chemistry could be seen in the results of our investigation. For the study we took four topics of B.Sc. Pt. I Organic Chemistry syllabus namely Alkanes, alkenes, alkynes and alkyl halides. The synthesis, reactions and other basic concepts related to these topics were taught to students by this innovative teaching method through power point presentations. The teaching was based on the fact that the chemical reactions follow a particular pattern in each of these compounds. These patterns allow a student to predict how a chemical will behave. Here this pattern is given as sample for two chapters -Alkane and Alkene.

Name of chapter: Alkane

Sequence of Reactions in Text books	Sequence of Reactions in PBT
Methods of formation –	**Methods of formation –**
1.From hydrogenation of alkenes & alkynes	1.From alkene (catalytic hydrogenation)
2.By reduction of haloalkanes	2.From alkyne (catalytic hydrogenation)
3.By Wurtz reaction	3.From alkyl halide
4.Reaction of alkyl halides with organometallic compounds	(a) reduction
	(b) (i) Wurtz reaction
(Corey-House alkane synthesis)	(ii) Fittig reaction
5.By G.R.	(iii) Wurtz-Fittig reaction
6.From alkanols	(iv) Frankland reaction
7.From carbonyl compounds	(c) From Organometallic compounds
(a) Red phosphorus/HI	(i) with GR
(b) Clemmensen reduction	(ii) Corey-House synthesis
(c)Huang-Minlon modification of Wolf-Kishner reduction	4.From GR
	5.From alcohol
8.Decarboxylation of carboxylic acids and their derivatives	6.From carbonyl compounds (i)reduction
	(ii) Clemension reduction
9.By Kolbe's reaction	(iii)Wolff-Kishner reduction
10.By reduction of Carboxylic acids	7.From carboxylic acids
Chemical properties –	(i)Reduction with phosphorus and HI
1.Halogenation	(ii)decarboxylation (by sodalime)
2.Nitration	(iii)Kolbe's electrolytic reduction
3Sulphonation	8.Special only for methane
4.Incorporation of methylene group	**Chemical properties –**
5.Chlorosulfonation (Reed reaction)	1.Halogenation
6.Pyrolysis	2.Nitration
7.Dehydrogenation	3.Sulphonation
8.Isomerization	4.Chlorosulfonation (Reed reaction)

9. Combustion	5.Isomerization 6.Pyrolysis 7.Dehydrogenation 8. Combustion 9.Incorporation of methylene group 10.Chlorinolysis

Name of chapter: Alkene

Sequence of Reactions in Text books	Sequence of Reactions in PBT
Methods of formation – 1.Dehydrohalogenation of alkyl halides 2.Dehalogenation of dihaloalkanes 3.Dehydration of alcohols 4.Hoffman elimination **Chemical properties –** 1.Hydrogenation 2.electrophilic addition (i) addition of X_2 (ii) addition of HX (iii)addition of H_2SO_4 (iv)addition of H_2O (v)addition of HOCl (vi) addition of NOCl 3.Oxidation 4.Substitution 5.Polymerization 6.Isomerization	**Methods of formation –** 1. Dehydration of alcohols 2. Dehydrohalogenation of alkyl halides 3.Dehalogenation of dihaloalkanes 4.Pyrolysis of Alkanes 5.Pyrolysis of Esters 6.Partial hydrogenation of alkynes 7.Kolbe's electrolytic reduction **Chemical properties –** 1.Addition of H_2 2.Addition of X_2 3.Addition of HX 4.Addition of NOCl 5.Addition of HOCl 6.Addition of H_2SO_4 7. Hydroboration 8. Hydroformylation 9.Hydroxylation 10.Ozonolysis 11.Oxidation 12.Alkylation 13.Acetylation 14.Isomerization 15.Polymerization 16.Substitution 17.Special (reaction with Sulphur monochloride) 18.Combustion

RESEARCH DESIGN

Learning and retention is better when teaching is systematic and follows certain pattern. This may be accomplished by audio-visual teaching, project-based learning [18], thinking-based learning methods [19]. Such methods enhance the retention power of learners because the set patterns fit into their minds. Based on this, we designed a PBT method for teaching Organic Chemistry which focused on students' retention of concepts, reactions and their mechanisms. In order to make learning more effective we reorganized the content, laid emphasis on mechanisms and rearranged the synthesis and reactions of these compounds into more meaningful patterns. Mechanisms of reactions were taught which led to better understanding as these help to breakdown the reactions into simpler steps. Lectures in this PBT method were interactive and discussion based and students showed interest in the subject. As PBT is a more systematic approach we expect students to have a deeper understanding that can be seen in their long-term retention of contents. The purpose of the present study is to investigate the effectiveness of this innovative teaching method on students' long-term retention of contents.

The participants in this study were 180 first year undergraduate degree students of following two colleges

- Shri R.K. Patni Girls' College, Kishangarh

- Shri R.K. Patni Government P.G.College, Kishangarh.

Admission process to these colleges is purely on merit basis. Hence, all participants are above average students, but most of them are not having above average or good marks in Organic Chemistry which suggests that they have low retention power of Organic Chemistry contents. These students have two options of subject combinations. Those who are from Science-Bio background in XII standard are supposed to opt for three subjects Chemistry, Botany and Zoology (CBZ). The students with Science-Maths group have to opt for Physics, Chemistry and Maths (PCM). Most of these students come from rural background and passed their 12th standard from Government Senior Secondary schools. Majority of them are from Hindi medium.

We took students from both backgrounds i.e., CBZ and PCM. These students were categorized into 6 groups of 30 participants each. Out of these six groups two were experimental groups and four were control groups. The sample groups are shown in the following table:

S.No.	Group type	Group Name	Group Size	Institution
1	Control group	B.Sc. Part I (CBZ) Girls	30	Shri R.K.Patni Girls College, Kishangarh
2	Control group	B.Sc. Part I (PCM) Girls	30	
3	Control group	B.Sc. Part I (PCM) Boys	30	Shri R.K.Patni Government P.G.College, Kishangarh
4	Control group	B.Sc. Part I (PCM) Girls	30	
5	Experimental group	B.Sc. Part I (CBZ) Boys	30	
6	Experimental group	B.Sc. Part I (CBZ) Girls	30	

The experimental groups were taught by using PBT method while the control groups were not taught by this method. They only used the contents of the subject given in the text books. The experimental groups chosen were students of CBZ groups of SRKP Govt. PG College Kishangarh (group no. 5 & 6). Sample of CBZ groups were used in the study because thinking skills are different for CBZ and PCM students. CBZ students study chemistry as the main subject but PCM students give third priority to Chemistry (their preference order being Mathematics, Physics and Chemistry). However, CBZ students of Shri R. K. Patni Girls' College Kishangarh (group no. 1&2) could not be used as experimental groups as the authors are posted at Shri R. K. Patni Govt. PG College Kishangarh and so they were not involved in the teaching of students of these groups. Thus only two groups (group no. 5&6) of SRKP Govt. PG College Kishangarh were taken as experimental groups.

Instrument

Two question papers were set, one for pre-test and one for post-test to examine the students' long-term retention in PBT method. Pre-test was conducted before providing pattern-based teaching for all the six groups and post-test was conducted for the two experimental groups after providing them learning through PBT method. The question papers consisted of 34 questions which included level appropriate and content appropriate questions. Section A had 8 multiple choice questions, section B consisted of 8 fill in the blanks type questions, section C included 10 short answer type questions and section D had 8 long answer type questions. Thus, the tests were designed so as to examine the cognitive skills and effectiveness of the students' learning through this innovative method. The topics covered in the tests were alkanes, alkenes, alkynes and alkyl halides. The questions were designed to test the understanding and retention power of students about free radical substitution, name reactions, common methods of preparation and understanding of structure of compounds. Section A was of 8 marks, section B also of 8 marks, section C included 10 question of 2 marks each and section D had 8 questions of 3 marks each. Maximum marks were 60 and the time duration of test was 90 minutes.

First a pre-test was conducted for all the six groups based on traditional lecture-based teaching. Then the two experimental groups [B.Sc. Part I (CBZ) Boys and B.Sc. Part I (CBZ) Girls of Shri R.K. Patni Govt.

P.G. College, Kishangarh] were taught these topics by PBT method through power-point presentations. Thereafter a post-test was conducted for these experimental groups to measure the students' retention of contents on PBT method. Students' performance in PBT method was compared to that in traditional lecture teaching method.

Hypothesis of the Study

There should be no significant difference between B.Sc. Part I (CBZ) Girls and B.Sc. Part I (PCM) Girls of Shri R.K. Patni Girls' College as these groups were not taught by PBT method.

RESULT AND DISCUSSION

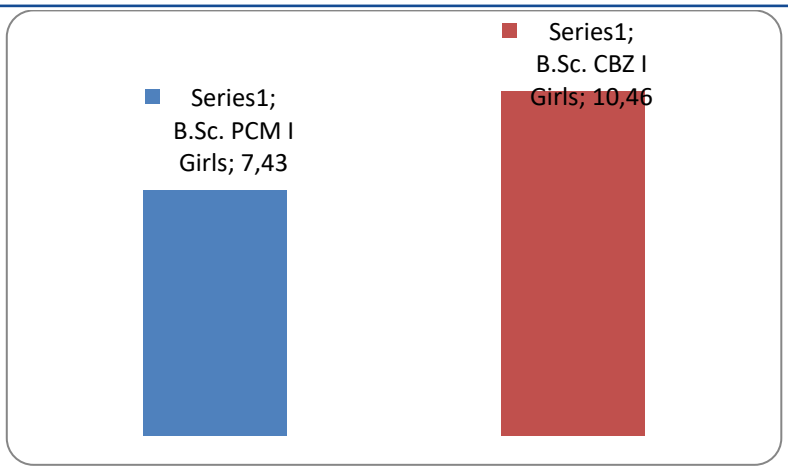
Students' performance in PBT was judged based on following four types of comparisons:

S.No.	Criterion	Basis of Criteria	Comparison groups
1.	Subject wise	Students of PCM are normally poor in Organic Chemistry	1. B.Sc. Part I (CBZ) Girls and B.Sc. Part I (PCM) Girls of Shri R.K. Patni Girls' college, Kishangarh. 2. B.Sc. Part I (CBZ) Boys and B.Sc. Part I (PCM) Boys of Shri R.K. Patni Govt. College, Kishangarh.
2.	Sexwise	Just to check whether the retention capacity of boys is different from that of girls	1. B.Sc. Part I (PCM) Boys and B.Sc. Part I (PCM) Girls of Shri R.K. Patni Govt. College, Kishangarh 2. B.Sc. Part I (CBZ) Boys and B.Sc. Part I (CBZ) Girls of Shri R.K. Patni Govt. College, Kishangarh.

The statistical analysis of results is shown below:

SUBJECT WISE COMPARISON STUDY OF GIRLS OF SHRI R.K. PATNI GIRLS' COLLEGE, KISHANGARH

Groups	No. of students	Mean	Variance	t value
B.Sc. Pt. I PCM Girls	30	7.43	57.08	1.63
B.Sc. Pt. I CBZ Girls	30	10.46	26.39	



It can be observed from the above table and graph that number of students of B.Sc. Part I PCM Girls is 30 and mean is 7.43 and B.Sc. Part I CBZ Girls are also 30 and mean is 10.46.

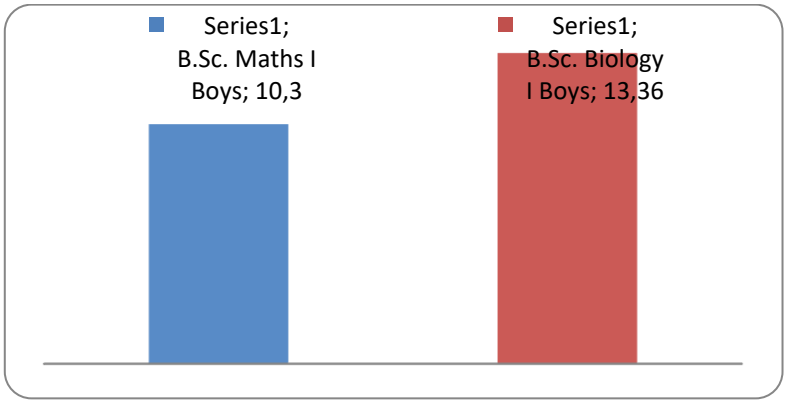
Source of Variation	df	F	P-value
Between Groups	1	3.30	0.07
Within Groups	58		

It can be observed from the above table that degree of freedom of between groups is 1 and within groups is 58, and both groups 'f' value is 3.30 and 'p' value is 0.07 and 't' value is 1.63. The 't' value between the two groups comes out to be 1.63 which is not significant at 0.05/0.01 level of significance. The null hypothesis formulated by the researcher is accepted.

It means that the B.Sc. Part I PCM Girls, and B.Sc. Part I CBZ Girls are not found significantly different in Biology and Maths. It can be further observed that the B.Sc. Part I CBZ Girls students have obtained higher mean scores in comparison of their B.Sc. Part I PCM Girls students.

SUBJECT WISE COMPARISON STUDY OF BOYS OF SHRI R.K.PATNI GOVERNMENT COLLEGE, KISHANGARH

Groups	Count	Mean	Variance	t-value
B.Sc. Pt I PCM Boys	30	10.3	60.7	1.86
B.Sc. Pt I CBZ Boys	30	13.36	36.92	



It can be observed from the above table and graph that number of students of B.Sc. Part I PCM Boys is 30 and mean is 10.3 and B.Sc. Pt. I CBZ Boys are also 30 and mean is 13.36.

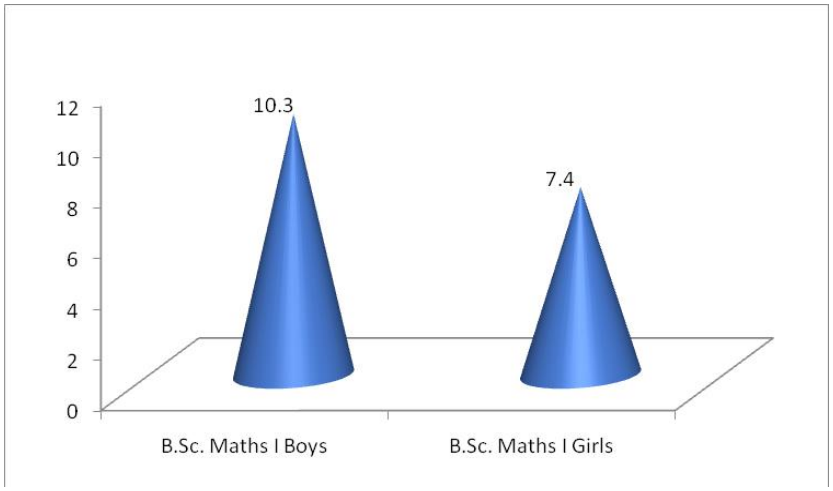
Source of Variation	df	F	P-value
Between Groups	1	2.88	0.09
Within Groups	58		

It can be observed from the above table that degree of freedom of between groups is 1 and within groups is 58, and both groups 'f' value is 2.88 and 'p' value is 0.09 and 't' value is 1.86. The 't' value between the two groups comes out to be 1.48 which is not significant at 0.05/0.01 level of significance. The null hypothesis formulated by the researcher is accepted.

It means that the B.Sc. Part I PCM Boys, and B.Sc. Part I CBZ Boys are not found significantly different. It can be further observed that the B.Sc. Part I CBZ Boys students have obtained higher mean scores in comparison of their B.Sc. Part I PCM Boys students on Effectiveness of Teaching Organic Chemistry through PBT Method among College students.

SEX WISE COMPARISON STUDY OF MATHS STUDENTS OF SHRI R.K. PATNI GOVERNMENT COLLEGE, KISHANGARH

Groups	No. of students	Mean	Variance	t value
B.Sc. Pt I PCM Boys	30	10.3	60.7	1.48
B.Sc. Pt I PCM Girls	30	7.4	57.0	



It can be observed from the above table that number of students of B.Sc. Part I PCM Boys is 30 and Mean is 10.3 and B.Sc. Part I PCM Girls are also 30 and Mean is 7.4.

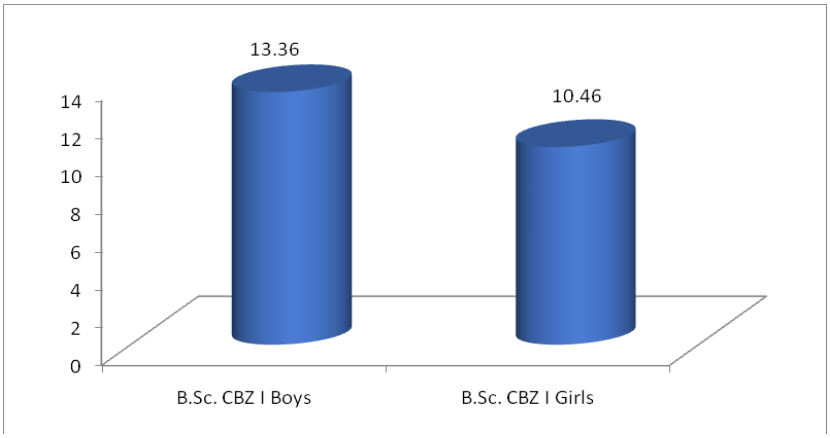
Source of Variation	df	F	P-value
Between Groups	1	3.98	0.05
Within Groups	58		

It can be observed from the above table that degree of freedom of between groups is 1 and within groups is 58, and both groups 'f' value is 3.98 and 'p' value is 0.05 and 't' value is 1.48. The 't' value between the two groups comes out to be 1.48 which is not significant at 0.05/0.01 level of significance. The null hypothesis formulated by the researcher is accepted.

It means that the B.Sc. Part I PCM Boys and B.Sc. Part I PCM Girls are not found significantly different. It can be further observed that the B.Sc. Part I PCM Boys students have obtained higher mean scores in comparison of their B.Sc. Part I PCM Girls students.

SEX WISE COMPARISON STUDY OF BIO STUDENTS SHRI R.K. PATNI GOVERNMENT COLLEGE, KISHANGARH

Groups	N	Mean	Variance	t value
B.Sc. Pt I CBZ Boys	30	13.36	36.92	-2.73
B.Sc. Pt I CBZ Girls	30	10.46	26.39	



It can be observed from the above table that number of students of B.Sc. Part I CBZ Boys is 30 and Mean is 13.36 and B.Sc. Part I CBZ Girls are also 30 and Mean is 10.46.

Source of Variation	df	F	P-value
Between Groups	1	3.98	0.05
Within Groups	58		

It can be observed from the above table that degree of freedom of between groups is 1 and within groups is 58, and both groups 'f' value is 3.98 and 'p' value is 0.05 and 't' value is 2.73. The 't' value between the two groups comes out to be 2.73 which is not significant at 0.05/0.01 level of significance. The null hypothesis formulated by the researcher is accepted.

It means that the B.Sc. Part I CBZ Boys and B.Sc. Part I CBZ I Girls are not found significantly different. It can be further observed that the B.Sc. Part I CBZ Boys students have obtained higher mean scores in comparison of their B.Sc. Part I CBZ Girls students on Effectiveness of Teaching Organic Chemistry through PBT.

CONCLUSION

In order to investigate the effectiveness of PBT on students' long-term retention of contents, the mean scores of students in pre-test and post-test have been compared in different groups. The mean scores indicate that the two experimental groups B.Sc. Part I CBZ Boys and B.Sc. Part I CBZ Girls of Shri R.K. Patni Govt. College, Kishangarh (who were taught by PBT method) have highest mean scores than all the other groups. This confirms the effectiveness of PBT method. Thus pattern- based teaching method helped students to retain the information better than the traditional lecture- based teaching method. It can therefore be concluded that this method is a powerful and systematic approach to better understand and learning in organic chemistry. Hence it is recommended that this method of instruction be used in teaching Organic Chemistry. The results of this study show that pattern recognition helps develop students' thinking skills and facilitate better understanding and learning. Hence further studies and research on chemical

education should be focused on the development of instructional strategies that prompt the use of cognitive skills of students and develop visualizing ability in the students.

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REFERENCES

1. http://www.acs.org/content/acs/en/careers/college-to-career/areas-of-chemistry/organic chemistry.html
2. N. P. Grove and S. L. Bretz, Chemistry Education Research and Practice, 13, 201-208,(2012)
3. D. J.Lynch and H. Trujillo, International Journal of Science and Mathematics Education, 9,1351-1365(2011)
4. N.Zhao, J.G.Wardeska, S.Y.McGuire, and E. Cook, Journal of College Science Teaching, 43,4, 48-54(2014).
5. I. Salame, P. Casino and N. Hodges, , International Journal of Chemistry Education Research, 3 (3), 1-9 (2020)
6. D.S. Mahajan., G.S.Singh, Education, 123, 4, (2003)
7. F, L.Lambert, Journal of Chemical Education, 40(4), 173, (1963)
8. K. Marlene, Journal of Chemical Education, 73 (5)**,** 440, (1996)
9. L.C. Hodges, and L.C.Harvey, Academic Exchange Quarterly, 6, 1, (2002)
10. F. J.Dinan and Frydrychowksi, Journal of Chemical Education, 72, 5, 429, (1995)
11. D. T. V. Anh, C. V. Tiem, P. T. Binh, American Journal of Educational Research, 8, 11, (2020)
12. C. Caroline, V. Bruno, Frontiers in ICT, DOI 10.3389/fict.2017.000, (30th Jan. 2018)
13. C. H. Arnaud, Chemical Engineering News, 91, 41-43, (2013)
14. J.M. Fautch, Chemistry Education Research and Practice, 16, 179-186, (2015)
15. H. E. Pence, Education, 113, 3, (1993)
16. www.chemistryview.org., Chemistry views, Innovative Learning and Teaching Practices, DOI:10. 1002/chem v. 201400012, (2014)
17. M.T.Gebru,A.J. Phelps and G.Wulfsberg, Chemistry Education Research and Practice, 13, 325-329, (2012)
18. D. N. Nuha, B. W. Febriana and K. Merdekawati, International Journal of Chemistry Education Research, 4, 1 (2020)
19. M. Taagepera and S. Noori, Journal of Chemical Education, 77, 9, 1224 (2000)