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Effect of Concept Based Cartoons as art integration on Alternative Concepts in Chemical Bonding

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Abstract

This study is carried out to investigate and analyze the effect of art integration in chemistry curriculum by concept-based cartoons integrated in the context based chemical concepts learning approach on class 9th students' alternative concepts in chemical bonding. The study was conducted with 45 students of grade 9, within a non-equivalent pretest-posttest group design (NEGD). A chemical bonding concept test conducted to gather the data with 16 multiple choice question (MCQs), and to probe their conceptions, a clinical interview with 5 open ended questions was used. Interview questions and MCQs were based on the same alternative concepts. The study concluded with a positive effect of context-based approach on the remediation of chemical bonding alternative conception. Although concepts-based cartoons found powerful tools and most helpful in resolving alternative concepts in chemical bonding but the study suggest to use more than one intervention for the remediation of alternative conception in chemical education.

Keywords: chemical bonding, context-based approach, alternative concepts, concept-based cartoons.

Introduction: Alternative conceptions have an important role in chemical education especially in chemical bonding not only making inadequate explanations to questions but in further learning also. Students construct their concepts as an explanation for the chemical behaviors, theories and properties in chemical education. Students believe that most of

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these explanations are correct because these explanations make sense in terms of their understanding. Teachers use multiple strategies as interventions to resolve these alternative concepts. Chemistry is highly spatio-visual based, it is very common that student's develop various alternative concepts in chemical education. Context based cartoons are among one of the strategies where cartoons are embedded in context-based chemistry to resolve the alternative concepts in chemistry and for better retention of the concepts. Cartoons not only provide conceptual information, they are also helpful in capturing the attention of the students, also stimulate the active learning, and student actively engage in learning process, hence cartoons are effectively used in chemical education[1]. Cartoons are powerful tools and are effective in remedying the alternative concepts in chemical bonding, however multiple interventions with cartoons have more remediation[2]. As visual tools are very important in meaningful learning, concepts cartoons provide an opportunity to student to interpret and understand the concepts firmly besides of adding humor[3]. The aim of creating the concept cartoon was to elicit learners' ideas, to challenge their thinking and improving the conceptual understanding. In stimulating learning environment, these affect the learning positively[4].

Some studies shows that concept cartoons when used in conceptual change pedagogy, created focused discussion with teachers' provoking questions and uncovered the reasoning behind student's alternative conceptions[5]. Animated concept cartoons bring a significant positive change in the understanding of science concepts, especially in the concepts that are difficult to comprehend. It strengthens their conceptual framework and make change in students' perception for concepts and they look these from a different perspective[6]. Primary education is based on the visual tools where teachers use visual clues for better construction of concepts in conceptual framework of students, however untrained teachers don't integrate such strategies in their curriculum, and students are not trained on the process of meaning making from visual tools[7]. Constructivism approach emphasis on engaging the students in active learning where students relate scientific knowledge with their pre-

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existing knowledge. Context based approach can influence the interpretation of conceptual problems, and concept cartoons embed scientific ideas in day-to-day context and found effective in conceptual understanding. Constructivism suggests using real world context in teaching learning for deep conceptual understanding and real-world context helps in nailing of concept for better understanding[8]. To perceive the relevance of chemistry, context-based approach should be followed that creates "Need-to-Know" by activating student's pre-existing knowledge and making connection between prior knowledge and new knowledge, it also develops coherent mental map of knowledge. So, context-based approach in chemistry helps the students to learn the chemical concepts in a meaning way[9]. In chemical education, context-based approach is used in many chemical concepts like reactions, periodic table, thermodynamics, electrochemistry, bonding, acids and bases to explore the learning of students in various concepts.

Students develop a wide range of alternative conception in chemical bonding because they find it abstract[10]. Due to abstract conception, students' feel difficulties in interaction between atoms and sub atomic particles[11]. Chemical bonding is not only abstract but also one of the most fundamental topics associated with spectroscopy, ions, molecular structure, etc., so student's need to visualize this microscopic world[12]. However, in the pandemic the students were not able to access the physical classroom, so the alternative conceptions and physical distancing impacted the mental health of the students' and educators' community, classroom interactions not only helpful in resolving misconception but also enhance positive mental health, and cognitive competencies[13]. Students' engagement in collaborative and cooperative learning allow them to make predictions satisfactorily about chemical and physical properties of substances[14], so assessment integrated pedagogy is also much helpful in resolving alternative conceptions[15].

In the chemistry education, educational testing and measurement helps students to identify their misconceptions and support in better understanding[16], there are lot of studies to claim that students' understanding, eliminate alternative

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conceptions in chemical education. One study conducted by Ekinci (2010) also investigated the impact of context-based teaching methods on IX Class students in chemical bonding and concluded that context-based approach used in experimental group was more successful in resolving the misconceptions[17]. Nicoll (2001) conducted study on UG student's alternative conception in chemical bonding and the study revealed that many students have misconception in understanding chemical bonds as the attractive forces between electrons[18]. Learners mental model of chemical bonding is flexible and can be restructured by integrating metacognitive stimulating curricular activities. Metacognitive strategies are much impactful in promoting the student learning and resolving the alternative conceptions[19]. Enriched lesson plan with frequent assessment can be a good tool to identify the alternate conceptions and its repair.

Aim of the Study

The main aim of the study was to investigate the 8th grade students' alternative conceptions in chemical bonding and impact of concept cartoons integrated within context-based learning on resolving the alternative conceptions. The research questions explored in the study are:

1. Do concept cartoons integrated in context-based learning approach bring significant positive change in students' conception in chemical bonding?
2. How students' change their conceptual framework of chemical bonding with the implementation of context-based approach?

Methodology

Research Design and Participants: The participants of the study were 45 students from 9th class in New Delhi Schools in India. The age group of the participants was 13 to 14 years from two different classes. The design of the study was a nonequivalent pretest-posttest control group design. The control group consist 24 students having 14 girls and 10 boys, and experimental group consist 21 students having 12 girls and 9 boys. The teachers were trained on context-based approach having relevant experience in the chemistry teaching and were also provided with

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teaching material, and sample material prepared in collaboration with subject experts and class teachers by the researcher. The participants were already learnt the chemical bonding concepts like ionic bonds, covalent bonds, etc., in the previous classes.

Implementation: Based on context-based approach, three lesson plans were prepared for both groups. Teachers were assigned with 8 hours of teaching in both groups. Cooperative learning strategies were used in the both classes, the only difference was that experimental group was introduced with the concept cartoons.

Each lesson plan in experimental group was embedded with concept cartoon based on specific concepts related to chemical bonding. Teachers in control group were using the cooperative learning without concept cartoons. Examples of some concept cartoons used are given below:

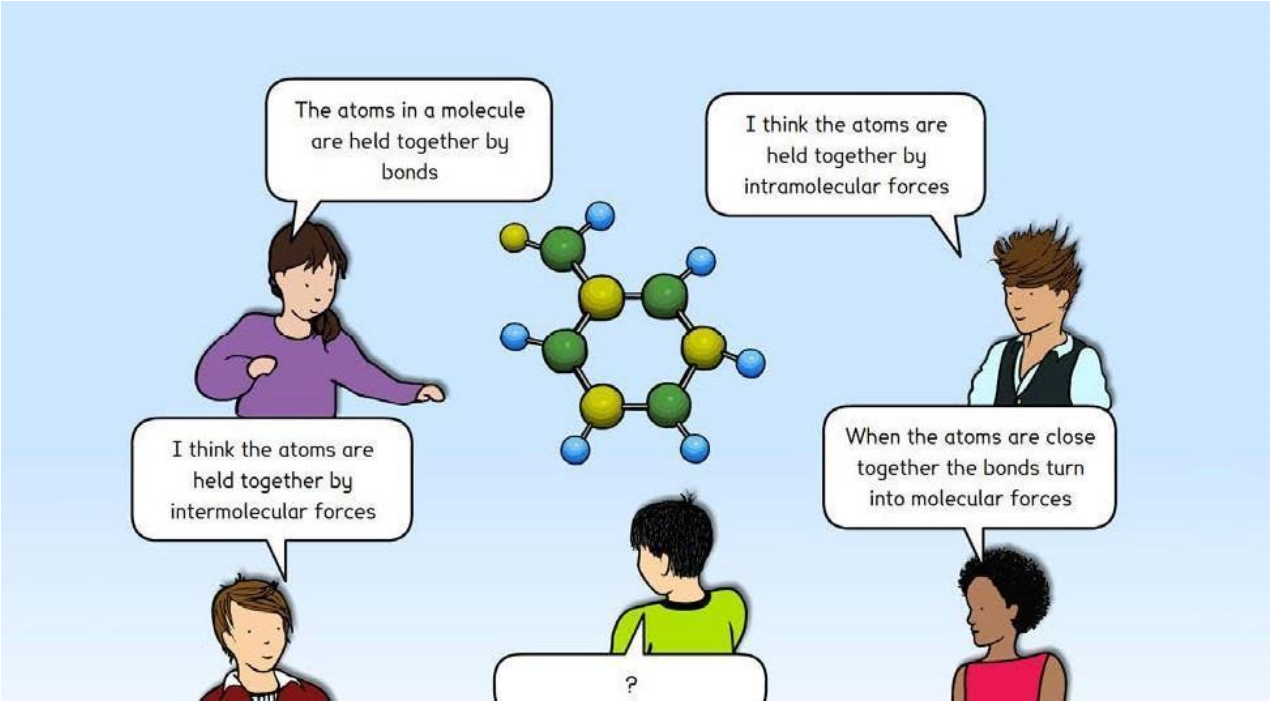

Figure 1
https://d1ymz67w5raq8g.cloudfront.net/Pictures/1024x536/8/1/3/511813_conceptcartoonwhatholdsatomstogetherimage_673710.jpg

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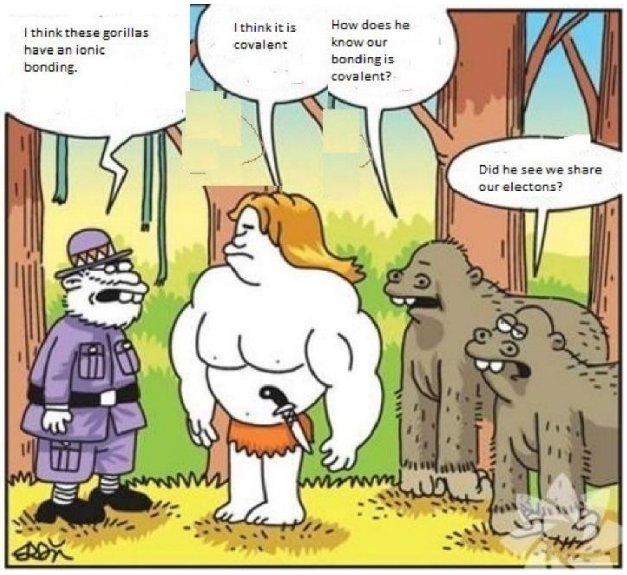

Figure 2 *https://d3i71xaburhd42.cloudfront.net/48eafd34b0afb72cd282a55c32b26b316effbf40/4-Figure1-1.png*

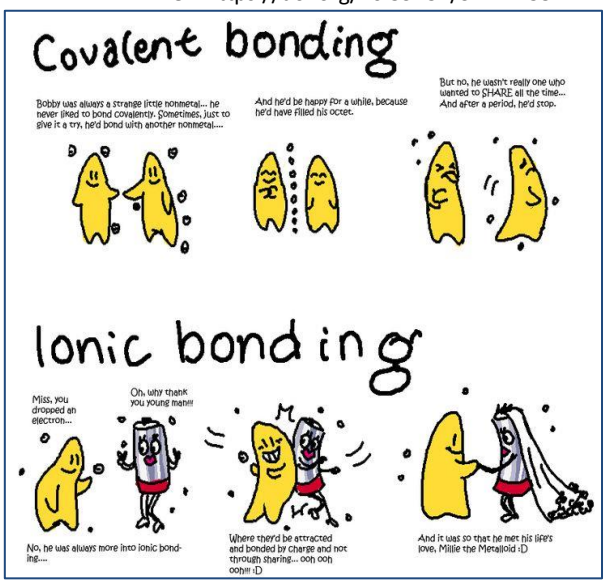

Figure 3 *https://i.pinimg.com/736x/0a/de/c3/0adec37b9807c46b4ac9801168939b87.jpg*

Teachers and researchers created some concept cartoons with dialogues whereas some concept cartoons were taken from the internet sources. Table 1 shows a lesson plan based on the art integration approach.

Table 1: Example of Teaching design in Experimental Group

Role of Teacher	Role of Student
Teacher conducted pre-test and collected the date on pre-conceptions in chemical bonding. Then teacher engaged the learners in discussion by posing some stimulating question on relating shopping and ionic bonding. A concept cartoon was shown and teacher fired the question "which atoms accept	Students attempted the pre-test and discussed the response with peer group. On the basis of pre-existing knowledge and available text book, the students answered the questions fired by the teacher. After watching the concept cartoon and reading the dialogue, they interpreted the information and tried to understand the analogy.

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electrons easily and which donate electrons very easily". The teacher explored the topic "classification of elements" and categorized the elements as Mentals, Non-Metals and Metalloids. Teacher then drew the electronic configuration of electrons and introduced next concept cartoon. Teacher explained the topic and opened the platform to share their knowledge on electron donation and acceptation. Next concept cartoon was shown to students Teacher elaborated the concept and asked student to drew the electron distribution of some metals and non-metals. Teacher explained the relationship between metals and non-metals to accept/ donate electrons. Teacher introduced next concept cartoon. To evaluate their learning, teacher engaged the students in drawing atomic model. Activity sheet was given to students.	The students pointed the Metals, Non-Mentals and Metalloids in the periodic table. Students drew the electronic configuration and tried to understand the octet and doublet rule. Students watched the concept cartoon and interpreted it. Students tried to grasp the concept as teacher explained and raised questions. They watched the cartoon and interpreted the cartoon. Students worked in the groups and discussed the electronic distribution, engaged themselves in understanding the chemistry of acceptance and donation of electrons. They interpreted the concept cartoon and tried to grasp the concept of election analogy. Students engaged themselves in the groups and with teacher in drawing atomic model. They filed the activity sheet and discussed the responses with peer group and the teacher.

Note: The outlined plan was implemented in the experimental group, although control was not provided with concept cartoon but rest of the plan was same for both classes.

Data Collection Tools

For data collection, the CBCT (Chemical Bonding Concept Test) with 16 MCQs (Multiple Choice Question) and 5 open ended items in clinical interviews were used. Subject teachers conducted clinical interviews by randomly selecting the

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students from both groups. Same alternative conceptions were considered while preparing the CBCT and clinical interview items. CBCT was mainly conducted to probe student's conceptual framework. One item from CBCT is given below.

Question: 4 Teacher: Write one example from the characteristics of covalent bonding?

Rohit: They don't conduct electricity in any state

Shreya: It involves electrostatic force of attraction

Nakul: No atom loses electron in this bonding

Chandra Das: This bond formation is between mental and non mentals.

Which student gave incorrect answer?

a) Rohit
b) Nakul
c) Shreya
d) Chandra Das

Clinical interview with five items were conducted to support the data collected in CBCT. One example item from the interview is the following.

Question 3: Define the 'bond'? Explain why compounds have bonds?

Table 2 contains the relation between concept cartoons and distribution of the concepts according to the item number in the CBCT. More than one item is introduced for each concept testing.

Table 2: Relation of the concepts with concept cartoons and distribution of the concepts according to the questions in CBCT.

Concepts	Questions	Concept Cartoons
Differentiate between covalent bonding and ionic bonding	1, 2, 5, 6, 8, 10, 14, 15	7, 9, 11, 12
Unable to explain ionic and covalent bond formation	1, 5, 8, 9, 12, 14, 15	8, 10, 11, 12
Failed to consider octet rule	7, 8, 11, 16	1, 2, 3, 4

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Atoms and molecules confusion Failed to explain metallic bonding Failed to explain characteristics of ionic compounds	10, 13 4, 6 3, 6, 12	3, 4, 6 5 7, 8

This study used the mostly similar items used by Ultay, N., 2015.

Informal data collected by observation and field experience of the experts including researcher. No separate data sheet prepared for the observational data, although it was used for analysis of the data and also when the items were prepared.

Validity and Reliability of Tools: Readability, appearance and content validity of CBCT and clinical interview items was ensured by a team of chemistry and science teachers having enriched experience in chemical education. To find unclear and un-understandable points, the researcher engaged some student form other schools who were not the part of sample. First version of CBCT having 25 items, was pilot tested with 70 students separate from the sample and revised as per the assessment and feedback. The last version of CBCT tested and found the reliability coefficient 0.95.

Data Analysis CBCT with MCQs analyzed and student having correct answer got 1 point and with wrong answer got 0 point. Point earned by the groups were compared and analyzed with independent samples t test and paired samples t test in SPSS. On the basis of analysis of clinical interviews, students were divided into five categories:

Sound Understanding (SU): Students explained the concepts accurate scientifically.

Partial Understanding (PU): Students explained the concepts with partial correct information but without alternative conceptions.

Partial Understanding with Specific Alternative Conception (PUSAC): Students; explained the concept with partial

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scientific understanding with some alternative conceptions.

Misunderstanding or Specific Alternative Conceptions (MU): Students explained the concept with inconsistent scientific information, and contain some alternative conceptions.

Empty/Irrelevant (E) (0 point): Students' irrelevant or not understood answers or left the question empty. Interrater reliability coefficient for clinical interview was found 0.87.

Results

The descriptive results from CBCT for the first research question "Do concept cartoons integrated in context-based learning approach bring significant difference in students' conception in chemical bonding?" is displayed in Table 3 below.

Table 3: Descriptive Results of CBCT

Groups	N	Pre-Test		Post-Tes		Change in Pre-Test and Post Test (%)
		Mean	Std Dev	Mean	Std Dev	
Experimental	21	7.47	1.91	9.94	2.24	33.02
Control	24	6.87	2.11	9.04	2.51	31.38

Date in the above table provide a comparison between experimental and control group, experimental group have increased their score in posttest.

For the analysis of the data, normal distribution for one sample is checked and found Normal by Kolmogorov Smirnov test in order to use parametric tests. Independent samples t test is done to check equality of variances and to identify the significant difference between the groups' Pre-Test and Post-Test scores. Data after the analysis is shown in Table 4

Table 4: Independent samples t test results for Pre-Test and Post Test of the groups.

		Test for Equality of Varian					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference
Pre-Test	Equal variances assumed	0.008	0.925	0.994	42.989	0.324	0.601
	Equal variances not assumed			1.002	42.938	0.322	0.601

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Post-Test	Equal variances assumed	0.001	0.971	1.273	43	0.208	0.91
	Equal variances not assumed			1.282	42.971	0.206	0.91

Based on equality of variances, no significant difference is found between groups pre-test and post-test. For the second research question "How students' change their conceptual framework of chemical bonding with the implementation of context-based approach?", to determine how significantly the topic was learned by the groups', paired samples t test was performed and data is shown in the below table.

Table 5: Experimental and Control Groups paired samples t test results for pre-test and post-test

Groups	t	df	Sig. (2-tailed)
Experimental	-9.08	20.00	0.00
Control	-4.19	23.00	0.00

The above table shows a significant difference between the pre-test and the post-test. Chemical bonding concept learned effectively by both groups.

Below table summarizes the percentages of alternative conceptions in pre-test and post-test of the CBCT.

Table 6: Percentages of the students' alternative conceptions in the pre-test and post-test of the CBCT.

Alternative Conception	Experimental		CC	Control		CC
	Pre-Test	Post-Test		Pre-Test	Post-Test	
Differentiate between covalent and ionic bonding	47.62	40.46	+7.13	48.93	42.68	+6.24
Unable to explain ionic and covalent bond formation	59.19	47.62	+11.58	64.27	52.96	+11.29
Failed to consider octet rule	73.9	34.51	+39.27	59.37	27.07	+32.31

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Atoms and molecules confusion	54.75	30.96	+23.80	66.63	54.11	+12.6
Failed to explain metallic bonding	35.69	26.18	+9.51	33.31	41.65	-8.32
Failed to explain characteristics of ionic compounds	38.08	36.49	+1.58	48.59	40.26	+8.33

The above table shows that both groups students' conceptual understanding is improved after implementation of concept-based cartoon approach. The above table shows that there is decrease in the percentages of alternative conceptions in post-test for both groups. But, the decrease of percentage in the experimental group is found more than in the control group. Even though in table 6, the statistical analysis does not show a significant difference between post-test results, and imply that the experimental group is better in resolving the alternative conceptions. The alternative conception "Failed to explain metallic bonding" show exception.

Table 7 shows sample student responses from the clinical interviews.

Table 7: Students' responses from the clinical interview in regard to the conceptual understanding levels

Item	CUL	Students		Frequency		Sample Students' Responses
		Experimental	Control	Experimental	Control	
Explain the octet and duplet rule?	PU	E1, E11, E14, E18	C9, C14, C21	4	3	According to the doublet rule, an atom should complete the outer shell to 2 electrons, and in the octet rule, the atom should complete the outer shell to 8 electrons. (E1, E11, E14, E18, C9, C14, C21)
How octet and doublet rule is associated with bonding	E		C3		1	

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What is bonding?	SU	E14	C9	1	1	It is attraction between atoms which allows the formation of chemical compounds that contain two or more atoms. (E14, C9)
Why do atoms bond?	PU	E1, E11	C21	2	1	
Please explain.	PUSAC	E18		1		The bond is due to electrostatic force. (E1, E11, C21)
	E		C3, C14		2	Atoms bonds to be more stable. (E18)
How to chemical bond form?	SU	E1, E11, E14, E18	C21		1	Ionic bonds involves electrostatic attraction between oppositely charged ions. Covalent bonds are between nonmetal atoms with electron sharing. (E1, E11, E14, E18, C21)
	PUSAC		C9		2	
	E		C3, C14			Covalent and ionic bonds form with electron exchange. (C9)
Can you explain the bonds formed between Sodium Chloride and Water	PU	E1, E14	C21	2	1	Oxygen needs two electrons to make a bond and two hydrogen atoms give two electrons. (E1)
	PUSAC		C9		1	
	E	E11, E18	C3, C14	1	2	Na gives one electron and makes a bond with Cl. (C9)
Explain the characteristics of ionic and covalent bond? Give examples from daily life?	SU	E1, E14	C21	2	1	Ionic compounds are electrically conductive. Covalent bonds are formed between non-metal atoms with sharing of electrons. Common Salt can be an example for ionic compounds and Water for covalent bonding. (E1, E14, C21)
	PU	E11	C9	1	1	
	E	E18	C3, C14	1	2	

PU*: Partial understanding*, CUL*: Conceptual understanding level*, SU*: Sound understanding*, MU*: Misunderstanding, or specific alternative conceptions*, PUSAC*: Partial understanding with specific alternative conception*, E*: Empty or irrelevant answer*

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Table 7 shows that experimental group have sound and partial understanding of chemical bonding concepts.

Discussion

Table 5 shows that context-based approach is significantly impactful for conceptual understanding of chemical bonding on both groups. Daily life examples and activities used in both groups might be the reason for this, however concept cartoons in context didn't provide any significant impact in experimental group. According to Table 6, after implementation both groups resolved alternative conceptions, except one alternative conception ("Failed to explain metallic bonding"). As per the data, the percentage of this alternative conception is increased, this might be due to teacher pedagogy.

Table 6 and 7 data support each other, so discussion on it could be more beneficial and informative.

In Table 6, it is shown that students cannot differentiate between ionic and covalent bonding. It clearly shows alternative conception in covalent and ionic bonding, and the data reflect that it is due to teacher pedagogy.

In the similar manner, in one question in Table 7, the student explained that chemical bonds formation is with only electron exchange in ionic bond, this shows alternative conception in chemical bonding such as ions, atom, and molecule. Chemical bonding includes relations between various chemistry topics and it requires enriched prior knowledge of fundamental chemistry concepts such as atom, molecule, ion, etc. Student who doesn't' learn this, find it quite difficult to comprehend.

Students failed to explain the characteristics of ionic compounds, but in the experimental group, a little change in a positive way was observed after the implementation, but not a significant difference. Next alternative conception was in octet and doublet rules. In Table 6, the experimental group resolved it slightly better than the control group. However, in interview students associated the octet and doublet rules satisfactorily. When CBCT results are considered, (see Table 6), the experimental group showed slightly better improvement than the control group, because concept cartoons are based on real life situations. As whole, Table 6 and 7

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shows that, experimental group performed better than control group.

Conclusions and Recommendations

The research findings suggest that both groups showed improvement in resolving alternative

conceptions about chemical bonding. It is found that relevant context-based approach is successful in chemical education, resolving their alternative conceptions, and relating the content knowledge with the daily life context. Without showing extraordinary effect, concept cartoons are found good tools to resolve alternative conceptions about chemical bonding. So, one intervention is not sufficient in resolving all alternative conceptions, it can be fixed by used more than one intervention effectively because each conceptual change method and the combination of

them result in conceptual change being stored in the students' long-term memory.

In conclusion, concept cartoons embedded within context-based approach are found effective at resolving chemical bonding alternative conceptions. But, to get a more impactful result, a combination of conceptual change methods can be used. Because it is important to deal with the alternative conceptions of students for subsequent topics' understanding, educators should add more plausible concepts than the students' existing ones by creating necessary conditions with conceptual change methods.

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