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Identification Of Students Misconceptions Regarding Chemical Bonding And Their Remediation: A Study On 11th Grade Students In India

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Abstract
The purpose of this study was to explore the misconceptions of 11th grade students of six Indian Schools concerning the topic of 'chemical bonding' and to remediate them using conceptual change and analogy method. A diagnostic test based on 9 concepts of chemical bonding was prepared with an aim of identifying students' misconceptions. Conceptual change texts were prepared to activate students' preconcepts and misconceptions and to help them understand chemical bonding concepts through the use of explanations, analogies and examples. The study was focused towards evaluating effectiveness of the remedial measure in removing the misconceptions. The results revealed that 1) the diagnostic instrument was effective in identifying the misconceptions & 2) conceptual change–oriented instruction produced a positive effect on students' understanding of chemical bonding concepts and in the removal of their misconceptions. The study was limited to 200 students.
Keywords*: Misconceptions, diagnostic test, Conceptual Change Text, Analogy Method, Misconceptions in Chemical Bonding, Remediation of Misconceptions, Alternative Conceptions.*

1- INTRODUCTION

In recent years, there have been a number of researches aiming at students' understanding of science concepts (Fisher, 1985[(1)]; Chambers & Andre, 1997[(2)]). It is found that many students have difficulties in relating their real world experiences with what is taught to them in science classroom (Novak, 1988 [(3)]). Studies have consistently shown that student come to school with varying experiences, ideas and explanations, which are often different from scientific ideas and explanations (Osborne et al, 1983[(4)]). These ideas are often strongly held and form mistaken conceptual structures (Driver and Easley, 1978[(5)]). Researchers have described these differing frameworks as misconceptions (Fisher, 1985[(1)]; Griffiths & Grant, 1985[(6)]). The misconceptions learners may hold hinder their subsequent learning (Taber, 2000[(7)]; Palmer, 2001[(8)]). Thus misconceptions are really big obstacles to promote meaningful learning.

Misconceptions may develop with respect to chemical bonding, as it involves a large number of abstract concepts (Coll & Taylor, 2001[(9)]), words from everyday language used with different meaning (Boo, 1998[(10)]), the lack of understanding of particulate nature of matter[(10)], inappropriate language used in the textbooks (De Posada, 1999 [(11)]) and used by the teachers (Taber & Watts, 1996[(12)]) and the non-constructivist approach of the textbooks (De Posada, 1999[(11)]).

Many educationists have researched on constructivist approach of teaching which considers that acquisition of knowledge is a process of self construction (Piaget, 1950[(13)]). Conceptual change model (Posner et al, 1982[(14)]) is one of the most widely researched teaching strategy based on this approach. Conceptual change is defined in terms of assimilation and accommodation (Posner et al, 1982[(14)]). The four conditions suggested for conceptual change to occur are: 1)

Dissatisfaction with existing conception 2) The new conception must be comprehensible 3) The new conception must be plausible & 4) The new conception must be applicable/fruitful.

Conceptual Change implies that a learner actively and rationally replaces existing prescientific conceptions with scientifically acceptable ones. One of the conceptual change instructional strategies is the use of conceptual change texts. These texts are designed to make readers aware of the inadequacy of their intuitive ideas and help them understand and apply the target scientific concept through the use of explanations and examples as suggested by Hynd et al (1994 [(15)]).

In the current study, conceptual change texts were chosen to remove students' misconceptions because teachers often rely on text for learning and teaching and can be used effectively in small as well as large classrooms to facilitate conceptual change [(2)]. Using analogies as explanatory devices can be a useful way to teach science (Glynn, 1997[(16)]). It facilitates text learning (Glynn & Takahashi, 1998[(17)]). Thus, we used analogies in the conceptual change text to help students take interest in chemistry and to explain the abstract concepts of chemical bonding along with removing their misconceptions. Although the need to identify students' misconceptions concerning chemical bonding has been widely expressed, there have been few studies on identifying and treating misconceptions concerning chemical bonding, especially in the Indian context and hence the current study is undertaken on the students of grade XI where they are formally introduced to the concepts of chemical bonding and molecular structure for the first time in detail.

2- METHODOLOGY

A sample of students was taken from different schools of Madhya Pradesh and Maharashtra from class XI who study according to their State Board or CBSE syllabi. Qualitative and quantitative research methodologies were adopted. Diagnostic tests and the clinical interviews were employed as tools of data collection. It was followed by quantitative analysis of data in terms of 't-tests'. First of all, diagnostic tests questionnaire was administered as pre instructional test to the students to identify their formal knowledge, conceptions, misconceptions and learning barriers. The students had already been taught the unit of chemical bonding by their school teachers using the traditional way of instruction in their regular classes before attempting the pre-instructional test. The questionnaire was based on 9 concepts i.e. Valency, atoms and molecule, elements and compounds, bonding, lattice, shapes of molecules, Electronegativity and polarity of bonds, intermolecular forces and properties of ionic compounds. Pre-instructional test was followed by clinical interview of randomly selected students. The data was analyzed to identify misconceptions & the interviews revealed their sources. Further, the researchers developed conceptual change text including analogies as remedial measure inspired by the work of Aybuke Pabuccu[(18)] .Students were then taught by this method over a period of time. Post-instructional test was conducted to evaluate the effectiveness of the remedial measures. All the relevant statistical treatment to the vast data collected was then carried out.

3- SUBJECTS OF THE STUDY / SAMPLING

The study was conducted on 200 students of class 11th belonging to different government and private schools of Madhya Pradesh and Maharashtra. The sample comprised of 116 boys and 84 girls. The concerned schools are affiliated to different boards of education. Intact classes were taken for the research. Three schools each of Madhya Pradesh and Maharashtra were the part of research.

4- TOOLS & TECHNIQUES

A diagnostic test was developed by the researchers to determine students' misconceptions in the concepts of chemical bonding. The content of the test was determined by examining the syllabus issued by the state boards and the CBSE, instructional objectives for the unit, related literature and opinion of Senior Chemistry Teachers. A multiple choice questionnaire of 40 questions was developed based on 9 different basic concepts mentioned earlier. Nine questions were 1 Tier multiple choice questions, all with 4 options; out of which one was the correct answer and three others were mostly misconceptions or statements irrelevant to the

question. Rest 31 questions were 2 Tier where an answer was to be justified with a correct reason. 4 options were provided for the reason/explanation, out of which one was correct and the other three were misconceptions/irrelevant statements. The misconceptions included in the options were those identified from the literature (Tan & Treagust [19]– 1999, Esen Uzuntiryaki [20]-2003 & Aybuke Pabuccu [18]-2006), teachers' suggestions, several school level reference text books and researchers' personal experiences.

It was first administered to the students of a school (not a part of the experimental group) as a pilot test. It was then revised. Each question carried 2 marks. Full marks were given only on choosing the correct reason/explanation for an answer.

An example of an item (question) in the diagnostic test instrument:

Q. In a crystal of NaCl, each sodium ion is electro statically attracted to:

I. One Chloride ion II. More than 1 Chloride ion.

Reason:

a) A sodium ion remains surrounded by 6 Chloride ions due to electrostatic attraction.

b) A sodium ion is attracted to 1 Chloride ion to which it gives its electron.

c) Na ion is attracted to Chloride ion with which it shares electron.

d) Na ion remains surrounded by many Chloride ions with which it shares electrons.

5- REMEDIAL MEASURES

The conceptual change text was constructed on the basis of Posner et al (1982) [14] conceptual change model. Firstly, questions were asked to make the readers aware of their naïve conceptions. Questions were like: What is a chemical bond? Why is a chemical bond formed? Students were then allowed to discuss these questions in the text by using their previous knowledge related to chemical bonding concepts. They had cognitive conflict when their ideas were not adequate to answer these questions and this caused dissatisfaction with their existing conceptions. This situation supports the first condition of Posner et al's [14] model. Then the students were directed to read the paragraph in which evidences were presented for proving a typical misconception incorrect or a scientifically correct explanation of the concept was provided. Analogies were used to explain the concept in the text e.g. Magnet analogy was used to explain nature of chemical bond and the correct conception that chemical bond means "electrostatic forces between the atoms" was presented. In this context, one common misconception held by the students was that the chemical bond is a material collection. Thus Posner et al's (1982) [14] next conditions of Intelligibility and Plausibility were also established as it stresses on the preconceptions and also helps to link their conceptions with scientific knowledge. It leads the students to replace or integrate the newly learnt concepts with their preconceptions. Moreover, students could see the application of their learning in explaining other related situations. Thus Posner et al's [14] (1982) last condition, fruitfulness was also achieved. During the discussion, like and unlike points of the analogies with the real model/situation were elaborately discussed.

6- TABULATION, STATISTICAL TREATMENT, DATA ANALYSIS & INTERPRETATION

The data obtained from pre and post instructional tests were used to compare the achievements in both in terms of question-wise achievement and concept-wise achievement.

Graph 1: Comparative Pre and Post Instructional Question-Wise % Score. (fig. 1)

40 most common misconceptions in various concepts have been identified on the basis of the maximum number of students opting for an incorrect answer. A few of them are :

1. Sodium chloride exists as discrete molecule.
2. Bonds are only formed between atoms that donate or accept electrons.
3. Ionic bond is formed by sharing of electrons.

Analysis confirmed that students hold misconception in every concept.

Table 1. Concept-wise Pre and Post Instructional Performance: The data was treated statistically to obtain the following concept-wise achievement result. (fig.2).

The value of CR (t) for 400 degrees of freedom at 0.01 level of significance is 2.60 as per the t-

table. [21] There is a positive improvement in the understanding of all the concepts after remedial teaching as indicated by CR (t) values >2.60 for all the concepts. It shows that there is significant improvement in the students' understanding of basic concepts of chemical bonding after the remedial teaching.

Graph 2: Comparative Grade-wise Analysis for Pre and Post Instructional Test: (fig. 3)

7- RESULTS

The students were taught the chemical bonding unit by their teachers using traditional method of instruction before taking the pre-instructional test. The mean of scores of the total sample in the pre-instructional test was 43.735 which indicates that students not only had their own pre concepts, but also school-made misconceptions arising from the way of teaching and due to the language and representations used in their textbooks.

1. Students were found to have misconceptions in the basic concepts of chemical bonding.
2. Grade-wise improvement is observed in the post-instructional test which shows that there is a significant effect of remedial teaching in rectifying the misconceptions.
3. Semi structured interviews were conducted which led to an insight into their pre-concepts, misconceptions and also to some extent about their sources.

8- DISCUSSION

Certain findings of the study of the pre instructional data show that students have lot of misconceptions in these concepts as evident from the following: 12.5% of students believed that valency and number of valence electrons are always same for an element. This may be due to incorrect language used by the teacher and less stress given on explaining valency and its difference from the number of electrons. It is distressing to see that 25% students cannot differentiate between symbolic representations of atoms and molecules. This shows very poor understanding right from class IX. 27% students were not able to distinguish between molecules of an element and a compound. It is another serious observation that 25% students do not understand how a metal and non-metal react to form ionic compound in terms of electron transfer on the basis of their electronic configurations and 33% students believed that NaCl exists as discrete molecule. They did not understand the 3-D nature of ionic bonding in solid NaCl. It was revealed during an interview that a 3-D ball and stick model of NaCl caused confusion among the student as many interpreted the 6 wires attached to each ball (ion) as bonds of some sort (specially covalent). Another revelation during an interview was that some students thought that the attraction between oppositely charged ions in an ionic compound causes neutralization of the charges, resulting in formation of a lattice consisting of neutral molecules. A staggering 42.5% student believed that bonds are formed only between atoms that donate/accept electrons. It was explained to the students through an analogy that when a metal atom such as Na atom loses its valence electron it can be compared to the earth attracting all the objects in all the directions towards it. The effect of the positive charge is Omni Directional and a positive ion would attract negative ions such as chloride ions in all directions. Similar explanation is given for chloride ion attracting sodium ions. This image helped students overcome their conception that one sodium ion will only be attracted to 1 Chloride ion. A large number of students (25.5%) had the view that in a covalent bond, the shared electrons are always equally attracted by the bonded atoms.

Students revealed in the interview that they believed a covalent bond is a pair of shared electrons. This misconception probably arises due to exposure of statements found in textbooks or made by the teachers such as 'one pair of shared electrons constitutes a single covalent bond'. It must be learnt from here that it needs to be clearly pointed out to students that a chemical bond is an attractive force, and a pair of electrons by themselves cannot constitute an attractive force.

It is also found that 17% students held the misconception that only an ionic bond is electrostatic in nature and a chemical bond is either fully ionic or fully covalent. This is due to incorrect way of representations of ionic bonding. While discussing ionic bonding, it is often mentioned that ions formed due to electron transfer are held together by electrostatic attraction between them. But

while discussing covalent bonding, no mention is made of what constitutes the covalent bond and that the covalent bond is electrostatic in nature. 19.5% students believed that energy is gained during bond formation and is favourable for stability. An alarming 27% of students believed that an ionic compound is formed by sharing of electrons. This may be due to lesser emphasis given on electro static nature of ionic bond. A shocking high number of students (**59%**) held the misconception that network solids / macro molecules like SiC has a high melting point and high boiling point due to presence of inter molecular forces in it. It was revealed in the interview that they believe so, as they felt that phase change happens only due to breaking of weak intermolecular forces. They did not understand the nature of continuous lattices and the forces in such lattices. 16.5% of students believed that the repulsion between non-bonding electron pairs is the only factor affecting the shape of a molecule. It may be due to lack of proper explanation about VSEPR theory. 23.5 % students were confused about the shape of methane molecule. He revealed that he had never seen a 3-D model or animation of the molecule. 24% students believed that a metal and a non-metal always form a 100% ionic bond, irrespective of the electro negativity difference. This happens due to lack of understanding of polarity and the concept of Electronegativity. 35% students held the misconception that strong intermolecular forces are responsible for relatively inert nature of Nitrogen gas. There were misconceptions regarding what happens when a substance changes state and when it decomposes. There is often confusion of several issues related to Inter and intra molecular forces. This appears to be founded in a lack of understanding that more than one kind of "force", or interaction can be occurring in one substance at the same time [(26)]. Furthermore, there is a lack of appreciation of the related magnitude of the forces within substances. Students appear to have difficulty in calibrating their thinking with regard to energy and forces. Linguistic issues also cause students to reverse the term they seem to relate 'inter' with 'internal' which results in misconceptions as revealed in an interview. 43% students did not appreciate the fact that ionic bond in, NaCl is broken on dissolving in water. They believed that the forces between sodium and chloride ions are too strong to be broken. Thus, various factors contribute to development of misconceptions and learning barriers in the understanding of chemical bonding e.g. Abstract concepts, inherent nature of the subject, Cognitive development stage, mathematical ability, analogical models mistaken for reality, anthropomorphic language used by teachers and textbooks, overload of information, Octet rule framework, Teachers' misconceptions, lack of laboratory work, symbolic and representational nature of chemistry, lack of interest in the subject, common words used in chemistry and in everyday life, incorrect representations / drawings by teacher / instructor or textbooks. There may be many more reasons but these are the most prominent ones identified by our research.

9- CONCLUSIONS

The following conclusions may be drawn from the study:

1. Students carry misconceptions and learning barriers with reference to understanding of chemical bonding.
2. Misconceptions maybe cured to a significant extent by implementing appropriate remedial measures.
3. The use of conceptual change text method and analogy method is effective in preventing and curing students' misconceptions.
4. Students' misconceptions may be identified with the use of an effective diagnostic test.
5. The sources of misconceptions and learning barriers may be identified through clinical interviews.
6. Misconceptions hamper further learning of the subject in the right way.
7. Some misconceptions are highly resistant to change.
8. Development of Misconceptions maybe prevented to a large extent by applying constructivist approach to teaching along with immediate testing, reinforcement and feedback.

10- REFERENCES

[1] Fisher,K.M., (1985), A misconception in biology: Amino Acids and Translations.

Journal of Research in Science Teaching, 22, 53-62.
[2] Chambers, S. K. and Andre, T. (1997). Gender, prior knowledge, interest, and experience in electricity and conceptual change text manipulations in learning about direct current. Journal of Research in Science Teaching, 34(2), 107-123.
[3] Novak, J. D. (1988). Learning science and the science of learning. Studies in Science Education, 15, 77-101.
[4] Osborne, R. J. (1983). Towards modifying children's ideas about electric current, Research in Science and Technological Education, 1, 73-82.
[5] Driver, R. and Easly, J. (1978). Pupil and paradigms: A review of the literature related to concept development in adolescent science students. Studies in Science Education, 5, 61-84.
[6] Griffiths, A. K, and Grant, B.A.C. (1985). High school students' understanding of food webs: Identification of a learning hierarchy and related misconceptions. Journal of Research in Science Teaching, 22, 421-436.
[6] Taber,K.S., (2000), Finding the optimum level of simplification: The case of Teaching about Heat & Temperature. Physics Education, 35(5), 320-325.
[7] Science Education, 23(7), 691-706.
[8] Coll, R. K. and Taylor, N. (2001). Alternative conceptions of chemical bonding held by upper secondary and tertiary students. Research in science and technological education, 19(2) 171-191.
[9] Boo, K. H. (1998). Students' understanding of chemical bond and the energetic of chemical reactions. Journal of Research in Science Teaching, 35(5), 569-581.
[10] De Posada, J. M. (1999). The presentation of metallic bonding in high school science textbooks during three decades: science educational reforms and substantive changes of tendencies. Science Education, 83, 423-447.
[11] Taber, K.S., & Watts, M., International Journal of Science Education, 18 (1996) 557.
[12] Piaget,J., (1950). The Psychology of Intelligence. New York: Harcout, Brace.
[13] Posner, G.J., Strike, K. A., Hewson, P. W. and Gertzog, W. A. (1982). Accomadation of a scientific conception: toward theory of conceptual change. Science Education, 66(2), 11-227.
[14] Hynd, C. R., McWhorter, J. Y., Phares, V. L. and Suttles, C. W. (1994). The role of instructional variables in conceptual change in high school physics topics. Journal of Research in Science Teaching, 31(9), 933-946.
[15] Glynn,S.M., (1997) Learning from Science Text: Role of an elaborate analogy. College Park, MD – National Reading Research Centre.
[16] Glynn,S.M., & Takahashi,T., Journal of Research in Science Teaching, 35 (1998) 1129.
[17] Tan, K. D. and Treagust, D. F. (1999). Evaluating students' understanding of chemical bonding. School Science Review, 81(294), 75-83.
[18] Uzuntiryaki,E., (2003) http://etd.lib.metu.edu.tr/upload/3/692046/index.pdf
[19] Pabuccu,A., (2006) http://etd.lib.metu.edu.tr/upload/3/12605121/index.pdf
[20] Asthana,B., (2012) Measurement and Evaluation in Psychology & Education, Agrawal Publications,Agra. pp 210.
[21]Miller,G.,http://apcentral.collegeboard.com/apc/members/courses/teachers_corner/47526.html

Fig. 1

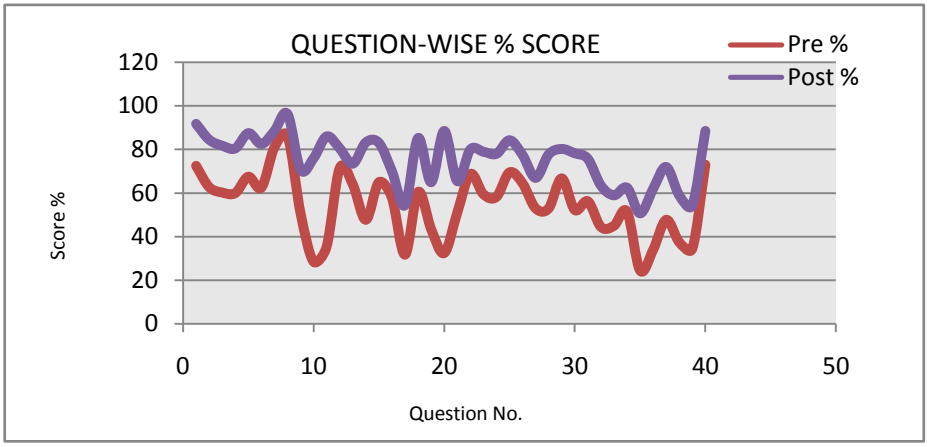
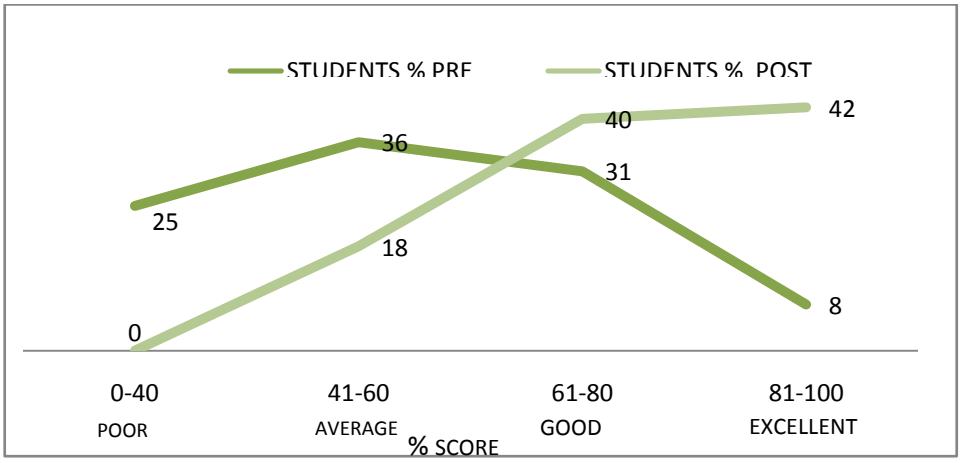


Fig.2

Concept No.	SED	D	CR(t)
1	0.1362	0.385	2.8273
2	0.18	0.865	4.808
3	0.259	1.36	5.2519
4	0.365	4.245	11.627
5	0.228	2.5	10.958
6	0.346	2.63	7.5982
7	0.27	1.84	6.8037
8	0.246	2.22	9.0304
9	0.174	0.71	4.0737

Fig.3



Highlights:

- Students have misconceptions regarding chemical bonding.
- Conceptual change text method is effective in remediating misconceptions.
- Analogy method is effective in arousing students' interest and curing misconceptions.
- The level of understanding chemical bonding concepts is independent of the gender.
- Clinical interview is a useful diagnostic tool to ascertain the sources of misconceptions to an appreciable extent.