Investigation of Misconceptions for Valency and Chemical Bonding among High School Students

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Abstract **- Chemistry is one of the important branches of Science. The subject matter of chemistry consists of numerous complex and abstract concepts. Therefore, sometimes students have flawed understanding of these concepts. These erroneous concepts are known as misconceptions. The purpose of this study was to investigate the misconceptions for Valency and Chemical Bonding among High school students. The data collecting tool used in this study was a two-tier diagnostic chemistry test consisting of statements based on the concepts and their reasons. 52 students studying in std. IX were administered with the tool. Their diagnosis was done using percentage. The diagnosis showed that misconceptions occur in students in case of abstract concepts of Chemistry i.e., Valency and Chemical Bonding. As these concepts are intangible in nature, the understanding of students regarding these concepts is not clear.**

Index Terms **- Misconceptions, Valency, Chemical Bonding, High School students.**

INTRODUCTION

It is aptly said that human beings start learning right from their birth. The term 'learning' refers to the process of responding to the stimulus received by an individual. Human beings encounter numerous sensations, observations in everyday life, reflect upon them, create their own depictions and then connect the old and the new knowledge to form understanding. Learning, thus, becomes unique owing to each one's own individual experience.

Right from the primary classes, the learners come to school along with their preconceived notions regarding everything around them. They are never in the form of a blank slate. The prior knowledge and experiences of students and the social context in which their learning has taken place affects the particular knowledge that they construct (Grayson et al. 2001; Von Glasersfeld, 1992). As the process of making connections between the prior knowledge and new information continues, learners often establish their own explanation about everything they learn. And many a times, this explanation contradicts with the actual content which is taught in their classrooms through prescribed textbooks.

These contradictory conceptions of the learners are termed as misconceptions. The conceptions of students that differ from those which are generally accepted by the scientific community have been termed as 'misconceptions' (Helm, 1980), 'preconceptions' (Novak, 1977), alternative frameworks (Driver, 1981) or 'children's science' (Gilbert et al. 1982). Hunt and Minstrell (1997) stated that students' conceptions before teaching are not considered. This hampers the communication between the teachers and the learners and as a result, students face difficulties in learning science. Although these ideas differ remarkably from accepted scientific viewpoints and may even fail to be verified with valid scientific explanation, students hold them strongly and also consider them logical, sensible and valuable (Osborne, 1982; Schoon and Boone, 1998).

Science as a subject is introduced in the primary school initially with a view to acquaint the learners with what is around them. In the later stages i.e., secondary school and then higher secondary school, the subject goes on becoming more specific and detailed. During this progression, the subject gets bifurcated into Physics, Chemistry, Biology etc. and scientific facts, terms, concepts, principles and theories start stepping in. In the context of science education, the ideas that students have about natural phenomena are sometimes contradictory to scientific conceptions. Also, these ideas are very complicated in nature. Therefore, numerous inaccurate conceptions are formed among the students.

Chemistry is a very important branch of science. However, it is looked upon as a difficult subject by the learners and is therefore, not an exception to the formation of misconceptions. Although there are many reasons for learners to find Chemistry difficult, abstractness of chemistry concepts and the difficulty of the chemistry language are few of them (Ayas and Demirbas, 1997). In order to deal with their confusion regarding these abstract concepts, learners mostly depend upon memorizing them instead of going to the depths of understanding the underlying science. As a result, they grow up with these misconceptions and learning suffers.

REVIEW OF RELATED LITERATURE

Coll, R. and Treagust, D. (2001) in their research 'Learner's Mental Models of Chemical Bonding' probed mental models for chemical bonding of Year-12, undergraduate and postgraduate Australian learners. Semi-structured interviews comprising a three-phase interview protocol was used for the investigation wherein samples of metallic, ionic and covalent substances were presented to each of the learners and they were asked to describe the bonding in the substance. From the responses of the students it was found that across all three academic levels, simple, realistic mental models for chemical bonding are preferred by the learners.

Nicoll, G. (2001) in the research 'A Report of Undergraduates' Bonding Misconception' discovered that the undergraduate chemistry students had a number of misconceptions related to electronegativity, bonding, geometry, and microscopic representations. Fifty-six students studying chemistry at the senior level from six different courses formed the sample. Through the qualitative coding scheme of the interviews, it was also found that inspite of increased chemistry education level, the misconceptions related to bonding of some students remain unaffected.

Unal, S. et.al. (2010) in their research entitled 'Secondary School Students' Misconceptions of Covalent Bonding' administered a test consisting of four open-ended questions to a sample of 58 eleventh grade students studying in a public high school. They also interviewed ten students with the help of semi-structured interviews. Analysis of both the test and interview questions revealed that students had many misconceptions about formation of covalent bonds, types of covalent bonds, types or properties of atoms forming covalent bonds and characteristics of giant covalent structures. They have also suggested how teachers, curriculum developers and textbook authors can prevent the formation of misconceptions and make students understand the subjects better.

Dogan and Demirci (2011) prepared and administered a two-tier true-false diagnostic test to 120 students studying in the first, second and third class of a regular highschool in Malatya and 24 prospective chemistry teachers in the last year of teacher education in a university in Turkey. From the analysis of the data, they discovered that most of the misconceptions related to the concept of ionic bonding, held by the high school students were same or similar to the misconceptions held by the prospective chemistry teachers. It was also found that the misconceptions held by the high school students were similar at all levels of education.

Fadillah, A. and Das, S. (2018) in their research entitled 'Analysis of Misconceptions of Chemical Bonding among Tenth Grade Senior High School Students using a Two-tier Test' administered a two-tier test consisting of three questions to 180 students studying into low, medium and high school levels based on national test scores for chemistry in 2016 and found that more than 50% learners have misconceptions of chemical bonding. The highest percentage of students having these misconceptions was studying in the high school level. The neglect towards the various different aspects of chemistry teaching affects the level of the conceptual understanding of the students. Therefore, misconceptions should be reduced.

Üce, Musa & Ceyhan, İlknur (2019) in their research 'Misconception in Chemistry Education and Practices to Eliminate Them: Literature Analysis' used the qualitative research method of literature review and found that chemistry includes numerous abstract concepts such as solubility equilibrium, covalent bonds, ionic bonds, hydrogen bond and molecule geometry, activity concept in elements, chemical equilibrium, dissolution, electrolyse and battery; which students find difficult to understand as compared to the concrete concepts. This leads to the formation of several misconceptions in the minds of the students. Also, instead of traditional teaching methods, constructivist learning methods can be useful in eliminating these misconceptions.

OBJECTIVES OF THE STUDY

1. To investigate the misconceptions for 'valency'.
2. To investigate the misconceptions for 'chemical bonding'.
3. To give suggestions based on the findings of the study.

RESEARCH DESIGN

On the basis of the nature and objectives of the study and the data required, the quantitative research approach was found appropriate. Hence, the descriptive survey research was employed to collect the data. For this, a two-tier diagnostic chemistry test was prepared to investigate the misconceptions for valency and chemical bonding.

SAMPLING

To investigate the misconceptions for valency and chemical bonding, purposive sampling method was employed. 52 students studying in std. IX in an English medium school from Kolhapur city formed the sample of the study.

TOOL USED FOR THE STUDY

The researchers prepared a two-tier diagnostic chemistry test to investigate misconceptions for valency and chemical bonding. The test consisted of six statements based on the concept of valency and five statements based on the concept of chemical bonding with four reasons for each statement.

STATISTICAL DATA ANALYSIS

The statistical tool - percentage was used to analyse the quantitative data obtained from the tool used in the study.

DATA ANALYSIS

VALENCY

Table No. 1 Statement wise responses of Students for the concept - Valency

Sr. No.	Statements	Correct Answer	Wrong Answer
		Percentage	Percentage
1.	The valency of an element is the number of valence electrons in the outermost shell.	88.09	11.90
2.	When a magnesium atom loses two electrons, its atomic size increases.	85.71	14.28
3.	It is unlikely for a Neon atom to bond with any other atom.	90.47	9.52
4.	Sodium chloride, NaCl, exists as a molecule.	64.28	35.71
5.	The sodium ion has a positive charge. The electron structure of the sodium ion is 2,8,2.	38.09	61.90
6.	The valency of $^{24}Mg_{12}$ is 6.	35.71	64.28

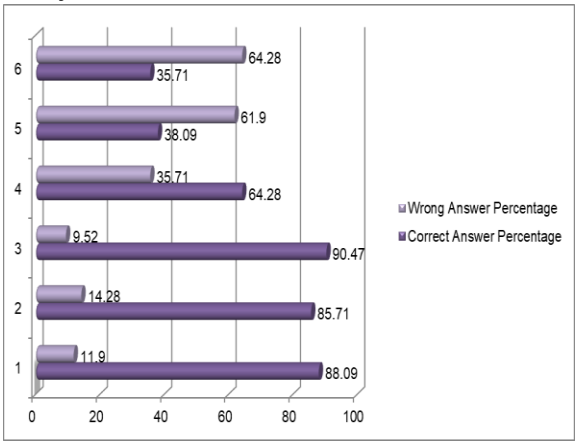
Statement	Correct Reason	Percentage of Correct Reason	1st Wrong Reason	Percentage of 1st Wrong Reason	2nd Wrong Reason	Percentage of 2nd Wrong Reason	3rd Wrong Reason	Percentage of 3rd Wrong Reason	No Reasoning	Percentage of No reasoning
1	C	56.75	A	5.4	B	5.4	D	27.03	E	5.4
2	C	63.89	A	22.22	B	11.11	D	2.77	E	0
3	C	47.36	A	21.05	B	13.15	D	18.42	E	0
4	B	55.56	A	33.33	C	11.11	D	0	E	0
5	A	31.25	B	6.25	C	12.5	D	43.75	E	6.25
6	D	26.67	A	0	B	20	C	53.33	E	0

Table No. 1.1 Statement wise percentage of reasoning of Students about the concept – Valency

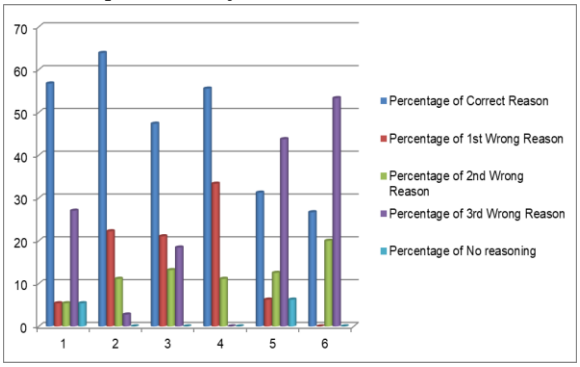
OBSERVATIONS AND INTERPRETATION

From table no. 1 and 1.1, it is observed that for statement 1, majority of students have answered correctly. However, only half of them have justified their answer with the correct reason. For statement 2, majority of students have answered correctly and more

than half of them have justified their answer with the correct reason. For statement 3, majority of students have answered correctly. However, less than half of them have justified their answer with the correct reason. For statement 4, more than half of the students have answered correctly and more than half of them have justified their answer with the correct reason. For statement 5, majority of students have answered incorrectly. Out of the students that have answered correctly, less than half have justified their answer with the correct reason. For statement 6, majority of students have answered incorrectly. Out of the students that have answered correctly, less than half have justified their answer with the correct reason.



Graph No. 1 Statement wise responses of Students for the concept – Valency



Graph No. 2 Statement wise percentage of reasoning of Students about the concept - Valency

CHEMICAL BONDING

Sr. No.	Statements	Correct Answer	Wrong Answer
		Percentage	Percentage
1.	When a chemical bond is formed between a metal and a non-metal, it is a metallic bond.	19.05	80.95
2.	Element *X* (electronic configuration: 2,8,2) and element *Y* (electronic configuration: 2,8,7) react to form an ionic compound, XY_2.	59.52	40.47
3.	In an ionic compound, molecules are held close to each other.	83.33	16.67
4.	Covalent bonds are formed when each atom shares its valence electrons with the other to complete its octet.	88.09	11.90
5.	O_2 is not a covalent compound.	42.85	57.14

Table No. 2 Statement wise responses of Students for the concept – Chemical Bonding

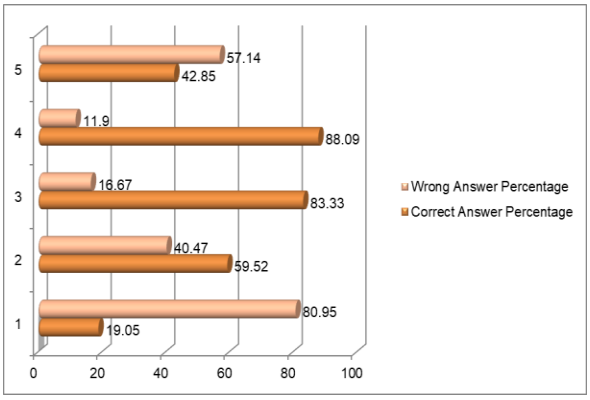
Statement	Correct Reason	Percentage of Correct Reason	1st Wrong Reason	Percentage of 1st Wrong Reason	2nd Wrong Reason	Percentage of 2nd Wrong Reason	3rd Wrong Reason	Percentage of 3rd Wrong Reason	No Reasoning	Percentage of No reasoning
1	B	37.5	A	50	C	12.5	D	0	E	0
2	C	48	A	4	B	12	D	36	E	0
3	D	37.14	A	31.42	B	14.28	C	17.14	E	0
4	D	24.32	A	13.51	B	45.94	C	13.51	E	2.70
5	C	0	A	11.11	B	11.11	D	72.22	E	5.55

Table No. 2.1 Statement wise percentage of reasoning of Students about the concept – Chemical Bonding

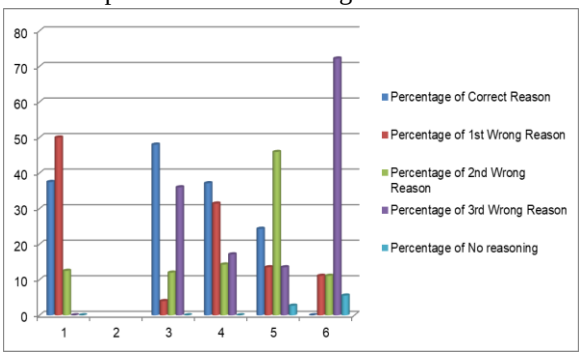
OBSERVATIONS AND INTERPRETATION

From table no. 2 and 2.1, it is observed that for statement 1, majority of the students have answered incorrectly. Out of the students that have answered correctly, less than half have justified their answer with the correct reason. For statement 2, more than half of the students have answered correctly. However, less than half of them have justified their answer with the correct reason. For statements 3 and 4, majority of students have answered correctly. Out of the students that have answered correctly, less than half have justified their answer with the correct reason. For statement 5, more than half of the students have

answered incorrectly and out of those who have answered correctly, none have justified their answer with the correct reason.



Graph No. 3 Statement wise responses of Students for the concept – Chemical Bonding



Graph No. 4 Statement wise percentage of reasoning of Students about the concept – Chemical Bonding

FINDINGS

In case of Valency, although students understood the main concept, they had alternate conceptions about the reasons that described valency. They faced problems in understanding the underlying concepts such as ion formation, charge on the ions, ionic bonding and ionic compounds. All these concepts are closely associated with the fundamentals of valency.

In Chemical Bonding, students are found to have erroneous concepts regarding the types of chemical bonds. Although they can answer the questions about chemical bonding, they are unable to provide correct reasons to their answers.

Due to these misconceptions, the further conceptualization of other related terms is hampered. Therefore, such misconceptions need to be identified and minimized.

The Most Common Misconceptions found among High School Students

Valency

- The valency of an element is the number of electron shells of the atom.
- When an atom loses two electrons, it becomes a negative ion and its radius decreases.
- Atoms with two electron shells do not bond with any other atom.
- Molecules of ionic compounds are formed when pair of electrons are shared.
- Chemical Bonding
- When a chemical bond is formed between a metal and a non-metal, it is a metallic bond.
- In ionic compounds, there are free electrons which hold the molecules together.
- When covalent bonds are formed, one atom gains electrons while the other atom loses electrons to complete the octet.
- Atoms forming covalent compounds cannot gain, lose or share their valence electrons.

CONCLUSION

From the observations and inferences, it was found that misconceptions occur in students in case of abstract concepts of Chemistry, such as, Valency and Chemical Bonding. As these concepts are intangible in nature, the understanding of students regarding these concepts is not clear.

SUGGESTIONS

The first step towards eradicating the misconceptions would be to identify them which can be done through literature review about misconceptions. From the review of the related literature, teachers can learn about the misconceptions that students generally bring to the class. After learning about these misconceptions which are likely to occur among the students, they can plan their lessons by adopting the best methods of teaching, so as to avoid them.

Structured two-tiered, three-tiered or four tiered tests, in-depth interviews, observation or diagnostic tests enable teachers to investigate the patterns of reasoning of the students. Such identification strategies should be used after regular intervals in Science classrooms. After identifying the misconceptions, the conceptual change model can be employed by the teachers which may be very beneficial for the students in order to change their misconceptions.

Innovative teaching strategies such as computer-assisted learning, experiential learning, simulations, projects, etc. should also be incorporated in the regular classroom teaching-learning processes. These will help in avoiding the alternate conceptions as also misconceptions.

Textbooks are the major sources of information for the students. Teachers can also critically examine the textbooks for any probable misconceptions that could arise in the minds of the students. Along with the textbooks, teaching materials, teachers' handbooks, guides etc. can also be effective if used as supportive instructional materials.

Teachers should also develop the necessary capabilities for identifying their own conceptions and misconceptions, if any. They should eliminate their misconceptions by creating an adequate knowledge base of the concepts and thus, having a clear understanding of the same.

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