EUROPEAN ACADEMIC RESEARCH
Vol. III, Issue 10/ January 2016

Impact Factor: 3.4546 (UIF)
DRJI Value: 5.9 (B+)

ISSN 2286-4822
www.euacademic.org

Teaching Chemistry with Analogies: Are Multiple Analogies better than One-Size-Fits-All Analogies?

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Abstract:

This paper investigated the effects of teaching one of the most fundamental concepts of Chemistry 'Atom and its Structure' using Traditional Teaching (TT), Traditional Teaching supplemented with One-Size-Fits-All Analogies (TTOA) and Traditional Teaching supplemented with Multiple Analogies (TTMA) on students' achievement in Chemistry. A total of 90 ninth-grade students participated in this pretest-posttest control group quasi-experimental study. Control Group (n = 30) was taught by TT, whereas the two Experimental Groups EG_1 (n = 30) and EG_2 (n = 30) were subjected to TTOA and TTMA respectively. An analysis of covariance on Chemistry achievement posttest scores with students' pretest scores as the covariate showed that TTMA was more effective in enhancing the students' achievement in Chemistry than both TTOA and TT. It is, therefore, suggested analogies are good tools for teaching Chemistry.

Key words: Chemistry, Atom, Atomic Structure, Traditional Teaching, Analogies, Multiple Analogies, Achievement.

INTRODUCTION

An analogy is a comparison between two domains of knowledge: one that is familiar and one that is less familiar. The familiar domain is often referred to as the "*vehicle*", "*base*", "*source*", or "*analog*" domain; the less familiar domain, or the domain to be learned, is usually referred to as the "*target*" domain (Naseriazar, Özmen & Badrian, 2011). According to Gentner (1989), an analogy is a mapping of knowledge between two domains such that the system of relationships that holds among the objects in the analog domain also holds among the objects in the target domain. Thus, the purpose of an analogy is to transfer a system of relationships from a familiar domain to one that is less familiar (Mason & Sorzio, 1996). Analogies are most often used in an educational setting to help students for understanding new information in terms of already familiar information and to help them relate that new information to their already existing knowledge structure (Beall, 1999). Studies have shown that the use of analogies correctly in teaching-learning process has some advantages on students' learning (Sarantopoulos & Tsaparlis, 2004): analogies motivate students to learn by provoking their interest; help students construct their own knowledge; provide visualization of the abstract concepts; help students compare similarities between the target and analog.

In order to learn Science, many times students have to understand abstracts concepts. But, most of the students could not understand such concepts properly with traditional instruction. To assist in the explaining of abstract scientific concepts, teachers may help their students achieve conceptual understanding by employing teaching tools such as analogies. These analogies are believed to help the students to structure the new knowledge and they are considered to be especially useful for topics of an abstract or submicroscopic nature (Thiele & Treagust, 1991). An analogy can allow new material to be more easily assimilated with the students' prior knowledge enabling those who do not readily think in abstract terms to develop an understanding of the concept (Thiele & Treagust, 1994). Studies about analogies have shown that analogies cause a significantly better acquisition of scientific concepts than the traditional instruction and help students integrate knowledge more effectively (Bilgin & Geban, 2001; Glynn, 2007; Piquette & Heikkinnen, 2005). In addition, many reports indicate that analogies may be useful for teaching target concepts that are conceptually difficult or abstract (Duit, 1991). Analogies have been used through the ages by researchers to help students understand theoretical concepts (Huddle, White & Rogers, 2000).

The use of analogies to teach abstract and difficult concepts like matter, atoms, molecules, mole concept, chemical bonding and chemical equilibrium, etc. is not new in Chemistry education all over the world. Although there have been many studies investigating the students' achievement in Chemistry related to '*Atomic Structure*' in other countries, there is a lack of such studies conducted in India. '*Atom and its Structure*' occupies a central place in Chemistry curriculum at secondary school level in India. Due to its abstract character and requirement for developing an understanding in other areas of chemistry such as electronic configuration, chemical bonding and reactions, acid-base behavior, and so on, attainment of mastery in '*Atom and its Structure*' is a huge challenge for both teachers and students. In this paper, two types of analogies were used (namely, One-size-fits-all Analogies and Multiple Analogies), based on assumption that analogies may help students learn abstract concepts. In this regard, a major aim of this study was to determine the effect of these analogies on students' achievement in Chemistry.

PURPOSE OF THE STUDY

The main purpose of this study was to investigate the comparative effects of Traditional Teaching (TT), Traditional Teaching supplemented with One-Size-Fits-All Analogies (TTOA) and Traditional Teaching supplemented with Multiple

Analogies (TTMA) respectively on ninth-grade students' achievement in Chemistry.

In order to suitably address the above mentioned purpose, the following null hypotheses were formulated:

H_0 1: There is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Control Group (CG).

H_0 2: There is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Experimental Group (EG_1).

H_0 3: There is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Experimental Group (EG_2).

H_0 4: There is no significant difference between the mean posttest Chemistry achievement scores for students in the Control Group and Experimental Groups (EG_1 and EG_2), after controlling for the effect of pretest scores.

METHOD

Participants

The participants included 90 students, who were enrolled in ninth-grade and belonged to three different sections during the session 2014-15, in a secondary school in Kishanganj, Bihar, India. These three sections were randomly assigned to Traditional Teaching (TT), Traditional Teaching supplemented with One-Size-Fits-All Analogies (TTOA) and Traditional Teaching supplemented with Multiple Analogies (TTMA) respectively. In other words, one section, subjected to TT, was considered as Control Group, namely CG (n = 30) and the second and third sections, subjected to TTOA and TTMA respectively, were considered as Experimental Groups, namely EG_1 (n = 30) and EG_2 (n = 30). The three B.Ed. trainees 'A', 'B' and 'C' (who were enrolled in B.Ed. course during the session 2014-15, at Department of Education, A.M.U. Centre, Kishanganj, Bihar) also participated in this study. All three of them were male, held an equivalent Bachelor's degree in Chemistry and had no experience of teaching Chemistry at secondary school level. The trainees were also randomly assigned to these three sections/groups. Trainees 'A', 'B' and 'C' taught CG, EG_1 and EG_2 respectively.

Research Design

In this study, a pretest-posttest control group quasi-experimental design (Campbell and Stanley, 1966) was used. This design permitted an investigation of the effectiveness of instructional methods used on students' achievement in Chemistry. This experimental design can be represented as:

	Pretest	Treatment	Posttest
CG	**T**	X_A	**T**
EG_1	**T**	X_B	**T**
EG_2	**T**	X_C	**T**

Where, **CG** represents the **Control Group**, subjected to Traditional Teaching TT (**X_A**), and **EG_1** and **EG_2** represent **Experimental Groups**, subjected to Traditional Teaching supplemented with One-Size-Fits-All Analogies TTOA (**X_B**) and Traditional Teaching supplemented with Multiple Analogies TTMA **(X_C)** respectively.

T represents the Chemistry Achievement Test (**CAT**). CAT was given as pre- and post-tests to students in all the groups at the beginning and end of the instruction to measure students' achievement in Chemistry.

Measuring Instrument

Students' achievement in Chemistry, based on 'Atom and its Structure', was measured using the Chemistry Achievement Test (CAT). The instrument, containing 25 four-option, multiple-choice questions, was developed by the author. The test was intended to determine the knowledge, comprehension and application levels of students related to the fundamental concepts. Its content validity was established by subject experts. Cronbach's alpha reliability coefficient of the test was 0.90.

Analogies

A One-Size-Fits-All Analogy here refers to single analogy. It is used to explain too many aspects of the target concept. A multiple analogy here refers to a group of single analogies, used one after the other in a logical sequence. Multiple analogies use sets of familiar objects, processes and events to explain a concept. Multiple analogies reduce the use of single analogies past the point where they break down. They are effective because each analogy explains only the ideas where it works well, and students can choose the analogies that best suit their experiences and thinking needs. On the other hand, single analogies may generate alternative conceptions (Harrison & Coll, 2008).

In this research study, the analogies mentioned in Tables 1 and 2 were used for teaching the Experimental Groups. '*The Solar System Analogy for an Atom*' was used for teaching EG_1. But for teaching EG_2, both '*The Sports Stadium Analogy for Hydrogen Atom*' and '*The Solar System Analogy for an Atom*' were used one after the other.

Table 1: The Sports Stadium Analogy for Hydrogen Atom

<u>**Concept**</u>:	
(i)	A Hydrogen atom consists of one proton in the nucleus and is surrounded by one electron.
(ii)	The atomic nucleus is minute, and the atom is mostly spacious. The ratio of nucleus diameter : atomic diameter = 1: 100,000
<u>**Students**</u>:	
(i)	Students visualize the atom as a solid sphere (from diagrams given in their textbooks and molecular models usually used by their teachers).
(ii)	They have great difficulty in conceptualizing that the atom is mostly spacious and nucleus is so tiny and dense.
(iii)	Most of them have seen or been in a large sports stadium and have some idea of its size.

Analog:

(i) If a grain of rice is placed in the centre of the playing area in a cricket /football stadium, then the outer row of seats is the limit of the electron's influence. The rest of the atom is empty space.

(ii) The electron seems to be everywhere at once like the seats surrounding the playing area.

Similarities: Matching/Mapping the Analog to the Target

Analog – Sports Stadium	Target – Hydrogen Atom
Grain of Rice (about 2 mm thick)	Hydrogen atom nucleus (one proton)
Playing area and seats out to the last row	Region where the electron might be found
Ratio of grain of rice : Whole Stadium	Ratio of nucleus : Electron cloud

Dissimilarities: Where the Analogy may Break Down

- This is a two-dimensional representation of a three-dimensional atom.
- Different elements have bigger nuclei and more electrons, and the ratio is a bit smaller than 1 : 100,000.
- It is the proportion that is important, not the size.
- The atom is filled with empty space, but the stadium is filled with air.

Table 2: The Solar System Analogy for an Atom

Concept:

Atoms are made up of: a central nucleus consisting of two heavier particles, protons (positively charged) and neutrons (not charged); and lighter particles, electrons (about 1800 times less heavy and negatively charged), which are arranged around the nucleus.

Students:

(i) Students have difficulty in visualizing tiny, submicroscopic particles like atoms and elementary particles like electrons and protons.

(ii) They are more familiar with the solar system and planets and find visualization of planets and planetary motion easier as a consequence of exposure to pictures and representations in books and encyclopedias.

Analog:

(i) Our solar system, consisting of the planets orbiting the sun, provides a simple analogy for students to grasp the essentials of the Bohr model of an atom.

(ii) The greater size of the planets and sightings of the sun make them seem more real to the students than things that cannot be seen.

Similarities: Matching/Mapping the Analog to the Target

Analog – Solar System	Target – Atomic Structure
Sun	Nucleus
Planets	Electrons
Planetary Orbits	Electron orbits
Planetary Rotation	Electron spin
Spherical shape of sun and planets	Spherical shape of nucleus and electrons
Planets at fixed distances from the sun	Electrons at fixed distances from the nucleus
Sun consists of Hydrogen and Helium	Nucleus containing two elementary particles

	(protons and neutrons)
Gravitational attraction between the sun and planets	Electrical attraction between the nucleus and electrons

Dissimilarities: Where the Analogy may Break Down

- The sun is hot, whereas the nucleus is not.
- The shape of orbits for electrons is circular; orbits for planets are elliptical.
- The electrons can change their orbits if they gain energy; planets remain in their respective stable orbits.
- Electrons occupy clouds of space around the nucleus rather than following a strict orbital pathway.
- Some planets have moons; whereas the electrons are alone in their orbits.
- Planets are of different sizes; electrons are of the same size.

Instructional Methods

The Control Group (CG) was subjected to Traditional Teaching (TT) without any exposure to analogies. This instructional approach emphasized direct lectures given by teachers, interactive discussions between the teacher and students, use of textbook materials and charts, and clear explanation of important concepts to students, but no use of analogies was done. B.Ed. trainee 'A' did not incorporate the use of any analogies in his lesson plans.

The Experimental Group (EG_1) was subjected to Traditional Teaching supplemented with One-Size-Fits-All Analogies (TTOA). This instructional approach consisted of TT (as was done in case of CG) along with appropriate use of only one analogy. B.Ed. trainee 'B' incorporated the use of single analogy ('*The Solar System Analogy for an Atom*') in his lesson plans.

The second Experimental Group (EG_2) was subjected to Traditional Teaching supplemented with Multiple Analogies (TTMA). This instructional approach consisted of TT (as was done in case of CG) along with appropriate use of multiple analogies. B.Ed. trainee 'C' incorporated the use of multiple analogies ('*The Sports Stadium Analogy for Hydrogen Atom*' and '*The Solar System Analogy for an Atom*') in his lesson plans.

All the three groups were subjected to their respective instructional method for one week. They attended six periods per week. Each period was of 35 minutes duration. These groups followed the same instructional sequence and had the same learning objectives. Thus, care was taken to ensure that an appropriate comparison was attained among these instructional approaches. The content validity of all the lesson plans was established by the author and subject experts. The author supervised the lesson plans of all the three B.Ed. trainees throughout the length of all the periods consumed for teaching the topics completely.

DATA ANALYSIS

The data from the Chemistry Achievement Test (CAT) were analyzed using SPSS 16.0. Means (M) and standard deviations (SD) were calculated. A paired samples t-test was used to determine if there was a statistically significant difference between the pre- and posttest achievement scores in Chemistry for each of the three groups. Analysis of Covariance (ANCOVA) was used to determine whether there was a significant difference between group means of achievement in Chemistry for the Control and Experimental groups when differences in pretest scores were controlled. An alpha level of 0.05 was used for all statistical tests. Post hoc tests were conducted using Bonferroni's test. It consists of pairwise comparisons that are designed to compare means of all different combinations of the treatment groups. Pairwise comparisons control the familywise error by correcting the level of significance for each test such that the overall Type I error rate (α) across all comparisons remains at .05. In Bonferroni correction, α is divided by the number of comparisons, thus ensuring that the cumulative Type I error is below .05 (Field, 2009).

RESULTS

In order to evaluate the impact of TT on Control Group (CG) students' achievement in Chemistry, descriptive statistics were calculated first for their Pretest and Posttest scores on CAT. The Pretest and Posttest means and standard deviations for the Control Group are reported in Table 3.

Table 3: Descriptive Statistics of Chemistry Achievement Scores for the Control Group (CG)

Achievement in Chemistry	**N**	**Mean**	***SD***
Pretest	30	5.16	2.96
Posttest	30	17.50	1.74

Then, a paired-samples *t*-test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the Control Group. The results in Table 4 indicate that there was a significant difference between the Pretest and Posttest scores, t (29) = -22.11, $p < .05$. The Control Group scored significantly greater on the Posttest (M = 17.50, SD = 1.74) than on the Pretest (M = 5.16, SD = 2.96). Therefore, the null hypothesis H_0 1 stating that, *there is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Control Group*, was rejected at 0.05 level of significance.

Table 4: Paired-Samples t-test for Chemistry Achievement for the Control Group (CG)

	Paired Differences					***t***	***df***	**Sig. (*p*)**
	Mean	***SD***	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
Pretest – Posttest	- 12.34	3.05	0.56	- 13.47	- 11.19	- 22.11*	29	.000

*p < .05

In order to evaluate the impact of TTOA on Experimental Group (EG_1) students' achievement in Chemistry, descriptive statistics were calculated first for their Pretest and Posttest scores on CAT. The Pretest and Posttest means and standard deviations for the Experimental Group (EG_1) are reported in Table 5.

Table 5: Descriptive Statistics of Chemistry Achievement Scores for the Experimental Group (EG_1)

Achievement in Chemistry	**N**	**Mean**	***SD***
Pretest	30	4.93	2.82
Posttest	30	21.56	2.32

Then, a paired-samples *t*-test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the Experimental Group (EG_1). The results in Table 6 indicate that there was a significant difference between the Pretest and Posttest scores, $t\ (29) = -40.19$, $p < .05$. The Experimental Group (EG_1) scored significantly greater on the Posttest (M = 21.56, SD = 2.32) than on the Pretest (M = 4.93, SD = 2.82). Therefore, the null hypothesis H_0 2 stating that, *there is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Experimental Group (EG_1)*, was rejected at 0.05 level of significance.

Table 6: Paired-Samples t-test for Chemistry Achievement for the Experimental Group (EG_1)

	Paired Differences					***t***	***df***	**Sig. (*p*)**
	Mean	***SD***	**Std. Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	**Upper**			
Pretest – Posttest	- 16.63	2.26	0.41	- 17.48	- 15.78	- 40.19*	29	.000

*$p < .05$

In order to evaluate the impact of TTMA on Experimental Group (EG_2) students' achievement in Chemistry, descriptive statistics were calculated first for their Pretest and Posttest scores on CAT. The Pretest and Posttest means and standard deviations for the Experimental Group (EG_2) are reported in Table 7.

Table 7: Descriptive Statistics of Chemistry Achievement Scores for the Experimental Group (EG_2)

Achievement in Chemistry	N	Mean	*SD*
Pretest	30	6.40	2.19
Posttest	30	23.23	1.63

Then, a paired-samples *t*-test was conducted to determine if there was a significant difference between the mean Pretest and Posttest scores for the Experimental Group (EG_2). The results in Table 8 indicate that there was a significant difference between the Pretest and Posttest scores, $t\ (29) = -54.77$, $p < .05$. The Experimental Group (EG_2) scored significantly greater on the Posttest (M = 23.23, SD = 1.63) than on the Pretest (M = 6.40, SD = 2.19). Therefore, the null hypothesis H_0 3 stating that, *there is no significant difference between the mean pretest and posttest Chemistry achievement scores for students in the Experimental Group (EG_2)*, was rejected at 0.05 level of significance.

Table 8: Paired-Samples t-test for Chemistry Achievement for the Experimental Group (EG_2)

	Paired Differences					*t*	*df*	Sig. (*p*)
	Mean	*SD*	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pretest – Posttest	- 16.83	1.68	0.31	- 17.46	- 16.20	- 54.77*	29	.000

*$p < .05$

In order to test hypothesis H_0 4, a one-way analysis of covariance was conducted to evaluate the effects of instructional methods on secondary school students' achievement in Chemistry. The independent variable was instructional method (TT, TTOA and TTMA). The dependent variable was scores on CAT, administered at posttest stage after the completion of the instructional period. Pretest scores on the CAT administered prior to the commencement of the instructional period were used as a covariate to control for individual differences. Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measurement of the covariate. The means and standard deviations for the pretest, posttest and adjusted posttest scores are presented in Table 9.

Table 9: Descriptive Statistics for Achievement Scores on CAT by Instructional Group

Instructional Group	N	Pretest		Posttest		Adjusted Posttest[a]	
		Mean	***SD***	**Mean**	***SD***	**Mean**	***SE***
CG	30	5.16	2.96	17.50	1.74	17.62	0.30
EG_1	30	4.93	2.82	21.56	2.32	21.76	0.31
EG_2	30	6.40	2.19	23.23	1.63	22.91	0.31

a. Adjustments based on the mean of Pretest (covariate) = 5.50

Results in Table 10 show that the ANCOVA yielded a significant effect for the covariate, F (1, 86) = 27.90, $p < .05$, partial $\eta^2 = 0.245$ and a significant main effect for the instructional method, F (2, 86) = 80.86, $p < .05$, partial $\eta^2 = 0.653$; this latter effect accounted for 65.3 % of the total variance in posttest scores on CAT, after controlling for the effect of pretest scores used as a covariate. The covariate (Pretest) accounted for 24.5 % of the total variance in achievement on CAT. Since the results of ANCOVA indicate that there was a statistically significant difference for the adjusted Posttest means between the groups, therefore the null hypothesis H_0 4 stating that, *there is no significant difference between the mean posttest Chemistry achievement scores for students in the control group and experimental group, after controlling for the effect of pretest scores*, was rejected at 0.05 level of significance.

Table 10: **ANCOVA Summary for Posttest Achievement Scores on CAT by Instructional Group**

Source	**Sum of Squares**	***df***	**Mean Square**	***F***	**Sig. (*p*)**	**Partial Eta Squared, η^2**
Pretest	78.96	1	78.96	27.90*	.000	.245
Group	457.67	2	228.83	80.86*	.000	.653
Error	243.27	86	2.83			
Total	39657.00	90				

*$p < .05$
Note. Pretest (used as covariate) represents pretest scores on CAT.

Follow-up or post hoc analyses to the significant main effect for instructional method are conducted to determine which instructional method is more effective. The post hoc tests consist of all pairwise comparisons among the three instructional groups and are conducted in order to find out whether the differences in adjusted Posttest means of the groups are significantly different from each other. EG_2 has the largest adjusted mean (M = 22.91), EG_1 has comparatively smaller adjusted mean (M = 21.76) than EG_2, and CG has the smallest adjusted mean (M = 17.62). The Bonferroni procedure is used to control for Type I error across the three pairwise comparisons (α' = .05/3 = .017). The results in Table 10 show that the adjusted Post-test mean for EG_2 differs significantly from that of EG_1 at.05 level but not at .017 level. Moreover, the adjusted Posttest mean for EG_2 differs significantly from that of CG at both .05 and .017 levels. Also, the adjusted Posttest mean for EG_1 differs significantly from that of CG at both .05 and .017 levels. Overall, ANCOVA followed by pairwise comparisons indicates superiority for the instructional methods as far as their effects on students' achievement in Chemistry are concerned in the following order: TTMA > TTOA > TT.

Table 10: **Pairwise Comparisons of Differences in Adjusted Posttest Means by Instructional Group**

Instructional Group (I)	**Instructional Group (J)**	**Mean Difference (I-J)**	**Standard Error of Difference**	**Sig. (*p*)[a]**
EG_2 (22.91)	EG_1 (21.76)	1.15*	0.445	.036
EG_2 (22.91)	CG (17.62)	5.29*	0.442	.000**
EG_1 (21.76)	CG (17.62)	4.14*	0.435	.000**

*$p < .05$ **$p < .017$

a. p-values are adjusted using the Bonferroni method.

DISCUSSION

The primary purpose of this study was to investigate the effects of Traditional Teaching (TT), Traditional Teaching supplemented with One-Size-Fits-All Analogies (TTOA) and Traditional Teaching supplemented with Multiple Analogies (TTMA) on ninth-grade students' achievement in Chemistry. The results indicated that traditional teaching supplemented with analogies (both TTOA and TTMA) had a better learning impact on students' achievement in Chemistry than TT. Moreover, TTMA had led to greater improvement in achievement than TTOA. Consistent with the results of many studies on the positive effects of traditional teaching supplemented with analogies on achievement in Chemistry (Çalık & Ayas, 2005; Chiu & Lin, 2005; Harrison & Jong, 2005; Iding, 1997; Orgill & Bodner, 2004; Pekmez Sahin, 2010; Silverstein, 1999; Silverstein, 2000; Tsai, 1999), this study confirms that analogies are useful tools for teaching and learning.

The results of the paired-samples *t*-tests computed for each group indicate that the posttest scores of achievement in Chemistry significantly increased for both the groups. The lower pretest scores of groups were due to the students' insufficient knowledge of the topic prior to instruction. The increase in students' performance from pretest to posttest in both the groups was very normal because they received instruction based on 'Atom and its Structure'. Therefore, an increase in students' performance in all the groups was not surprising. All groups benefited from their respective instructional method, and their posttest results for achievement were consequently higher. However, the results clearly show that both the experimental groups (EG_1 and EG_2) exhibited better performance than the control group on CAT. This is an indication of the benefits of analogies over traditional teaching on students' knowledge and understanding. The most probable reasons for this effectiveness are that the analogy is like a link that spans the gap between what a teacher wants students to learn and what they already know and moreover, it builds on the framework of the students' existing knowledge. Furthermore, analogies are related to students' real and familiar world, and thus capable of simplifying the abstract and complex concepts to a greater extent.

The results of pair-wise comparisons show that the students of EG_2 exposed to TTMA achieved significantly better than their counterparts of EG_1 exposed to TTOA. This reveals that the multiple analogies are more beneficial than one-size-fits-all analogies as far as their effects on students' achievement are concerned. This proves that the multiple analogies are highly structured instructional strategies that seem to work more effectively with students of varying abilities. Multiple analogies make students feel that their interests, experiences, ideas and views have been incorporated into analogy construction. Such analogies accommodate individual differences among students, offer them choice and provide multiple reasons for grasping the target concept correctly and changing alternative conceptions. Thus, multiple analogies enable students to be the active participants in the teaching-learning process by raising their interest and motivation, and add meaningful contributions to their world of knowledge, which eventually lead to their higher achievement.

CONCLUSION

The results of this research study showed that the traditional teaching supplemented with analogies led to better achievement in Chemistry for students of both the experimental groups than those of the control group. The main findings of this study are as follows:

1. Paired-samples *t*-test results showed that there was a significant difference between the Pre-test and Post-test means for the Control Group. This indicates that Traditional Teaching had positive impact on achievement in Chemistry for students in the Control Group.

2. There was a significant difference between the Pre-test and Post-test means for the TTOA group, as indicated by the paired-samples *t*-test. This shows that TTOA had greater positive impact on achievement in Chemistry for students in the Experimental Group (EG_1) as compared to Traditional Teaching but lesser positive impact as compared to TTMA.

3. Paired-samples *t*-test results showed that there was a significant difference between the Pre-test and Post-test means for the SCCAI group. This indicates that TTMA had the greatest positive impact on achievement in Chemistry for students in the Experimental Group (EG_2.

4. At the post-test stage, ANCOVA results followed by pairwise comparisons indicated the superiority for the instructional methods, as far as their effects on students' achievement in Chemistry was concerned, in the following order: TTMA > TTOA > Traditional Teaching.

RECOMMENDATIONS

The findings of this study imply the need of re-defining and re-structuring of traditional teaching by including innovative methods and techniques such as analogies. Based on the findings of this study, the author would like to make the following recommendations:

1. Curriculum planners should recommend innovative analogies to improve students' knowledge, comprehension and assimilation of Chemistry concepts.
2. Relevant stakeholders at all levels should organize conferences, seminars, workshops and in-service training for Chemistry teachers to maximize the benefits of using analogies in the teaching-learning process.
3. Authors of Chemistry textbooks should design and include elaborative analogies to facilitate students' knowledge, comprehension and assimilation of textbook contents.
4. Chemistry teachers should expose students to the use of analogies instead of using the traditional teaching strategy alone, taking into consideration the nature of topic as well as learning needs and styles of their students.
5. Although analogies allow teachers to make abstract concepts concrete for students, they may lead to students developing various meanings in the form of alternative conceptions if they are developed improperly and not used appropriately. Some students may not comprehend the connection between the analog and target concept. Therefore, in order to avoid such chances, the teachers should check regularly the students' understanding regarding the similarities and differences between the analog and target concept.

REFERENCES

Beall, H. (1999). The ubiquitous metaphors of chemistry teaching. *Journal of Chemical Education*, *76*, 366-368.

Bilgin, I., & Geban. Ö. (2001). The effects of analogies to overcome misconceptions about chemical equilibrium. *Hacettepe University Journal of Education*, *20*, 26-32.

Çalık, M. & Ayas, A. (2005). An analogy activity for incorporating students' conceptions of types of solutions. *Asia Pacific Forum on Science Learning and Teaching*, *6*(2), Article 6.

Campbell, D. T., & Stanley, J. C. (1966). *Experimental and quasi-experimental designs for research*. Boston: Houghton Mifflin Company.

Chiu, M. H. & Lin, W. (2005). Promoting fourth graders' conceptual change of their understanding of electric current via multiple analogies. *Journal of Research in Science Teaching*, *42*(4), 429-464.

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education*, *75*, 649-672.

Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). Los Angeles: Sage Publications.

Gentner, D. (1989). The mechanisms of analogical learning. In S. Vosniadou & A. Ortony (Eds.). *Similarity and analogical reasoning*. pp. 199-241. Cambridge, MA: Cambridge University Press.

Glynn, S.M. (2007). The teaching with analogies model. *Science and Children*, *44*(8), 52-55.

Harrison, G. A., & Coll, R. K. (2008). *Using analogies in middle and secondary science classrooms*. New Delhi: Corwin Press.

Harrison, G. A., & Jong , D. O. (2005). Exploring the use of multiple analogical models when teaching and learning chemical equilibrium. *Journal of Research in Science Teaching*, *42* (10), 1135-1159.

Iding, M. K. (1997). How analogies foster learning from science texts. *Instructional Science*, *25*, 233-253.

Mason, L., & Sorzio, P. (1996). Analogical reasoning in restructuring scientific knowledge. *European Journal of Psychology of Education*, *11*, 3-23.

Naseriazar, A., Özmen, H., & Badrian, A. (2011). Effectiveness of analogies on students' understanding of chemical equilibrium. *Western Anatolia Journal of Educational Sciences*, 525-534.

Orgill, M. & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. *Chemistry Education: Research and Practice*, *5*(1), 15-32.

Pekmez Sahin, E. (2010). Using analogies to prevent misconceptions about chemical equilibrium. *Asia-Pacific Forum on Science Learning and Teaching*, *11*(2), 1-35.

Piquette, J. S., & Heikkinnen, H. W. (2005). Strategies reported used by instructors to address student alternate conceptions in chemical equilibrium. *Journal of Research in Science Teaching*, *42*(10), 1112-1134.

Sarantopoulos, P., & Tsaparlis, G. (2004). Analogies in chemistry teaching as a means of attainment of cognitive and affective objectives: a longitudinal study in a naturalistic setting, using analogies with a strong social content. *Chemistry Education: Research and Practice*, *5*, 33-50.

Silverstein, T. P. (1999). The "big dog-puppy dog" analogy for resonance. *Journal of Chemical Education*, *76*(2), 206-207.

Silverstein, T. P. (2000). Weak, strong acids and bases: the football analogy. *Journal of Chemical Education*, *77*(7), 849-850.

Thiele, R., & Treagust, D. F. (1991). Using analogies in secondary chemistry teaching. *Australian Science Teachers Journal*, *37*, 10-14.

Thiele, R. B., & Treagust, D. F. (1994). An interpretive examination of high school chemistry teachers' analogical explanations. *Journal of Research in Science Teaching*, *31*, 227-242.

Tsai, C. C. (1999). Overcoming junior high school students' misconceptions about microscopic views of phase change: a study of an analogy activity. *Journal of Science Education and Technology*, *8*(1), 83-91.