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RESEARCH PAPER

Effect of Analogy Based Teaching on Students 'Chemistry Learning at Secondary School Level

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ABSTRACT

Main objective of the study was to investigate the effect of analogy-based teaching on students 'chemistry learning at secondary school level. 21st century education ranks students' skills for higher order thinking and flexible reasoning over memorization of disciplinary fact in science subjects. To create interest and constructive environment, effective and student-centered teaching methodologies support the better learning abilities of students. The study was conducted through true experimental pretest posttest control group design. Two equal science groups from a public school having 40 participants in each were selected through random sampling. Intervention was comprised of analogy-based teaching of selected content of chemistry book of grade 9th published by Punjab Curriculum and Text Book Board, Lahore. During 12week period of intervention, each group was received an equal amount of teaching. CG was taught through conventional teaching method and EG through analogy-based teaching. Pretest posttest were administered for data collection. Chemistry Learning Achievement Test (CLAT) was developed by the researcher to find the difference of learning between control group and experimental group. Data was analyzed through SPSS. The difference of scores of pretests and posttest was apparent from the results of ANCOVA. There was no significant difference between both groups in pretest scores. While the post-test result as significant between two groups showed the positive effect of intervention on experimental group. Important findings of the study proved that teaching with analogies supported the improvement of student's analyzing, applying, synthesizing and evaluating skills by developing understanding of abstract concepts of chemistry. The results revealed the effectiveness of analogy - based teaching so it was suggested to science teachers to include analogies in their daily lesson plans to make teaching learning process effective, constructive and meaningful.

Keywords: Analogy Based Teaching, Analogy, Chemistry, Secondary School Level, Teaching

Introduction

Finding similarities between objects, movements or situations is one of the most common rational processes of human cognition. Indeed, it is closely scrambled with human thought and knowledge. Much of our brain involves to find flatness and continuity in the world. The ability of finding things similar is part and parcel of everyday thinking to the extent it governs the periodical changes in our environment (Hofstadter, 2001).

Today, we are facing the challenge of educational paradigm shift in public education particularly in the fields of science and technology. (Faize & Dahar, 2011). Educational reform must start with how student learn and how teachers teach, not with what students learn and what teachers teach. Developing of conceptual understanding, is a core element in the process of teaching and learning reinforced by constructivist teaching (Kim, 2002). In science teaching at secondary school level, chemistry is considered fundamental subject that deals with several areas of creative knowledge. Chemistry is one of the curriculum components of school science that can promote the rational growth of the students through

its effective renovations. (Lavaqui & Batista,.2007). The abstract nature of chemistry along with content learning difficulties means that chemistry class require a high-level of skill set and effective methods of teaching (Taber, 2002).

The nature of chemistry concepts and the way through concepts are taught, make chemistry difficult to learn. Methods of teaching that promotes theoretical learning are in struggle with the nature of science, i.e. traditional methodology and lack of creativity (Johnstone, 2000). To make the content easy to recall, learners actively need to construct, organize, and create links that hold the information together. Use of analogy is one of the teaching methods in science in which an idea, a thing or a process is compared to another concept (Harrison & Treagust, 2006). According to Gentner (2009) analogy is a mapping of knowledge between two domains. The more 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. The principle of use of analogies in science teaching is, to think about a new, typically more abstract area of knowledge, in an area and knowledge of how, why, and when to apply this knowledge to solve problems in another area (Pellegrino & Hilton, 2012).

Analogy based teaching is striking to educational perceptions that underline what students already known as a starting point for teaching and learning with focus on students building their own knowledge, which ultimately results to enhance higher order skills of the learners (Deborah, 2014).The phenomenon of use of analogy and developing analogy involves higher order mental processes i.e. analyzing different situation, applying proper options to solve problems, evaluating best solutions and finally construct new knowledge (Blake, 2004). It is important to take a start of teaching science concept by building the connections between the motivational and the cognitive mechanisms of student understanding while using analogy-based teaching for effective learning (Walton & Hyra, 2018).

Theoretical Frame work

Theoretical frame work of the research was based on existing theory related to hypothesis of the study (Linn, 2006). The research was influenced with constructivist theory of learning and Glynn's model of analogy-based teaching to change the mode of teaching and learning from teacher centered classroom to student centered class room of grade 9th students in chemistry subject. Main idea of constructivism is that the learners construct their learning through linking their experiences of already existing knowledge and new knowledge. (Holyoak, 2009).

The theory of constructivism is based on observation and scientific study about the mechanism of learning. Learners try to develop their own understanding of the real world from their experiences and develop own process of learning, students are at the stage of constructing knowledge (Beall, 2009). The study proved that how the teacher used analogy to provide bridge to link between existing knowledge and new information as a result students were able to draw their own meanings, interpret new information and to apply reproduced material into new situations.

Theoretical frame work was illustrated through a model explained by Glynn (2011) to use analogies in classroom environment to reproduce learned material through cognitive mechanism. The learners participate actively to differentiate base or analog (prior knowledge) and target (to be learned, new concept), they found shared and unshared attributes (match & mismatch between old and new concept) with great interest and as a result of this activity they produce own analogies to retain and understand the concepts. Constructivist theory of learning guided the researcher to produce effective learning by improving the skills of applying, analyzing. Evaluating and creation of new knowledge.

Conceptual Framework

According to the literature review it was hypothesized that analogy-based teaching has positive significant effect on chemistry learning of seconder school students in this experimental study analogy-based teaching is an independent variable learning of students including higher order skills i.e analyzing, applying, evaluating and creating is dependent variable. Intervention was developed, to find the change in learning and improvement of higher order skills of learners according to the chemistry learning achievement test (CLAT), prepared by the researcher.

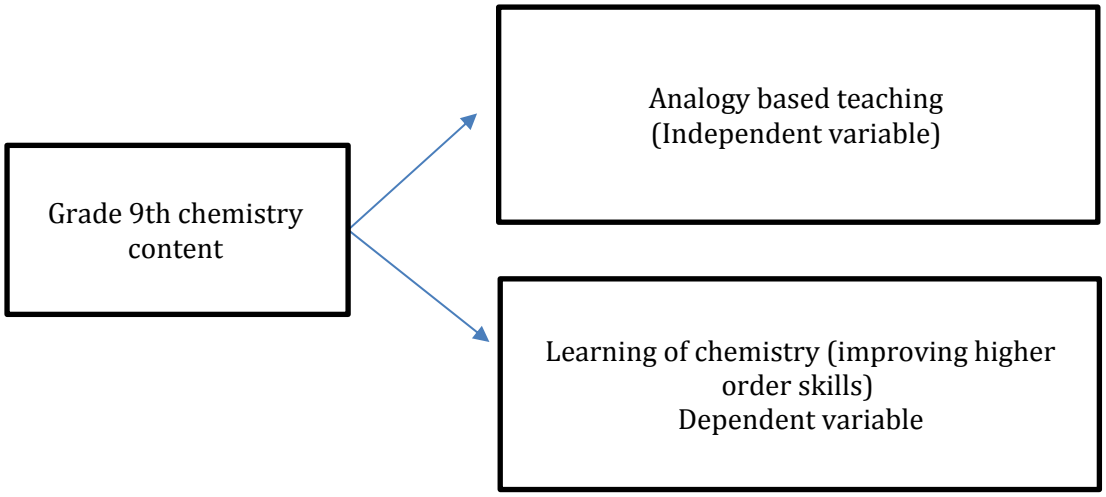


Figure 1 Conceptual framework

Literature Review

The concept of Analogy in an educational setting is a source of understanding, new information in relation of already familiar information and to help learners, to relate the new information with already existing structure of knowledge (Beall, 2009). According to Hofstadter (2001), Analogy is a powerful, cognitive process, a support of psychological thought and the vital process by which people understand the different situations (Gentner & Holyoak 2001). It involves "recognizing a common relational system between two situations and generating further inferences directed by these cohesions" (Gentner & Smith 2013).

According to Peterson (2020) analogy is something that shows how two things are alike, but with the endmost goal of making a point about this comparison is meaningful learning. The purpose of analogy is not simply apparent, but also to explain a situation or a phenomenon. For this reason, an analogy is more complex than a simile or a metaphor. Judy Blume (2018), defined analogy as something is like something else to make some species of explanatory point, as Life is like a box of chocolate. An analogy is a comparison between two objects, or systems of objects that highlight acknowledgments in which they are thought to be similar (Barth, 2010).

Use of Analogies in Science Teaching

Using analogies as a method of teaching has been widely adopted in science subjects. Using and creating analogies help students to develop comprehension and concepts by enhancing their reasoning ability and critical thinking skills (Duit, 2001). So, analogies are described as valuable tools for conceptual change in science education.

Studies showed the effectiveness of analogy- based teaching like the study "effect of conceptual change tests on students 'understanding of chemical equilibrium (Canpolat et al. 2006, Ozmen, 2007). In the same context Pekmez (2010) used analogies to prevent students 'misconceptions of chemical equilibrium and Turk, Ayas and Karsli (2010) investigated the effectiveness of analogy on students 'achievement for the effect of concentration and temperature on rate of reaction.

The positive effects of analogies on comprehension and retention of concepts have been identified with regard to the topics including molecules and atoms (Harrison & Treagust, 2000), electrical circuits (Lee & Park, 2014), genetics (Baker & Lawson, 2001), geology (Blake, 2004), chemical dissociation (Nawaf, 2016), protein synthesis (Pittman, 1999), disordered systems in physics (Duit, 2001), structure and properties of matter (Shulman, 2007), enzymes (Taber, 2014), and electrical current (Aykutlu & Şen, 2011). More than 5 analogies were used to elaborate movements of atoms by Eskandar (2013).

Teaching of science subjects not only involves transfer of knowledge but to inculcate the concepts in minds and long-life learning through implementing effective teaching methodologies. Understanding of science concepts, principles, and ideas are achieved through empirical reasoning, Ausubel (2001). He believed that learning of new knowledge depends on what is already known. Hence construction of knowledge begins with our observation and recognition of measures and objects through concepts we already have. We learn by constructing a network of concepts and adding them continually in cognitive system in a regular manner (Weller, 2016).

Analogy as constructive process

Constructivism is a theory based on observation and scientific study about how people learn. When we come across something new and merge it with previous ideas and experience, maybe changing what we believe, or maybe discarding the new information as irrelevant. In any case, we are active creators of our own knowledge. To do this, we must ask questions, explore, and assess what we know, Sharma (2005). In the light of these ideas, in this study, use of analogy-based teaching supported by constructivist learning approach and its implications in teaching of chemistry by improving higher-order thinking skills and deep understanding.

Analogy as a Source of Meaningful Learning

Meaningful and effective learning was a term developed during the 1960s and is within the trend of constructivism. It develops a connection between the previous knowledge of the students and the newly acquired knowledge, while rote learning consists of memorizing concepts without understanding (Weller, 2016). Meaningful learning allows students to associate acquired material with previous knowledge or experiences that serve as a bridge when obtaining new knowledge. It enables the student to make connections of learning to be a wide-ranging and lasting one throughout their life (Venville, 2006).

Analogy and higher order thinking

Worldwide shifts in technology, the advancements of internet, the global market economy, and fast-growing public requirements to formal education, have altered the goals and functions of formal education. Theoretical knowledge across various fields needs to express a series of skills often called higher order thinking that are distinct from the traditional academic tools of facts e.g., mathematics, science, history and that may be more analytical of high quality education in the current market (Gick & Holyoak, 2007).Cognitive skills that support the role of knowledge to categorize, generalize, draw assertions from, and transform it for successful academic performance may be termed as higher order skills (Yener, 2012).

The study explored how analogies serve as a merging device underlying higher order thinking skills, both as a tool for promoting content quality and a basic cognitive instrument for using knowledge. Nersessian (2008) has investigated how Maxwell used perception into mechanics in drawing analogies in development of theory of electromagnetism. He stated that analogies are abundantly used in science textbooks as well as in the classroom as an aid to the teaching-learning process.

Shulman (2007) explained that analogies play a role in the restructuring of students 'conceptual frameworks in science. He investigated the effects of interactive-engagement and analogy as instructional strategies on self-efficacy of senior secondary school chemistry students. In his study he found that the analogy enhanced instructional strategy was most effective in highlighting the self-efficacy of chemistry students.

Hypotheses

H1: There is a significant difference of learning of experimental group after teaching through analogy-based when compared with control group.

H_2**:** There is a significant difference of applying skill in chemistry learning of experimental group after analogy-based teaching when compared with control group

H_3: There is a significant difference of analyzing skill in chemistry learning of experimental group after analogy- based teaching when compared with control group.

H_4: There is a significant difference of synthesizing skill in chemistry learning of experimental group after analogy - based teaching when compared with control group.

H_5: There is a significant difference of evaluating skill in chemistry learning of experimental group after analogy - based teaching when compared with control group.

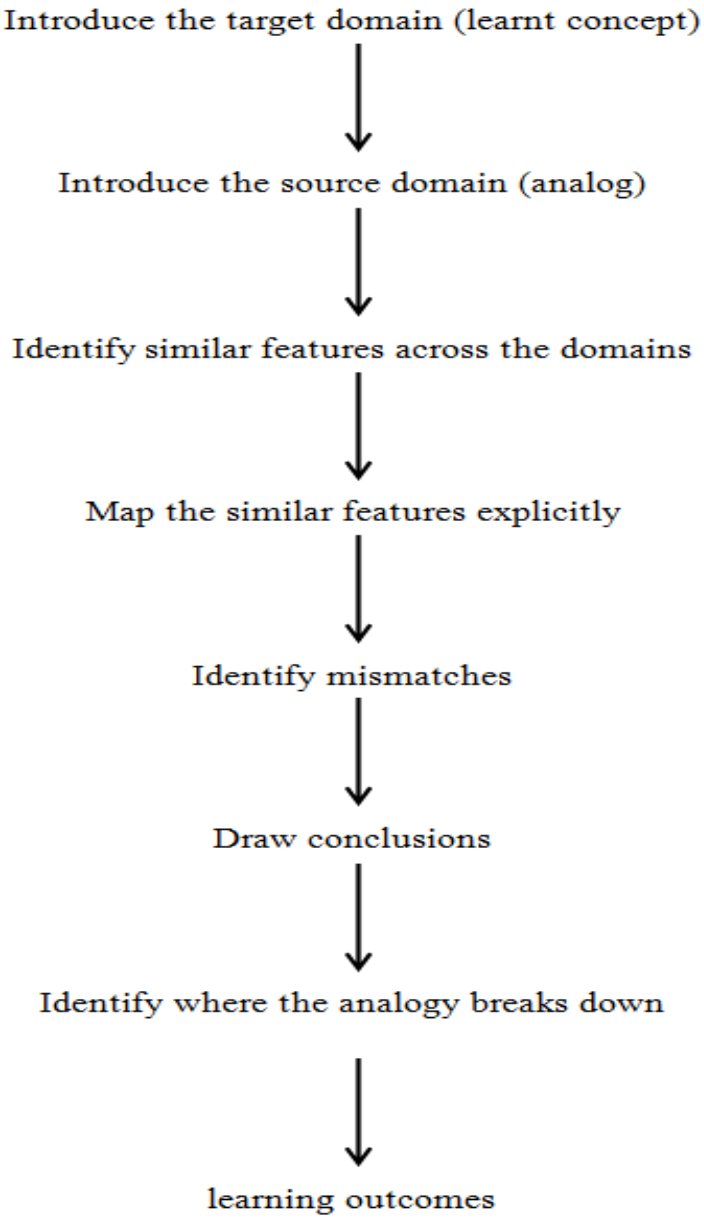
Glynn's Model of Analogy Based Teaching

Zeitoun (2004) has developed the General Model of Analogy Teaching (GMAT) as a nine-stage model of how to conduct teaching with analogies in a cycle of continuous revision and improvement. This model is included the following activities to adopt analogy as a method of teaching:

- Introducing the students to what analogies are;
- introducing the topic;
- providing the source domain;
- presenting analogous features across the domains;
- presenting non-matching features in order to avoid misconceptions;
- evaluating the learning outcome.

Glynn and colleagues have revised and modified the Teaching with Analogies (TWA) model given by Zaitoun (2004). The model provides guidelines for constructing analogies systematically and using them strategically during science instruction to explain important concepts in ways that are meaningful to students.

Analogy Based Teaching model adopted from Glynn's Model



Self-generated Analogies

The use of self-generated analogy in teaching means encouraging students and teachers to generate their own analogies for meeting concepts or phenomena. Zeitoun (2004) was the first person who suggested the idea of self-generated analogy in science teaching, with students self-developed analogy strategy. There is considerable value in many analogies between behavior and chemical behavior suggested by Pogliani & Berberan (2006). Analogies are used in science for productive teaching in a variety of ways and at a variety of educational levels (Turk et al, 2010).

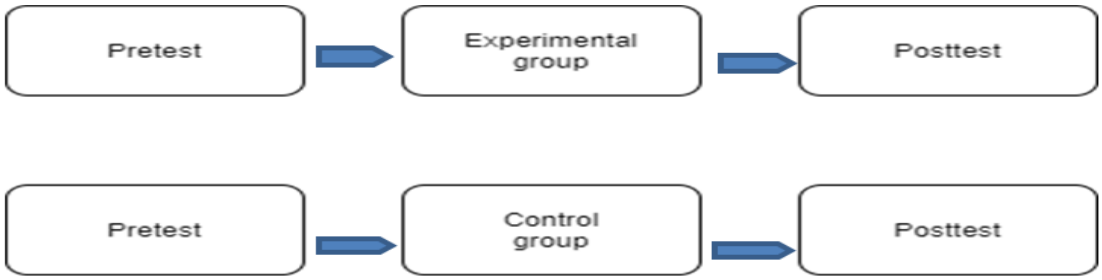
In this study, during intervention students of experimental group students generated own analogies and shared with other fellows. They were guided by the teacher to develop analogies by following the steps as explained in Glynn's model of analogy- based teaching.

Material and Methods

To study the effect of students' chemistry learning in the sense of improvement of higher order skills i.e applying, analyzing, evaluating and synthesizing, an experiment study

was designed. A true experimental pretest posttest control group design was followed by the study. This research design fits well in the experimental setting of the study because randomized distribution of groups i.e control group and experimental group is suitable to study the effect of analogy-based teaching through providing intervention to one group and other was treated as conventional method of teaching in classroom. A pretest and posttest were conducted for both groups to find the difference of learning in control group and experimental group.

Research Design



Pre-test Post-test control group design is given below:

Treatment group	**O_1**	**X**	**O_2**
Control group	O_1	C	O_2

Here X represents the exposure of a group to an experimental variable or event, the effects of which are to be measured. O_1 refers to the Pretest and O_2 Posttest. X indicates experimental and C indicates control group. Data collected through pretest and posttest was analyzed through SPSS statistical process.

In this experimental study analogy-based teaching of selected content of chemistry from book 9 recommended for grade 9th by Punjab curriculum wing taken as independent variable and learning of students of chemistry topics was as dependent variable.

The most important characteristics of pretest posttest control group is randomization. At first stage two sections of students' grade 9th were selected from all sections of this grade through random sampling from 6 sections and at second stage 40 participants from each selected sections were selected through hat and lottery method.

In the study according to the nature of topic and objectives, the instrument was comprised of chemistry Learning Achievement Test (CLAT) for secondary school grade 9 students. It was developed by the researcher according to selected content through reviewing the literature. CLAT was included four self-directed higher order learning skills i.e. application, analysis, synthesis and evaluation. The main structure of CLAT was consisted of 50 multiple-choice questions from selected content after removing outliers.

Pretest and Posttest was prepared by following the table of specification in the super vision of experts of test development. The table of specification has been designed for selected topics by following Bloom 's taxonomy according to the learning objectives.

Table 1

Table of specification to prepare chemistry learning achievement test.

Cognitive level according to blooms taxonomy	Objectives	Item No.	Total no. of items	Weightage %
Application	Investigate the effect of Analogy-based teaching on application skill of secondary school students.	18, 21, 22, 23, 24, 29, 30, 33, 42, 44, 45, 47, 49	13	26%

Analysis	Explore the effect of Analogy-based teaching on analysis skill of secondary school students	1, 2, 3, 6, 12, 14, 15, 17, 19, 20, 25, 32, 34, 38,	13	26%
Synthesis	Study the effect of Analogy-based teaching on evaluating skill of secondary school students.	7, 10,11,14, 28, 29, 31, 36, 40, 41, 43, 48	12	24%
Evaluation	Find the effect of analogy-based teaching on synthesis skill of secondary school students	4,5,8,9,13,16,19,27,35, 37, 39,46	12	24%
Total no. of items		50	50	100%
Total marks			50	

Procedure of experiment

The study involved an experiment of 14 week on Grade 9th students to implement intervention. The experiment was conducted at an urban public school. Prior to conduct of experiment the purpose, content, scope and application process of this activity was shared to the students.

A pretest was conducted at the start of experiment for both experimental and control group. Content was completed in three months according to intervention plan with students of both groups. Experimental group was taught through analogy -based teaching while the control group was taught through traditional lecture method. Only theoretical based topics were selected for the study.

Table 2
Content of the study

Sr no	Topic
1.	Concept of mixture
2.	Chemical symbols
3.	Chemical formula
4.	Radical and free radical
5.	Models of structure of atom
6.	Periodic table
7.	Chemical bonding
8.	States of matter
9.	Solutions
10.	Gas laws

Lessons of above-mentioned topics were delivered with the help of self-generated analogies to achieve the study targets. Following table shows the few topics with suggested analogies used for respective topics, remaining analogies would be provided on request of the readers.

Table 3
Topics of the study and proposed analogies

Sr. No	Topis/sub topics	Analogies

1	Topic **Concept of mixture** A mixture is a substance which consist of two or more elements or compounds not chemically combined together. For example, Air is a mixture of gases like oxygen, nitrogen, argon, carbon dioxide etc.	Pasta is a mixture of noodles, spices, chicken pieces, and sauces. Amna has orange flavor tang in her bottle, Saba has mango flavor and Hina has strawberry flavor. Amna has an idea to combine all flavors she mixed all the three and they enjoyed a homogeneous mixture of different flavors.
2	**Energy levels** or shells where electrons revolve according to its energy content.	Today my teacher forgot his mobile phone at home. He called his driver and told him to go his home and bring phone. He explained the exact position of his phone where it was lying. He said that when he will enter the home, he will be moved to upper portion of the home then towards right side second one is his room, inside the room there will be side table of the bed. Inside the lower drawer of the table, he will find the phone. His home is like shell of electrons where one can move anywhere and the most probable position of phone is subshell of electrons where the chances of finding electrons are maximum.
3	**Chemical bond** (Binding force between two atoms)	Our relationships are binding force between each other like bond of love and affection of parents for their kids, family, colleagues, friends, student and teacher etc. Story of every living being to get stable position by completion of studies, good job making family and struggle for stable social status.
	Periodic table It is a table of specific arrangement of elements in the form of periods and group according to increasing atomic numbers of elements. In periodic table horizontal and vertical arrangement of elements is called groups and periods.	Arrangement of students in class room in the form of vertical and horizontal rows. A class room can be designed according to the arrangement of periodic table. Sitting arrangement of students in class in rows and columns like periods and groups in periodic table

Shielding effect the number of electrons present between outermost shell and nucleus, high atomic number more shielding effect **Principal of solubility**, Like dissolves like	Movement of Prime Minister on the road with lot of security all around. This mass of security with authoritative persons is like shielding effect of electrons around nucleus…more authoritative people have more security and more shielding effect.
Process of boiling On heating when molecules gain maximum energy, forces of attraction weakens and liquid starts to boil. Liquid changes to gaseous state.	Same nature people develop friendship in short time
lot of distance causing minimum forces of attraction	When we feel angry (boiling) we lose our relations as water lost its original identity and changes into gas. Anger always causes mis understandings; forces of attractions weaken and relation lost their true spirit.

Remaining part of analogies will be provided on request of the readers.

Results and Discussion

This part is based on statistical analysis. Analysis is based on data screening tests, outliers' graphs, Data description, Reliability test. It also presents hypotheses' statistical tests. Though ANCOVA was conducted to compare the effectiveness of different levels of Analogy-based teaching on students' learning of chemistry for Pre-test and Post-test of control and experimental group. For the Comparison of Pre-test and Post-test results t-test was applied on the test score. ANCOVA is similar to traditional ANOVA but is used to detect a difference in means of three or more independent groups, while controlling for scale covariates. A covariate is not usually part of the main research question but could influence the dependent variable and therefore needs to be controlled for. t-test is used to confirm the mean difference between pre-test and post-test of control and experimental group.

Table 4
Reliability Statistics of Test

Particulars	Cronbach's Alpha	N of Items
Application	.613	13
Analyses	.613	13
Syntheses	.689	12
Evaluation	.612	12
Overall Reliability of Knowledge test for chemistry	.705	50

The result of reliability is summarized in table 4.1. The value of Knowledge test for chemistry is.705. that shows that reliability is tolerable and acceptable, on the other hand Reliability for factor-wise test was also shown in the above table that is, for "application, .613, for analyses, .613, for synthesis, .689, for evaluation it is .612. All the values are acceptable and shows the reliability of the test.

Table 5
Summary of ANCOVA effect of Analogy-based teaching on students' learning of chemistry at Secondary school level on post test score

Source	Type III SS	df	MS	F	p	Partial η^2
Pre-test	1666.754	1	1666.754	97.713	.000	.559
Group(E+C)	1743.218	1	1743.218	102.195	.000	.570
Error	1313.446	77	17.058			
Total	57214.000	80				

a. R Squared = .726 (Adjusted R Squared = .718)

Above table shows the result of tests between subject effects. There is significant difference in the (Chemistry test) between G1 and G2 students' results (F (1, 77) = 102.1, p=0.00 between G1and G2 test. The partial Eta squared value indicates the effect size is large 0.57. This value is also used to describe how much of the variance in the dependent variable is explained by the independent variable (57%). Ideally this number would be fairly large. R square shows that model is fit. It shows variation is 72%.

Table 6
Summary of ANCOVA effect of Analogy-based (Applying skill) teaching on students' learning of chemistry at Secondary school level on post test score

Source	Type III SS	df	MS	F	P	Partial η^2
Pretest Application	86.478	1	86.478	30.005	.000	.280
Group	104.391	1	104.391	36.221	.000	.320
Error	221.922	77	2.882			
Total	3952.000	80				

R Squared = .464 (Adjusted R Squared = .450)

Above Table shows the result of tests between subject effects. There is significant difference in the (Chemistry test) between G1 and G2 students results for analogy- based teaching level application (F (1, 77) = 36.2, p=0.00 between G1and G2 test. The partial Eta squared value indicates the effect size is small 0.32. This value is also used to describe how much of the variance in the dependent variable is explained by the independent variable (32%). Ideally this number would be fair. R square shows that model is fit. It shows variation is 46%.

Table 7
Summary of ANCOVA effect of Analogy-based (Analyzing skill) teaching on students' learning of chemistry at Secondary school level on post test score

Source	Type III SS	Df	MS	F	p	Partial η^2
Pre-test Analyzing	74.784	1	74.784	24.173	.000	.239
Group	75.094	1	75.094	24.273	.000	.240
Error	238.216	77	3.094			
Total	3842.000	80				

a. R Squared = .419 (Adjusted R Squared = .404)

Above table shows the result of tests between subject effects. There is significant difference in the (Chemistry test) between G1 and G2 students results for analogy- based teaching level "analyzing skill" (F (1, 77) = 24.2, p=0.00 between G1and G2 test level. The partial Eta squared value indicates the effect size is small 0.24. This value is also used to

describe how much of the variance in the dependent variable is explained by the independent variable (24%). R square shows that model is fit. It shows variation is 42%.

Table 8
Effect of Analogy-based (synthesizing skill) teaching on students' learning of chemistry at Secondary school level on post test score

Source	Type III SS	df Summary of ANCOVA	MS	F	P	Partial η^2
Pre-Test Synthesizing	87.482	1	87.482	37.570	.000	.328
Group	66.851	1	66.851	28.710	.000	.272
Error	179.293	77	2.328			
Total	3379.000	80				

a. R Squared = .474 (Adjusted R Squared = .460)

Above table shows the result of tests between subject effects. There is significant difference in the (Chemistry test) between G1 and G2 students results for analogy- based teaching level synthesizing skill (F (1, 77) = 28.7, p=0.00 between G1and G2 test. The partial Eta squared value indicates the effect size is small 0.27. This value is also used to describe how much of the variance in the dependent variable is explained by the independent variable (.27%). R square shows that model is fit. It shows variation is 47%.

Table 9
Summary of ANCOVA effect of Analogy-based (evaluating skill) teaching on students' learning of chemistry at Secondary school level on post test score

Source	Type III SS	Df	MS	F	p	Partial η^2
Pre-Test Evaluation	125.992	1	125.992	36.474	.000	.321
Group	143.773	1	143.773	41.621	.000	.351
Error	265.983	77	3.454			
Total	3753.000	80				

a. R Squared = .483 (Adjusted R Squared = .470)

Above Table shows the result of tests between subject effects. There is significant difference in the (Chemistry test) between G1 and G2 students results for analogy- based teaching level "evaluating skill" (F (1, 77) = 41.6, p=0.00 between G1and G2 test. The partial Eta squared value indicates the effect size is small 0.35. This value is also used to describe how much of the variance in the dependent variable is explained by the independent variable (35%). R square shows that model is fit. It shows variation is 48%.

Table 9
Summary of results of hypothesis test

Particulars	Results
H:1	Supported
H:2	Supported
H:3	Supported
H:4	Supported
H:5	Supported

The activity resulted to improve the higher order skills i.e. applying, analyzing, evaluating and synthesizing skills of students.

Table 10
Student generated analogies

Topic	Analogies generated by the students (Respondents name were given in brackets)
Types of mixtures Homogenous & heterogenous	Almond milk is a homogenous mixture of milk, sugar, almonds and cardamom. (Khadija) Tomato ketchup is a homogenous mixture of tomato concentrate, salt, sugar, vinegar and corn powder. (Maryam)
Symbols of elements	Name of my pet is jerry. (rabia) signs of road, gestures of greetings and anger. (asma)
Free radicals	Having no friend in class (amna) Single child (abida)
Shells and sub shells of atomic structure	Players in cricket stadium (Shazia) Capsule lift in malls (noor)
Blocks in periodic table	Blocks in museum, blocks in hospital building, blocks in university (Hadia)
Shielding effect	Use of mosquito net for sleeping, use of fence around wrestles stage. (maria)
Chemical bonding	Making friendship (zoya)
Ionic bonding	Give donations, spending money for close relations (huma)
Covalent bond	Equal sharing of money for business (salma) 

Results of the study showed that the posttest score was found significant in favor of experiment group that means the learning with analogies have positive contribution in learning of students. The majority of students expressed that they thought about using analogies in other subjects also. Findings of this study exhibited that creating analogies by students help them to understand concepts in the subject of chemistry. These results are similar with previously conducted studies where it is argued that analogies are beneficial in learning science (Akamca, 2008; Akar, 2007; Akyuz, 2007; Dilber, 2006; Kayhan, 2009).

Analogies may help students to relate new information to prior knowledge, to integrate information for one subject area into another, and to relate it to daily life experiences. The same results were found by Nawaf (2016). Result of this study shows the positive effect of analogy-based teaching on higher order thinking skills i.e., applying, evaluating, application and synthesizing. Previously conducted studies also endorsed similar findings and demonstrated significantly higher levels of understanding by the students. (Evans, 2006).

One is positive effect of analogy-based teaching on the affective responses of students towards the learning situation. The second is the nature of analogy, and their encouragement of perception of the natural environment as an integrated whole (Wang, et al. 2019; Erokten, & Kahraman, 2013). From the higher order thinking skills perspectives, it is evident that analogies have a positive effect for most students' analysis level, as well as synthesis, and evaluation for all levels it played a definitive role, students are favorably inclined towards the use of analogies in teaching for retaining concepts and better understanding. The effect of application level is slightly higher as compare to remaining

three levels observed in this study. Students who were taught through the analogies scored much higher than control-group students on conceptual questions and problems.

The opinion of Synder (2006), is thus confirmed that students of low cognitive ability benefited more from the analogies and have good results when they enjoy in making the analogical connection along with facilitation of the teacher. Improvement in synthesizing skill is slightly lower as compare to analysis and application skills. This may be due to that the target population is not novel in their thinking. As mentioned by Vasilyeva & Browser, (2006). In case of synthesis and problem solving, the target population or presented problem must be sufficiently novel and challenging. Considering the implications for instructional analogies should be used only when they contribute significantly to acquire new concepts and processes. Thus, the use of analogies is linked with the difficulty of the target domain for the learner, Gentner & Frobus (2011). Analogies should be, and are used as an aid to understanding when the target is difficult to understand, Pellegrino & Hilton (2012). On the basis of findings, it is suggested that the teachers should use analogies in their teaching to make learning process more effective.

Conclusion

There are numerous concepts in chemistry curriculum that students feel difficulty to understand because of its abstract character, it demands of a mastery of a large number of related concepts and the essential role in developing an understanding in other areas of chemistry such as types of bonding, reactions, electronic configuration and isomerism (Nawaf, 2016). The present study concluded that analogy-based teaching in the subject of chemistry positively enhanced the higher order thinking skills of students i.e. application, analysis, and synthesis. The results of the study specified that the students in the experimental group showed significantly greater achievement than the students in the control group like the same results were found in the study done by Aykutlu & Sen (2011). Based on the results, it is concluded that analogies help students to comprehend, analyze, and synthesis the abstract concepts, establish their thinking about a given topic, and learn a topic expressively.

Recommendations

Based on this knowledge, it is suggested that a combination of different analogies may enhance students' understanding of concepts in chemistry.

- It is recommended that analogy-based teaching may be incorporated into the teaching of chemistry at secondary level.
- Teachers should make analogies a part of daily lesson plans to produce an effective and productive class room.
- Authors of chemistry textbooks should need to integrate analogies text books to enable students to comprehend, analyze and synthesize the textbook contents.
- Curriculum planners should recommend innovative instructional strategies, such as analogies, when reviewing the existing curriculum of chemistry.

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