Impact of Certain Cognitive Strategies on Chemistry Outcomes in Organic Chemistry among Standard IX Students

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Abstract: Chemistry has been looked upon as a challenging subject by teachers, students and researchers because of the abstract nature of content in chemistry, teaching styles applied in class, and the difficulty of the language of chemistry. Cognitive load for the novice learner has a significant role in creating difficulties in chemistry learning. Cognitive strategies that teachers use as part of instruction may reduce the cognitive load and enhance learning the novel chemistry concepts. The sample sizes were 48 in experimental group and 48 in control group. The experimental group was taught by cognitive strategies like analogies, concept map, concept cartoons, story lines, worked examples, and puzzles to teach organic chemistry which is unfamiliar to them so far. The control group received constructivist mode of teaching. The impact of cognitive strategies was measured on chemistry outcomes like achievement, attitude and self-efficacy. Results showed that cognitive strategies have significantly enhanced the achievement, attitude and self-efficacy in organic chemistry.

Key terms: Organic chemistry, Cognitive strategies, Achievement, Attitude, Self-efficacy

The subject chemistry has been viewed as abstract, tough to learn and unconnected to the normal world by mainstream secondary school students. This leads to poor understanding and even misunderstanding of fundamental chemistry concepts. Kamisah and Nur(2013) observed that many secondary school students do not correctly comprehend various fundamental chemistry concepts. Even their interest and achievement in chemistry have declined for the past decades (Osborne & Collins, 2000). Learning chemistry needs a constant interplay between the macroscopic and microscopic levels of thought which may be easy for a chemist or chemistry educators, but very difficult for a novice learner to be concerned (Bradley & Brand, 1985). According to Aikenhead (2003) one of the reasons for this decline in chemistry may be because of the instruction is not linked to the world outside of school.

Johnstone (1974) reported that the difficult areas in the subject, from the pupils' point of view, the mole, chemical formulae and equations, and, in organic chemistry. While coming to the present scenario in Kerala, Organic chemistry is a novel topic for the standard IX students. From a survey among standard X students of Kerala, Gafoor and Shilna (2014) observed that more than 15 percent

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of students had faced difficulty on Organic chemistry in their 9th standard. At this juncture, it may be remarkable to suggest some alternatives to the present teaching strategy to overcome the particular difficulties faced by a novice learner.

Most chemistry syllabi at school level move very rapidly into atoms, molecules and equations. The novice students cannot cope, as their working memories are easily overloaded (Gafoor & Shilna, 2012). Cognitive load theory suggests that the free exploration of a highly complex environment may generate a heavy working memory load that is unfavourable to learning. This suggestion is particularly important in the case of novice learners, who lack proper schemas to integrate the new information with their preceding knowledge (Mayer, 2001; Paas, Renkel, & Sweller, 1999, 2003, 2004; Winn, 2003). Field-dependence is another cognitive variable which also lead to cognitive load. Field-dependent persons have difficulty in separating an item from its context and are tending to respond to the prevailing properties of a field offered to them. Tinajero and Paramo (1998) concluded that whatever may be the nature of assessment, field-independent students can perform better than field-dependent students.

Here comes the importance of particular strategy for teaching particular novel chemistry topics. A same strategy may not be effective for teaching all topics alike. Here in this study, cognitive strategies like Analogies, Concept map, Concept cartoons, Worked examples, story lines, and Puzzles were used to teach organic chemistry for the standard IX students. Students' Achievement, Attitude and Self-efficacy in organic chemistry were measured to verify the effectiveness of these cognitive strategies. Organic Chemistry is a much harder and unfamiliar subject for a secondary school student is concerned as it relies up on the use of two dimensional structures and figures to represent three dimensional molecules. This topic covers nomenclature and structures of organic compounds that were unaware to ninth standard students so far.

Definition of Key Terms

Certain Cognitive Strategies

A cognitive strategy is a mental procedure for achieving cognitive goals like solving a problem, learning for a test, or comprehending what is being read (Dole, Nokes, & Drits 2009). Cognitive strategies has evolved when cognitive psychologists began to focus on the mind wholly, thinking about how humans process, organize and store information in memory which owes its origin to the field of psychology. According to Salovaara (2005) cognitive learning strategies are deliberately selected according to the needs of the task at hand, and they involve both cognitive and motivational aspects.

Research on cognitive strategies has established important connections between cognitive learning strategies and academic performance (Pintrich & De Groot, 1990; Weinstein & Mayer, 1986; Zimmerman & Martinez-Pons, 1986). A widespread amount of facts on different types of cognitive learning strategies has been made during the last few decades. One of the most cited categorizations, introduced by Weinstein and Mayer (1986), distinguishes between rehearsal, elaboration, organizational, metacognitive, and affective strategies. The research findings support the idea that deeper level cognitive strategies related to solving problems and developing understanding, are essential in academic learning (e.g., Pintrich & De Groot, 1990; Pintrich, Brown & Weinstein, 1990; Pressley & McCormick, 1995).

Here in this study the term certain cognitive strategies means different cognitive strategies suitable for various aspects of a particular novel chemistry concept say organic chemistry have been used in a single classroom. The particular cognitive strategies used were analogies, concept map, concept cartoons, story lines, worked examples, and puzzles.

Chemistry Outcomes

Specific Knowledge, Conceptual Understanding, Problem Solving, Attitude towards chemistry and Self-efficacy in chemistry are the outcomes on which the impact of the cognitive strategies is tested. The specific knowledge, conceptual understanding, and problem solving were collectively measured using the achievement test in chemistry. A detailed account of the measuring of chemistry outcomes are as follows.

Achievement in organic chemistry

Achievement in organic chemistry was measured using an achievement test contains 18 items. This test measures the extent to which a learner has achieved specific knowledge, conceptual understanding and problem solving in world of carbon, hydro carbons, Bonding in hydro carbons, and structure of hydro carbons. Items were prepared based on the blue print in consultation with chemistry teachers in secondary schools. First nine items were presented in the form of a concept map, by which the students have to fill in the blank boxes of the concept map. Rest nine items were given as multiple choice items. Each correct answer carries one mark. Concurrent validity of the test was calculated by correlating the test scores of students with their marks of a recently conducted test obtained from the school. The coefficient of correlation obtained was .44. The test-retest reliability is found to be .78.

Attitude towards organic chemistry

Attitude towards organic chemistry was measured using Guttman scale contains 12 items. To understand at which point the student feel dislike towards organic chemistry is better predicted with Guttman scales rather than Likert type scaling. Adequate representation was given to the four domains under consideration i.e., Hydro Carbons, Organic compounds, Structure of Organic compounds, Organic chemistry in everyday life. Students are asked to make a tick mark in rectangular boxes given corresponding to each statement in terms of agreement or disagreement. The two response patterns are Agree and Disagree. As the statements have a gradation pattern, the score of attitude of a particular student is that, up to which item he or she has agreed. If the student disagreed to a statement, and agreed to all of the above statements, then his or her score will be that of the previous statement. Items in the Scale of Attitude towards Organic Chemistry were prepared on consultation with seven co-researchers in education who have post-graduation degree in chemistry. Hence, theoretically the scale can be considered valid. The scale showed a correlation of .86 with Achievement test in Organic chemistry (Gafoor & Shilna, 2013) and .38 with Scale of Self-efficacy in Organic chemistry (Gafoor & Shilna, 2013). The test-retest reliability is found to be .72.

Self-efficacy in Organic chemistry

The efficacy beliefs of students in the topic organic chemistry was measured using a Likert scale of Self-efficacy in organic chemistry consists of 14 statements. The different domains considered were the number of carbon atoms in hydrocarbons, root name of hydrocarbons, molecular formula of hydrocarbons, structure of hydrocarbons, bonding in hydrocarbons, and common formula of hydrocarbons. A student who has self-efficacy in the topic organic chemistry means he can tell the type of bonding in a hydrocarbon from its molecular formula, represent the structure of hydrocarbon from its molecular formula, name a hydrocarbon by knowing the number of carbon atoms in it, write the molecular formula of a hydrocarbon by knowing the common formula. Here the respondents are asked to react to each item in terms of several degrees of frequency of occurrence. The five-response pattern is 1. Always, 2. Often, 3. Sometimes, 4.

Occasionally, 5. Never and the response alternatives are weighted 5,4,3,2,1 respectively. When scoring the tallies on negative items would reverse. The scale showed a correlation of .37 with Achievement test in Organic chemistry (Gafoor & Shilna, 2013) and .38 with Scale of Attitude towards Organic chemistry (Gafoor & Shilna, 2013). The test-retest reliability is found to be .86.

Objective

To test the effectiveness of certain cognitive strategies on

- Specific knowledge, Conceptual understanding, and Problem solving in organic chemistry
- Attitude towards organic chemistry
- Self-efficacy in organic chemistry

Method

The study employed quasi- experimental design.

Sample

The sample includes 96 standard IX students, 48 students each in experimental and control groups, from a government rural secondary school in Kerala, India. Two intact groups were matched on previous achievement, working memory capacity and field dependence. The pretest score on chemistry achievement (M_1=2.02 & M_2=2.13), attitude towards chemistry (M_1=129& M_2=128.85), self-efficacy in chemistry (M_1=130& M_2=130.25) showed these two groups do not differ significantly.

Design

O_1 X O_2
R C O_2

X -Experimental Group

C -Control Group

O_1& O_2 -Posttests conducted in experimental and control group respectively.

Procedure

The lesson organic chemistry was taught in the experimental group with the help of certain cognitive strategies including analogies, concept map, concept cartoons, story lines, worked examples, and puzzles; and in the control group with the existing constructivist learning strategy. The posttest scores were analyzed and compared between the two groups.

Results

From the analysis of the data, the results can be summed up as follows

Effect of the innovative instructional strategy on achievement in organic chemistry

Statistical indices namely mean, standard deviation of distribution of the posttest scores of achievement in organic chemistry obtained for the experimental and control groups of secondary school students are indicated in Table 1.

Table 1

Comparison of mean pretest and posttest scores of achievement in organic chemistry for experimental and control groups

Groups	Pretest scores			Posttest scores			
	Mean	Standard Deviation	Critical Ratio (*t*)	Mean	Standard Deviation	Critical Ratio (*t*)	Effect Size (Cohen's *d*)
Experimental Group	6.94	2.26	-0.51	12.1	2.19	4.72**	1.74
Control Group	7.19	2.5		10.1	1.15		

Note. N= 48.
** $p<.01$

Table 1 shows that there is no significant difference between the mean scores of Achievement in organic chemistry (t=-0.51; p>.05) for experimental and control groups before intervention. Achievement in organic chemistry is significantly higher for the group taught by the cognitive strategy (M_1=12.1, SD=2.19) than that taught by standard constructivist practices (M_2=10.1, SD=1.15), (t=4.72, p<.01). In terms of effect size (Cohen's d= 1.74), the advantage of cognitive strategies over standard constructivist classroom instruction in enhancing student achievement in organic chemistry is large which is evident in Figure 1.

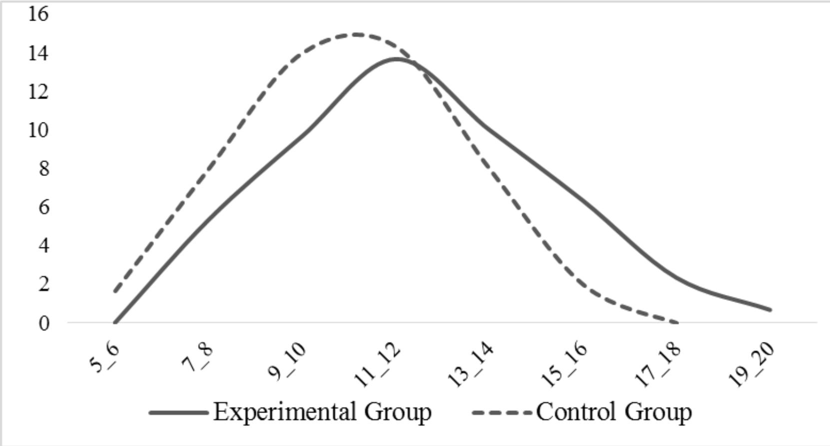

Figure 1. Effect of certain cognitive strategies on achievement in organic chemistry

Effect of the innovative instructional strategy on attitude towards organic chemistry

Statistical indices namely mean, standard deviation of distribution of the posttest scores of attitude towards organic chemistry obtained for the experimental and control groups of secondary school students are indicated in Table 2.

Table 2
Comparison of mean pretest and posttest scores of attitude towards organic chemistry for experimental and control groups

Groups	Pretest scores			Posttest scores			
	Mean	Standard Deviation	Critical Ratio (*t*)	Mean	Standard Deviation	Critical Ratio (*t*)	Effect Size (Cohen's *d*)
Experimental Group	2.6	0.82	0.11	9.73	1.19	4.21**	0.78
Control Group	2.58	1.07		8.73	1.28		

Note. N= 48.
** $p<.01$

Table 2, shows that there is no significant difference between the mean scores of Attitude towards organic chemistry (t=0.11; p>.05) for experimental and control groups before intervention**.** Attitude towards organic chemistry is significantly higher for the group taught by the cognitive strategy (M_1=9.73, SD=1.19) than that taught by standard constructivist practices (M_2=8.73, SD=1.28), (t=4.21, p<.01).In terms of effect size (Cohen's d= 0.78), the advantage of cognitive strategies over standard constructivist classroom instruction in enhancing student attitude towards organic chemistry is large which is evident in Figure 2.

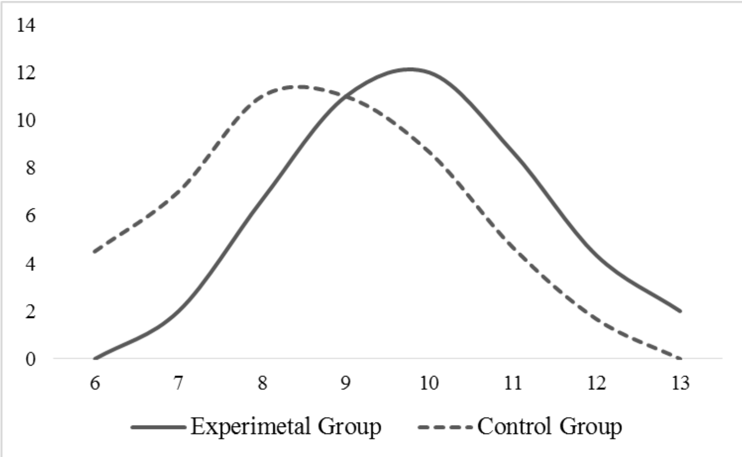

Figure 2. Effect of certain cognitive strategies on attitude towards organic chemistry

Effect of the innovative instructional strategy on self-efficacy in organic chemistry

Statistical indices namely mean, standard deviation of distribution of the posttest scores of self-efficacy in organic chemistry obtained for the experimental and control groups of secondary school students are indicated in Table 3.

Table 3

Comparison of mean pretest and posttest scores of self-efficacy in organic chemistry for experimental and control groups

Groups	Pretest scores			Posttest scores			
	Mean	Standard Deviation	Critical Ratio (t)	Mean	Standard Deviation	Critical Ratio (t)	Effect Size (Cohen's d)
Experimental Group	37.23	3.48	0.83	55.73	4.09	7.61**	1.7
Control Group	36.56	4.33		48.5	4.26		

Note. N= 48.

** $p<.01$

Table 3 shows that there is no significant difference between the mean scores of Self-efficacy in organic chemistry (*t*=0.83; *p*>.05) for experimental and control groups before intervention. Self-efficacy in organic chemistry is significantly higher for the group taught by the cognitive strategy (M_1=55.73, *SD*=4.09) than that taught by standard constructivist practices (M_2=48.5, *SD*=4.26), (*t*=7.61, *p*<.01).In terms of effect size (Cohen's *d*= 1.7), the advantage of cognitive strategies over standard constructivist classroom instruction in enhancing student self-efficacy beliefs in organic chemistry is large which is evident in Figure 3.

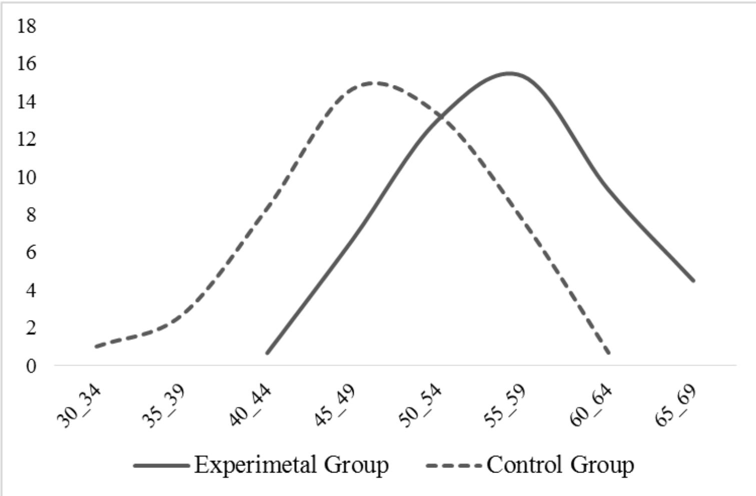

Figure 3. Effect of certain cognitive strategies on self-efficacy in organic chemistry

Conclusion

Results showed that cognitive learning strategies was effective in learning novel chemistry concepts meaningfully. It provides a manageable way to plan and carry out teaching according to students' ideas. They liberate students from outdated lecturing and also helps teachers to improve their teaching tactics. Students are getting more actively involved in the lesson as the strategies are interesting and entertaining. It creates discussion environment where student can improve their critical thinking skills, which may have an important role in improving the students' academic achievement. Therefore, chemistry teachers can make use of this cognitive strategies for effective transaction of novel concepts.

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