Students' Learning Difficulties on Covalent Bonding and Structure Concepts

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Introduction

Covalent Bonding and Structure concepts are considered difficult among Chemistry concepts because they involve the interaction of atoms and molecules at the microscopic level. This article will briefly illustrate a process to discover students' understanding and misconceptions and then identify their learning difficulties in this area.

A Practical Way to Diagnose Students' Understanding

It is commonly agreed that diagnosing students' understanding and misconceptions is a very time-consuming process. One way to tackle this problem is to use two-tier multiple choice questions which require students to select both the correct answer and its reason. Figure 1 shows an example of this kind of multiple choice questions used to assess students' understanding of the shape of a molecule.

The molecule SCl_2 is likely to be

(1) V-shaped (2) linear

Reason:

(A) Repulsion between the bonding and non-bonding electron pairs results in the shape.

(B) Repulsion between the non-bonding electron pairs results in the shape.

(C) The two sulfur-chlorine bonds are equally repelled to linear positions as SCl_2 has an electron dot structure shown as

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  ..   ..   ..
: Cl : S : Cl :
  ..   ..   ..
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(D) The high electronegativity of chlorine compared with sulfur is the major factor influencing the shape of the molecule.

(E) ______________________________

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Figure 1

An Example of Two-Tier Multiple Choice Questions

The above is one of the questions in the "Covalent Bonding and Structure" diagnostic test developed by Peterson and Treagust [1988. 1989(a) and (b)]. The fifth option (E) for the second tier of each item (i.e. the reason part) does not appear in the original test. We make this slight modification because this can provide a channel for the students to express themselves, if they do not agree with the reasons given. In this way, any misconceptions that the students may have and which have not been identified already, can be diagnosed.

Such a diagnostic test has been validated (Peterson, Treagust and Garnett, 1989a) and proved to be useful for Chemistry teachers in Australia (Peterson and Treagust, 1988).

Of course, for researchers to derive a valid diagnostic test, proper construction and testing procedures have to be followed. However, classroom teachers can adopt a simplified approach for setting such a test. Through interaction with students in daily classroom teaching situations, a teacher can make a record on those misconceptions students have about certain concepts. Then exchange of such records with other teachers can take place either in interschool or intraschool situations. These records of misconceptions will then be converted into the reason part of the test questions. Through such practice, at the school level, a teacher can set up a reasonably good test instrument for finding out students' understanding of certain Chemistry concepts.

What are the Learning Difficulties?

We have administered the two-tier diagnostic test instrument on Covalent Bonding and Structure as mentioned to a total of 478 Grade 12 students from seven different coeducational junior colleges.

Table 1

Summary of Results of the Two-Tler Multiple-Choice Test

Categories	Question No.	Correct Responses (%)	Main Misconceptions
1. Octet Rule	10	72.4	(a) Number of bonds formed equals the number of electrons in the outer-shell.
	15	39.7	(b) Nitrogen atoms can share 5 electron pairs in bonding.
2. Bond Polarity	14	75.9	(a) The number of valence electrons on sulphur and chlorine determines the polarity of the bonds.
	3	72.2	(b) Non-bonding electrons on each atom determine the polarity of the bond.
	1	59.4	(c) Equal sharing of the electron pairs occurs in all covalent bonds.
3. Shape of Molecules	13	85.1	(a) The shape of molecule is due to the repulsion between the atoms in the molecule.
	2	55.0	(b) The shape of molecules is due only to the repulsion between the bonding electron pairs.
	5	54.4	(c) The shape of molecules is due only to the repulsion between the non-bonding electron pairs.
	8	43.1	(d) Bond polarity determines the shape of a molecule.

Categories	Question No.	Correct Responses (%)	Main Misconceptions
4. Polarity of molecules	9	57.3	(a) The molecule is non-polar because there is very little difference between the electronegativity values of the two atoms involved
	6	39.2	(b) The polarity of the molecule due to the high electronegativity of an atom.
5. Inter-molecular Forces	12	52.1	(a) Intermolecular forces are due to the difference in polarity of the molecules.
	7	45.2	(b) Intermolecular forces are the forces within a molecule.
	11	42.5	(c) Intermolecular forces are the bonds within the molecules of a substance.
	4	**33.3**	(d) Strong intermolecular forces exist in a continuous covalent (network) solid.

Some Observations:

(1) Within the same category, there exists different levels of difficulty. Those questions which focus more on application of the concepts seem to cause more problems. Among the categories, it appears that the difficulty level increases from bond polarity to shape of molecules, then to polarity of molecules and finally to intermolecular forces. In terms of the concept formation, such order is reasonable, understandable and acceptable.

(2) Our students are better equipped with the concepts of polarity of a single bond and the Valence Shell Electron Pair Repulsion (VSEPR) Theory than with those of polarity of molecules, and the applications of the VSEPR Theory to predict the shape of molecules which may involve non-bonding electron pairs.

(3) Our students seem to know well some important rules such as Octet Rule and VSEPR Theory. They are able to apply these rules rigidly to solve familiar problems as reflected by the responses to the questions 15 and 13.

(4) From the nature of certain misconceptions in some of the categories, for example category 2 and category 3, the main learning difficulty appears to be that students have only partial understanding of the respective concepts. Here they fail to recognise some of the attributes of the concepts. The misconceptions shown in Table 1 on bond polarity and shape of molecules belong respectively to this type.

(5) The misconception under category 3(d) shows that students are confused with the cause-effect relationship. It is very surprising that a high percentage of the students believed that bond polarity determines the shape of a molecule.

(6) The most difficult concept here is probably that of intermolecular forces. Students seem to confuse the intermolecular forces with intramolecular forces. On average about 40% of our students believe that intermolecular forces are the forces within a molecule and they are strong in a continuous covalent (network) solid. This is reflected in Table 1 Category 5.

All the above-mentioned observations appear to be obvious to the experienced chemistry teachers, even without presenting them the collected data such as Table 1. What could it mean? The message here is clear that, as Chemistry teachers, the year in and year out normal instruction has to be looked at critically, if such misconceptions are to be eradicated.

One way to tackle such a problem is to focus teaching on the propositional knowledge statements which provide both the teacher and the students with a more precise description of the concept understanding to be acquired from a topic such as covalent bonding and structure. And the use of the models will help students to view the nature and properties of covalent bonding and structure from the macroscopic level and hence to have a better understanding of the cause-effect relationship.

Furthermore, we should also ask whether the following changes do take place during the instruction:

* Do we incorporate the students' misconceptions into the teaching process?

* Do we explicitly teach students how to apply the concepts taught?

* Do we provide sufficient opportunities for students to practise?

However, just implementing the above changes in instruction cannot resolve all the problems on learning difficulties as well as misconceptions. Some other problems which occurred during the instruction should not be overlooked; for example:

(1) Gaps appear in the instruction, such as different versions of the same concept. The VSEPR Theory seems to be well received by students, but not its application. Why? This is mainly because there are two versions when we consider the shape of a molecule. One is the "electron-pair geometry" (or geometrical distribution of electron pairs) of a molecule which takes both lone-paired and bond-paired electrons into consideration. Another is the "molecular geometry" (or molecular shape) which ignores the position(s) occupied by the lone-paired electrons. This type of inconsistency may cause confusion and information overload for students. Should we simplify or unify the application of the VSEPR Theory?

(2) Language difficulty in instruction (for example, the two types offorces, "intermolecularforces" and "intramolecularforces")

seems to cause some problems for students. The primary confusion arises from the terms "inter" and "intra". In order to tackle this problem, it seems better to replace them by the vocabulary which shows more direct meaning of the terms, e.g. "within the molecules" and "among the molecules".

These are some of the practical ways of reducing students' learning difficulties and misconceptions in the area of covalent bonding and structure.

Conclusion

The two-tier multiple choice test used in our study serves well to diagnose students' learning difficulty/misconceptions in science in the classroom teaching situations. Hence administering such diagnostic test, as part of instruction, should be further encouraged. Regarding the ways to reduce students' learning difficulties/misconceptions, examining carefully every detail in instruction is likely to ensure the success of their implementation.

References

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