Effectiveness of Constructivist Approach for Promoting Conceptual Change in Chemistry

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Abstract:*Previous studies indicate that learners have many misconceptions in learning the basic concepts of chemistry. It demands to change such ideas or to develop scientific conceptions among science students. Therefore, the aim of this experimental study was to know the effectiveness of constructivist approach for promoting conceptual change in learning a concept of chemistry 'composition of matter' at high school level of Pakistani students. For this purpose 207 subjects were selected from two boys secondary schools of Lahore, who were randomly assigned as experimental and control groups. Twelve constructivist lesson plans of one hour each were prepared. Treatment was given by the researcher himself, once a week, to the experiment groups of 102 subjects of for three months. Whereas 105 male students were randomly assigned as control groups and were taught as usual through traditional text- book approach. Total 7 instances of an instrument known as interview-about-instances (IAI) were used to investigate students' misconceptions about this concept. The reliability of the instruments was determined by Cohan Kappa through inter-rater reliability. Content validity was established by experts. The comparison of qualitative nature of students understanding in experimental and control group was made through frequencies, percentages of misconceptions and scientific responses. Chi-Square ($\chi 2$) Test was used. Five different categories of alternative conceptions were identified which showed five alternative ways or frameworks of thinking. The findings indicated that experimental groups significantly outperformed their counterparts and these results clearly provided an evidence for the effectiveness of constructivist approach for promoting conceptual change.*

Key Words: Misconceptions, Alternative Conceptions, Composition of matter, IAI(interview-about-instances), Constructivist Approach.

1.Introduction

Over the past two decades or so, studies have revealed that children's concepts are often alternative to standard science. In the past, these ideas might have been dismissed as mistakes or errors, perhaps resulting from confusion, examination fevers or lack of revision time. However, what now has emerged is that these errors are not just random guesses but are children's representations of scientific concepts. From a constructivist perspective, learners are seen as developing ideas through an active process in which prior ideas have a fundamental role. So, children's ideas become highly significant as they potentially form the basis of future thinking and understanding. The recognition of children's ideas about science and the important role that these have in learning science has led to a number of innovative teaching initiatives. These initiatives explicitly recognize the existence of children's ideas prior to teaching and learning science is considered as a process of changing, restructuring, adopting or adding to these ideas. Viewed in this way, learning science is a process of conceptual change and addition. (Osborne & Freyberg, 1985). And central to teaching with this agenda in mind understands how and why children change their ideas. That is why; the inquiry/discovery activities generally follow the constructivist learning model (Yager, 1991).

Conceptual change is closely aligned to constructivist approach as well as to alternative conceptions. That is why, one of central objective in teaching science and chemistry is to promote conceptual change in the science students. Research indicates that students of all ages hold quite stubbornly to their alternative conceptions, even after considerable instruction that explicitly contradicts those alternative conceptions (Cary, 1995; Ormrod, 2002). Many science educators have pointed out that cognitive conflict is a crucial factor for promoting conceptual change (Park & Han, 2002).

Conceptual change is a learning process that changes an existing conception (i.e. belief, idea or concept) not merely accumulating new facts or learning a new skill but primarily a way of thinking about learning when learner does an intentional act rather than something done by the teacher. The first and most significant step in teaching for conceptual change is to make students aware of their own ideas about the topic or phenomena under study and then deciding whether or not to reconstruct them. This clearly places the responsibility for conceptual change with the learner (Trumper, 2001).

Constructivist does not align itself with any teaching methods but advocates a change in the approach towards the scope and nature of teaching-learning activity. Therefore, a constructivist teacher can manipulate any (or combination) of the existing teaching methods to assist students in constructing knowledge for themselves. This needs teachers to not only understand the philosophical and theoretical rationale of constructivism for becoming constructivist practitioners, but also to know the student understanding about the concept of science (Novak 1993; Zafar Iqbal, 2003).

However, the constructivist point of view is broader in scope even than discovery. In discovery, lessons are designed so that learner can arrive at only one possibility (if they follow directions correctly). But, in constructivist view, learners invent their own realities instead of discovering the teacher reality. Here, learners make meaning about experience, and invent visions which may never have been seen before in any teaching approach. As a theoretical ground for learning, constructivist impacts on both teaching and curriculum. The role of the teacher becomes that of analyzing and drawing upon the learner’s current state of knowing, providing an environment and context for learning, coaching, guiding and facilitating. In order to promote conceptual change the inquiry activities based on constructivist model would be the best choice.

Osborne, Bell, & Gilbert (1983) pointed out that school students understand little about the nature of matter or about other chemical phenomena in their everyday lives. At secondary level chemistry is core subject of science education. Unfortunately it is considered a difficult field of study both by the science students and teachers. It may be due to abstract nature of the fundamental concepts of chemistry. The other problem seems to be not having the cognitive sophistication and the cumulative background of experiences necessary for the development of basic concepts of chemistry. In learning chemistry the basic unseen particles of matter like molecules, atom, electron, proton etc; are taught in abstract manner. Another major problem is concerned with teaching methodology, which doesn’t meet the requirement to deal with the above-mentioned complexity i.e. the abstract nature of basic concepts of chemistry. The ability to handle concepts as they currently exist and deal with them in a flexible and changing fashion is joint objective of school learning. Many of our science graduates do not understand that our teeth and bones are built from the element of calcium and phosphorous. The hemoglobin that carries oxygen in our blood contains the element Iron (Fe) and the element Carbon, Hydrogen, Oxygen and Nitrogen derived from the digesting of food are used by the cells of our body to build protein.

The core dependent variable ‘promoting conceptual change’ is actually the implication or more clearly the consequence of cognitive development theories of Piaget and Vygotsky. As Piaget contends that cognitive development can be promoted through equilibration or creating cognitive conflict and Vygotsky emphasizes to assess child zone of proximal development (ZPD) to navigate with scaffolding (Moreno, 2010). In this context, it is evident that Piaget and Vygotsky theories are the base of constructivist approach. Therefore, the views of both proponents of constructivists would be tested or verified in this research study by using an eminent instrument which is called as interview-about-instances (IAI).

1.1.Objectives of Study

1. To determine the effectiveness of constructivist approach towards promoting conceptual change in science students at secondary level about the concept composition of matter.
2. To explore students’ understandings about the concept composition of matter, in chemistry at secondary school level.

3. To find out the alternative ways of thinking, through categorizing the alternative conceptions.
4. To measure conceptual change, through comparison of alternative conceptions over scientific responses about this concept in control and experimental groups.

1.2.Research Questions

1. What conceptions related to the concept composition of matter in chemistry do students hold at secondary level?
2. Are the alternative conceptions equally distributed in all categories?
3. Are there any common patterns in students' responses, that suggest common alternative frameworks, or ways of reasoning?
4. Is the constructivist approach effective for conceptual change of the concept composition of matter at secondary level?

2.Methodology

For this research study the 'post-test only control group design' was chosen. One group received the experimental treatment while other did not, and both of these groups were post-tested on the dependent variable. In this design, the control of certain threats was made in an excellent way e.g. the use of random assignment; the threats of subjects characteristics, and maturation were well controlled for. Following seven instances and non-instances were developed to explore the student's alternative conceptions.

i) Distilled water (instance about compound)
ii) Carbon dioxide (CO2) (instance about compound)
iii) Milk (instance about mixture)
iv) Flame (non-instance or non-example)
v) Sun-light (non-instance or non-example)
vi) Wooden chair (instance about composite mixture)
vii) Copper wire (instance about element

Following three general questions about each instance were asked.

i) Do you know, what is this (instance name)?
ii) Is it a kind of matter?
iii) Why do you think so?

2.1.Sampling

To proceed the research study a random sample of 207 subjects was selected from two boys secondary schools of 9th class. These subjects were divided into two groups which were randomly assigned as experimental and control groups. The experimental groups of 102 subjects were treated through constructivist approach and the control groups of 105 subjects were taught as usual through traditional textbook approach. Experimental treatment to all the subjects of experimental group was made by the researcher in both public high schools. The major role of research was as a facilitator, a guide or a leader of discussion. Motivation and real situation for constructivist learning was assured. Twelve lesson plans were developed according to the Model Lesson Plan Format (MLPF). This model lesson plan has the following five parts:

Invitation/Starter(the students are provided different materials for activities)
Elicitation(different questions are asked to elicit the students understanding)
Teacher Intervention(cognitive conflict is created and teacher give some clue to resolve the problem)

Restructuring/Formulation of ideas(communication or explanation of students understanding in a new situation)

Review of Conceptual Change(making link to topic and everyday experiences as well as evaluation of new learning)

One lesson per week in both schools was given as an experimental treatment for three months. Whereas the same concept was also taught through traditional textbook approach during this period.

2.2.Reliability of the Instrument

Reliability of the instrument IAI was determined. Cohen Kappa was used to identify the inter-rater reliability of the instrument. There were six categories of students conceptions identified for this concept of chemistry in which five categories were about the alternative conceptions and one category was about the scientific responses. Its values are given in following table:

Table1.Inter-rater reliability of the instrument

		Value	SE(a)	T(b)	Sig.
Measure of agreement	Kappa	.823	.019	39.064	.000
No of valid cases		520			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

2.3.Validity of the Instruments

In the light of IAI research instrument which was developed by Osborne & Gilbert (1979), the researcher developed 7 instances about this concept of chemistry along with open-ended questions which were related to the local curriculum of chemistry. Its content validity was established with the consultation of the experts having Doctoral/M.Phil. degree in chemistry as well as master degree in Science Education and related experience. Three experts have established the content validity of the instrument.

2.4.Exploration of student's ideas

To explore students understanding of this concept, 105 boys of control group and 102 boys of experimental group were presented seven instances /non-instances. According to the formula of "one instance = one response = one frequency" 735 responses (frequencies) of control group were coded in which only 18 responses were found as scientific ideas whereas 717 responses were identified as alternative conceptions. These were further classified into five categories with respect to their nature.

In contrast, total 714 responses were obtained from the experimental groups and only 90 responses (frequencies) were of alternative conceptions. These conceptions were further classified into five categories, whereas majority of the 624 frequencies were the scientific responses. A brief description of the data of both control and experimental groups is presented in five categories of alternative conceptions from category of higher frequencies to category of lower frequencies in the following way:

The maximum frequency number (308) of alternative conceptions with highest percentage of 41.85% subjects of control group classified in to *category-I (incorrect use of scientific terms).* For instance, distilled water is an 'elemental' substance of two gases like hydrogen and oxygen with not a fixed ratio (22). Co_2 is not a form of matter but a 'mixture' (36). Milk is a molecular form of matter and its components can be separated by heating(43). Flame is 'ionic' as well as 'gaseous' form of matter or sunlight is a 'molecular' type of matter (48+40). Wood is a 'compound' and 'molecular' type of matter (55). Copper wire is a 'compound', made up of copper or zinc some other metals.(54).

In the experimental group only 27 frequencies with 3.78% respondents were found in category-I about the concept composition of matter. Such as, distilled water is a 'mixture' and its solution has many mineral particles which are suitable for health (6). Since, subjects used the terms such as elements, compounds, molecules, colloids etc. to describe the composition of matter where that were not applicable. However, there was a big difference between control and experimental groups both in quantity as well as quality.

There were 23.88% subjects with second highest frequencies of 175 who had *self-centered/human centered* views about the concept 'composition of matter', when seven instances were used to probe their understandings in *boys control group.* Such as, distilled water is a drinking water and also used in drug manufacturing (12). The properties of Co_2 gas are not different from their constituents elements and dangerous for human life(22). The white colour of milk is its natural property and its use make a person white(38). The flame is produced by burning and smoke is produced instantly with it. Both have some common properties (10). Sunlight is produced at sun's surface and travels through radiations towards us(1). Similarly the composition of wood is tree like back, leaves and wood and nothing else(47). Copper wire is used as coiling and has three metals like, Fe, Zn and Pb and used in our houses(40).

In the *experimental group* 13 subjects were of the self-centered views (1.82%). Such as, Co_2 is not a matter but a gas which is produced during breathing (3). All the above responses are explained in the context of daily life. However, big difference is found in quantity and quality between control and experimental groups.

The third most common with 20.4% of alternative conceptions (150) were found in category-5 where subjects used correct scientific terms such as atoms, molecules, compounds etc. but explained incorrectly. Such as distilled water is a molecule and liquid matter but 'not fixed ratio' and atoms separate and again combine by passing electricity (42). Co_2 is a matter but has 'no weight' as its molecules are very small and move freely – not concentrate at one point (40). Milk is unsaturated mixture formed by other 'unsaturated' compounds (22).

There were 4.34% highest percentages with 31 frequencies of responses within the experimental group in this category-5. (However, much less than control group). For example, Wood is a composite mixture and its molecules are strong due to special force of strong chemical bonding (8).

The fourth with respect to the higher frequencies of 78 alternative conceptions is *self-contradictory views* with average of 10.61% about all the instances of composition of matter in control group. Such as, milk is not a matter but a liquid compound (2). Copper (Cu) is an element but its wire is a compound of Zn and Cu (3).

In the experimental group, 1.96% subjects were self-contradictory views (14). Such as Co_2 is not a matter. However, its molecules are material particles (4). The lowest number of frequencies of alternative conceptions (6) or 0.81% were the category-4 where *no scientific term used but explained correctly* in control group. Such as Copper wire cannot decompose into simpler components (1).

The average percentage of alternative conceptions in experimental group hold .70% with 5 frequencies such as Co_2 is pure type of matter and it is transparent substance with fixed ratio (2). Thus, overall in the above responses the frequencies of alternative conceptions is not only low but the quality of using terms is better in experimental groups e.g. using the terms like compact matter, pure matter, fixed ratio etc. are very close to the scientific areas as compared to control groups.

Table: 2 Table 2.N. Ctl = 53 + 52 = 105 N Exp. = 52 + 50 = 102

Instances/ Events		Distilled water		Carbon dioxide gas CO_2		Milk		Flame		Sunlight		Wooden chair		Copper wire		Total frequency & average %	
Categories of alternative concept		Ctl	Exp	Ctl	Exp	Ctl	Exp	Ctl	Exp	Ctl	Exp	Ctl	Exp	Ctl	Exp	Ctl	Exp
Incorrect use of scientific term	f	32	6	36	10	43	3	48	4	40	1	55	2	54	1	308	27
	%	30.47	5.88	34.28	9.80	40.95	2.94	45.71	3.92	38.09	0.98	52.38	1.96	51.42	0.98	41.83	3.78
Self-contradictory views	f	7	1	1	4	2	2	24	2	41	2	-	2	3	1	78	14
	%	6.66	0.98	0.95	3.92	1.90	1.96	22.85	1.96	39.04	1.96		1.96	2.85	0.98	10.61	1.96
Self-centered or human centered views	f	12	1	22	3	38	5	10	2	6	1	47	-	40	1	175	13
	%	11.42	0.98	20.95	2.94	36.19	4.90	9.52	1.96	5.31	0.98	44.76		38.09	0.98	23.88	1.82
No scientific term but correct explanation	F	3	-	-	2	-	-	1	-	-	-	-	3	2	-	6	5
	%	2.85			1.96			0.95					2.94	1.90		0.81	0.70
Scientific term but incorrect explanation	F	42	4	40	6	22	2	21	1	16	5	3	8	6	5	150	31
	%	40	3.92	38.09	5.88	20.95	1.96	20	0.98	15.23	4.9	12.38	7.84	5.71	4.9	20.4	4.34
Total alternative conceptions	F	96	12	99	25	105	12	104	9	103	9	105	15	105	8	717	90
	%	91.43	11.76	94.28	24.50	100	11.76	99.05	8.82	98.10	8.82	100	14.70	100	7.84	97.56	12.6
Total scientific responses	F	9	90	6	77	-	90	1	93	2	93	-	87	-	84	18	624
	%	8.57	88.24	5.72	75.50		88.23	0.95	91.18	1.90	91.18		85.30		92.16	2.44	87.4

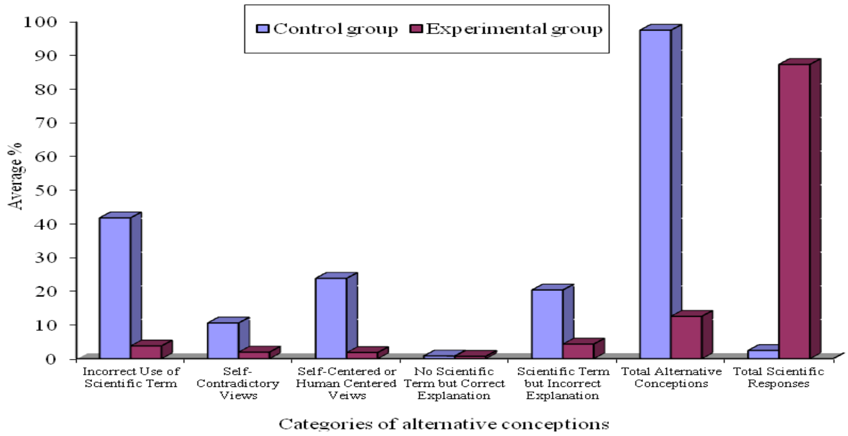

Figure 1. Bar graph of the concept 'Composition of Matter'

Table: 3 Comparison between alternative conceptions and scientific responses of Control and Experimental Groups

Name of concept	Alternative conceptions		Scientific responses		
	Control group	Experimental group	Control group	Experimental group	χ^2
Composition of matter	717 (97.55%)	90 (12.60%)	18 (2.45%)	624 (87.40%)	1059.9 ***

***p<.001, **p<.01, *p<.05

3.Findings

The comparison of alternative conceptions between control and experimental groups of boys reveals that frequencies or percentages (717 or 97.55%) of alternative conceptions about this concept of chemistry in control groups are almost eight times more as compared to the experimental groups (90 or 12.60%). In contrast, the frequencies or percentages (624 or 87.40%) of scientific responses in experimental groups are thirty four times more as compared to the control groups (18 or 2.45%).

Chi-square test was conducted to find out the association between alternative conceptions and scientific responses of control or experimental groups. The results of chi-square show that there is significant association between alternative conceptions and control group. In contrast, there is significant association between scientific responses and experimental groups with χ^2 (df=1, N=1449=1059.9). p=0.000 for concept of *composition of the matter*. These results show significant association.

The categorical analysis shows that 308(41.83%) alternative conceptions were found in the control group of category *incorrect use of scientific term.* In contrast only 27 (3.78%) of alternative conceptions were coded in the experimental group.

There were 175 (23.88%) alternative conceptions in the category of *self-centered or human centered views* of control groups and only 13(1.82%) alternative conception were present in the experimental group

Similarly, 150 (20.4%) alternative conceptions were obtained in control group in the category of *scientific term but incorrect explanation* as compared to the experimental group with only 31 (4.34%)

In the category of *self-contradictory views*, a considerable number of alternative conceptions i.e 78 (10.61%) in the control groups and 14 (1.96%) in the experimental group were found.

The lowest number of alternative conceptions were found in the category *no scientific term but correct explanation* with 6(0.81%) and 5(0.70%) in control group as well as experimental groups respectively.

4.Discussion

Previous research study such as Chaille, 2007; Fosnot,2005 have given their views that constructivists teaching approaches emphasize the students direct experiences and the dialogue of the classroom as instructional tools while deemphasizing lecturing and telling. The present research studies also strongly recommend all the above mention suggestion and further stresses on the use of teacher questions in the start of a lesson under the heading *elicitation* which indicates the actual level of development of students. Therefore, teacher directly approaches the student's way of thinking and in this way teacher can easily focuses on student's misconceptions to ensure conceptual change. For instance, the subjects of the study responded that *Co_2 was not a form of matter but a mixture.* The researcher discussed with the subjects of the study about the properties of matter as well as mixture in detail. The subjects reflected their previous ideas and applied them in response of this question and easily reached at the conclusion that Co2 not only represents the state of a matter but it consisted as molecules and not a mixture. In the category of self-centered and human centered views many subjects responded that *copper wire is used as ceiling in our houses and is a combination of three metals like iron, zinc and lead.* The researcher discussed with his subjects and came to know that they were intermingling their ideas and using the concept of metals in the sense of human being. Therefore, the researcher got insight from the Vygotsky's concepts i.e. zone of proximal development (ZPD), scaffolding etc. and asked the subjects to tell the use of iron or zinc or lead in their daily lives or the importance of these metals in their environment as an element or as a mixture. Similarly, the researcher also used the Piaget's concept's i.e. assimilation, accommodation, and equilibration and discussed with the subjects about the use of the above mentioned metals as an element, or molecule or compound or mixture. In this way the constructivist approach was successful in retrieving or recalling or reflecting the students ideas in the form of different daily life examples and then applying them in different situations for more than two or three times in different situations. Therefore, the subjects in experimental groups were more active, participative and cooperative with their peers as well as with the researcher.

In contrast, in the control groups where traditional textbook approach was used, the teachers transmitted the information's to their students like one shot of a ball and did not discussed the ideas of their students about different examples and rely only on the source of textbook. Thus, it may be concluded that only the conventional lectures or textbooks are inefficient in promoting conceptual change rather, such practices are the main source of spreading the alternative conceptions in students specifically at secondary school level. Thus, the above discussion strongly recommends the constructivist approach which was effective for promoting conceptual change about the basic concept composition of matter. It also indicates the successful application of the constructivist approach was possible due to the categorization of alternative conceptions into five categories. The researcher made this conceptual change by knowing the nature of misconceptions and then negotiated with the subjects.

5.Conclusion

On the basis of findings of the research study it may be concluded that:

Majority of the subjects in control groups hold alternative conceptions because traditional text-book strategy was used. In contrast, majority of the subjects in experimental groups hold scientific ideas due to application of constructivist approach.

All the above mentioned results (through frequencies, percentages and χ^2 test) of comparison between alternative conceptions and scientific responses of control and experimental groups measure the conceptual change and definitely determine the effectiveness of constructivist approach towards promoting conceptual change in experimental group at secondary school level.

The categorical analysis of alternative conceptions indicates that majority of the misconceptions of control groups were found in the category of *incorrect use of scientific terms.* Whereas, the misconceptions were found almost equallyin the categories of *self-centered or human centered views* and *scientific term but incorrect explanation.*

However comparatively less number of alternative conceptions was found in two categories such as *self-contradictory views* and *no scientific term but correct explanation.*

The categorical analysis also helps to find out the five alternative ways of thinking, which guide the teacher to promote conceptual change through applying the interactive strategies such as questioning, problem solving, inquiry learning, cooperative learning, dialogue and discussion etc. in the perspective of constructivist approach.

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