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Students Understanding about Learning the Concept of Solution

Ahmed Sher Awan*
Muhammad Zafar Iqbal**
Tariq Mahmood Khan*
Tahseen Mahmood*

Abstract

It is to discourage the traditional methodology and implement constructivist approach but the curriculum planners and educationists do not have proper data to assess the limitations of traditional approach in understanding the basic concepts of chemistry. To solve this problem, a sample of 120 students both male and female of 10^{th} class was randomly selected that has learnt chemistry for two years through traditional text book approach. This research study aims to evaluate students understanding about the concept of the solutions. Seven instances or non-instances were used to probe students understanding of each subject. To determine the reliability of the instrument (IAI), Inter-rater reliability Cohan Kappa cross tab statistics was used. Content validity of the instrument was established through experts' judgemental procedures. Overall high proportion of alternative conceptions in girls and boys at secondary level depicted the main cause for not understanding the concept of solutions. Further, categorical analysis revealed five categories of alternative ideas in which many misconceptions were found. However many misunderstandings were found in two main categories such as self-centered or human-centered views and incorrect use of scientific terms. There were found three other categories of alternative ideas but comparatively less in numbers. Thus, this study will guide to change the students misconceptions through more cooperative and inquiry methods under the umbrella of constructivist approach of teaching and learning chemistry at secondary and higher secondary level.

Key Words: Learning, traditional approach, alternative conceptions, students understanding, solution, Interview about instances, (IAI)

*Assistant Professor, Institute of Education and Research, University of the Punjab Lahore
** Professor, University of Management and Technology Lahore

Introduction

It has been proved that understandings require the careful integration of new input with a potentially vast amount of prior knowledge which is common tenet between *constructivism* and *cognitive* psychology. Similarly, deep understandings are indicators of conceptual change and the main agenda of constructivism but promoting conceptual change is easy neither for the teacher nor for the learner (Feden & Vogel, 2003). All the curriculum reforms and teachers training at elementary and secondary level aim to emphasise the importance of students understanding in learning science. For this purpose it is to discourage the traditional methodology and implement constructivist approach but the curriculum planners and educationists do not have supportive data to assess the limitations of traditional approach in understanding the basic concepts of chemistry. Understanding is all about making mental connections between facts, concepts, ideas and procedures. In science, these connections establish relationship between ideas, situations and events and in science lesson there is the need to understand words, like bond & valency and substance (Newton, 2005). Thus, in this research study, the concept such as, 'solution' is selected to explore the mental connection of students' ideas to judge the level of understanding in learning chemistry.

The concept of solution is very important in understanding chemistry. As almost all the processes of chemical changes as well as chemical bonding takes place within solutions as a result of which the composition of matter is determined through different states of matter. We study that why certain substances dissolve in certain solvents and not in others? For instance, motor oil will not dissolve in water but dissolves in gasoline. Similarly sugar dissolves in water but insoluble in gasoline. Traditional teaching approaches just content to transfer of information from teachers or books to the learners and do not provide such an inquiry atmosphere where students may discover these concepts in a meaningful way to construct knowledge for themselves. (McMurry & Fay, 2006).

A brief summary given by Medin, Ross & Markman (2005) that understanding consists of integrating presented information with previously acquired knowledge to construct a unified representation. They have described three important points about understanding or comprehension as follows:

1. Meaning is a function of both the input and activated knowledge i.e. meaning is not simply the words in the sentences but also the knowledge that you bring to bear to understand these sentences.

2. Comprehension is an active, not passive process. Meaning does not come through some passive assimilation of the meaning of the sentences because the meaning of the sentences is partly in the reader. Therefore, understanding is not simply a matter of decoding but rather actively supplementing the input into knowledge.
3. Understanding consists of constructing an integrated representation i.e. to understand something requires fitting it into some integrated representation. Thus we understand something when we are able to figure out how all this information fits together to make sense

Alternative conceptions in chemistry are very widespread and not just among weak or lazy students. The literature reports a wide range of areas where pupils commonly misconceive the chemistry they are taught.

1. **Atoms burn:** Children often assume that our particles (atoms) are bits of ordinary matter that melts, boil, burn, and expand (Ross, 2010). But our particles are different and very strange. As they remain as such; that is 'matter is conserved at an atomic level' (except in radioactive processes).
2. **Half-way Liquids:** Many students (and texts) show the arrangement of liquids as being 'half-way' between a solid and a gas. But liquids are virtually incompressible and have densities similar to solids. The particles must therefore still be in contact, but now randomly distributed and able to slide or past each other.
3. **Fast Gases:** Many students (and textbooks0 assume that particles (molecule) of a gas must be moving with more energy than those of a liquid or solid. But it is only true if the gas is at a higher temperature than the solid or liquid.
4. **Dissolving:** Many children will describe dissolving in terms of the disappearance of the solute, e.g. when sugar is added to water the sugar disappears or it evaporates. As secondary level, the most common explanation for sugar dissolving in water is that the sugar has become liquefied i.e. it has melted. Many students believe dissolving and melting or 'break' are similar.
5. **Change:** Many students could identify melting in water and understood the change from solid to liquid with water, they were not able to generalize this into other substances that change from solid to liquid.
6. **Melting** is believed to always involve water e.g. when meting paraffin wax, water is formed, when melting butter, water (or a similar substance) is formed.(Solsona, 2003 &Sirhan. 2007).

Therefore, keeping in view the above mentioned misconceptions, the main objective of the study is to explore students' understanding about the concept of solutions at secondary level and to assess the gender differences in reasoning about different instances and non-instances

Methodology

To probe the students understanding, a sample of 120 male and female was randomly selected. The selected students of class 10^{th} had studied these concepts during their academic session for two years. Therefore, it was assumed that all the students had proper understanding of those concepts.

Development of Research Instrument

As a research instrument, IAI (Interview about Instances) seven instances were developed to explore student misconceptions about the concept solutions in chemistry. The Interview About Instances (IAI) approach was used in this research which was earlier developed by Osborne and Gilbert (1980). This method of exploring students understanding and revealing the current concept of students can be traced back to the clinical interviews developed by Piaget in 1920's and 1930's. It is based on the idea that a particular concept held by a person can be explored by asking the person to distinguish between instances and non-instances of the scientifically accepted concept and by asking them to give reasoning behind their action. Therefore for this research seven instances / non-instances were developed to probe students' misconceptions for the concept of solution at secondary level. These instances are given below.

(i)	White of an egg (non-instance)	(ii)	NaCl in water
(iii)	Steel spoon	(iv)	Soda water
(v)	IM alcohol in water	(vi)	Oil in water (non-instance)
(viii)	Air		

The following three general questions were asked during interview about each instance under this concept.

(i) What does this diagram/instance explain?

(ii) Is it a type of chemical bond?

(iii) Why do you think so?

Reliability of the Instrument

Reliability of the instrument IAI and IAE was determined. Female and male students understanding were assessed with both research instruments. Cohen Kappa was used to identify the inter-rater reliability of the instrument. There were six categories of students ideas identified separately for male and female for the four concepts of chemistry in which five categories were about the alternative ideas and one category was about the scientific responses. SPSS output has been given in the following table:

Table 1 - Inter-rater reliability of the instrument (IAI)

		Value	SE(a)	T(b)	Sig.
Measure of Agreement	Kappa	.823	.019	39.06	.000
N of Valid Cases		520			

a Not assuming the null hypothesis. b Using the asymptotic standard error assuming the null hypothesis.

It is indicated in the above table that kappa T(b) 39.06, p<.05 level of significance. The reliability of the instrument, Interview about instance /events is determined.

Validity of the Instruments

In the light of IAI instrument which was developed by Osborne & Gilbert (1980), seven instance were developed about the concept with open-ended questions which were related to the local curriculum of chemistry. Its content validity was established with the consultation of the experts having Doctoral/M.Phil degree in chemistry as well as master degree in Science Education and related experience. Three experts have established the content validity of the instrument.

Data Analysis

A specially designed paper-sheet for transcription of summary of the responses of the subjects of study was prepared by synthesizing into a coherent description for each instance of this concept to each subject. A simple formula "one instance = one response = one frequency" (and one score) was devised keeping in view the nature of data. This sheet had four columns; (i) name of instance, (ii) knowledge level responses, (iii) reasoning level responses, and (iv) name of category - this part was assigned for writing the expected category after reading the responses. A sample for one instance is given as follows:

Concept: Solutions

Name of the Instance (I)	Knowledge Responses (II)	Reasoning Responses (III)	Name of Category (IV)
White of an Egg			

All the alternative ideas identified about all instances of this concept were classified into five categories which have been mentioned as follows: (i) Incorrect use of scientific term (ii) Self-contradictory views (iii) Self-centered/human-centered view (iv) No scientific term but correct explanation (v) Correct use of scientific term but in correct explanation. The above mentioned five categories have been deduced through in-depth observation study analysis of the subjects responses and review of the previous studies such as, Novak & Gowin (1986; Osborne & Freyberg (1985); Driver (1989); Brown (1993); ZafarIqbal (2003).The frequencies of alternative ideas of each instance were tallied and then presented in tabular form. The total frequencies of each instance with respect to different categories of this concept are given along with the average percentage in tables . All the data presented in tables in the form of frequency and percentage and chi square test was used to determine the association between scientific responses and alternative conceptions to judge the level of students understanding. The core response about one instance was evaluated and assigned into either one of five categories of alternative conceptions or sixth category of correct scientific response. In this way, for the group of sixty boys, only 28 responses about seven instances/non-instance of students were scientific whereas the remaining 392 responses were coded as alternative conceptions and classified into their respective five categories of alternative conceptions in the following way.

Table 1: Comparison between alternative conceptions & scientific responses of class 10 students

Concept	Alternative conceptions	Scientific responses	χ^2
Solutions	770 (91.67%)	70 (8.33%)	583.33***

*** $P < 0.001$

Above table shows that majority of the students of class 10 hold alternative conceptions with total frequencies 770 (91.67%) of the selected concept solution as compared to scientific responses of total frequencies 70 (8.33%) only.

The results of the concept solutions χ^2(df=1, N=840)=583.333, p=0.000 shows that they are not equally distributed. This provides evidence that majority of students at secondary level hold many alternative conceptions as compared to scientific responses.

Table 2: Gender Comparison between Alternative Conceptions and Scientific Response of Class 10 students

Name of Concept		Alternative Conceptions		Scientific Response		
		Boys	Girls	Boys	Girls	χ^2
Solutions	f	392	378	28	42	3.05
	%	93.33	90	6.67	10	

There is big difference between alternative conceptions and scientific responses of class 10. But, there is no gender difference in students understanding. χ^2 test was conducted to find out association between gender and obtained responses (alternative conceptions & Scientific response) of the concept solutions χ^2 (df=1, N=840)=3.055, p=0.081 shows that there is no association between gender and selected concepts of the concept solutions.

Table 3 - Gender Comparison of Five Categories on Alternative conceptions of class 10

Concept	Incorrect use of scientific term		Self-contradictory views		Self-centered/ human centered view		No scientific term but correct explanation		Scientific term but incorrect explanation		
	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	χ^2
Solutions	93	102	24	36	160	143	-	2	115	95	7.42

Overall similar trend of alternative conceptions can be observed in class 10 of both boys and girls in each category which indicate some common patterns in students understanding. However, above tables shows, higher frequencies of alternative conception is found in category-3 self-centered/human centered view for boys and girls and then category 5 (scientific terms but incorrect explanation) and then in category-1 (Incorrect use of scientific terms) for boys and girls almost equally. Self-contradictory views are also prominent.

However, χ^2 test was conducted to find association between gender and five categories of alternative conceptions(Incorrect use of scientific term, Self-contradictory views, Self-centered/ human centered view, No scientific term but correct explanation & Scientific term but incorrect explanation) of , the results of χ^2test on solutions of χ^2 (df=4, N=770)=7.422, p=0.115. show that there is no significant association between gender and categories of alternative conception about the concept solutions. It is notable that distribution of huge numbers of alternative conceptions into only five categories clearly shows ‘five alternative frameworks’ or ways of alternative reasoning among both boys and girls.

Table 4: Categorical analysis of alternative conceptions of class 10 students

Concept	Incorrect use of scientific term	Self-contradictory views	Self-centered/ human centered view	No scientific term but correct explanation	Scientific term but incorrect explanation	χ^2
Solutions	195	60	303	2	210	382.84***

*** P < 0.001

Chi-square was conducted to find out the difference in frequencies of alternative conceptions in five categories (Incorrect use of scientific term, Self-contradictory views, Self-centered/ human centered view, No scientific term but correct explanation& Scientific term but incorrect explanation) the results of chi square shows that there is no significant difference between these categories. The results of chi-square on solution is χ^2 (df=4, N=770)=382.844, p=0.000. These results supports the above discussion. Therefore, it is concluded that there were found five different alternative frameworks or ways of alternative reasoning because all alternative conceptions are not equally distributed in all these five categories which means five alternative frameworks do not guarantees the equal distribution of alternative conceptions in all categories.

Conclusion

On the basis of research findings, it can be concluded that majority of science students at secondary level hold alternative conceptions in selected concept areas of chemistry such as solutions. A comparison of students understanding indicates higher frequencies of alternative conceptions and lower frequencies of scientific responses in the subjects

1. In the non-instance of solution 'oil in water' was mostly termed as 'chemical solution'. The reasons were given such as, non-polar oil, chemical bondings, non-aqueous solution or unsaturated solutions. However, almost 18% subjects correctly replied that it was not a solution.
2. A large majority of subjects hold views that air was not kind of solutions but a mixture of gases and liquid was essential for making solutions.
3. Similarly, steel spoon was not recognized as kind of solutions due to its 'solid' nature by majority of the subjects. The main reason was the lack of its liquidness.
4. For the event 'NaCl in water,' many subjects termed it as saturated or supersaturated solution, salty solution, a mixture, polar solution etc. Its

solubility increases by rising temperature. Chemical reaction of NaCl with H_2O was producing acids and bases and oxidation occurred.

5. Mostly it was viewed that one mole of alcohol in water was a saturated solution/a mixture/ a chemical solution/with ionic bonding/ polar with non-polar solution etc. but could not use the correct term (a molar solution). Some subjects replied that it was solution because both components were liquids which were mixed through a chemical process.
6. In the event/instance Soda Water was viewed as a soft drink formed due to chemical reaction of CO_2 and water. It was not a solution in their views but just a liquid and its solubility increases by increasing temperature.

Discussion

The data obtained through exploration of student understanding in the present study about the concept solution in the subject of chemistry at secondary level give strong evidence about the existence of high frequency of alternative conceptions and as compared to low frequency of scientific responses. Previous research studies demonstrate that students have considerable difficulties in understanding the sub micro level (such as electron, ions and molecules) and symbolic level (mole, atomic mass) of chemical concepts (Bunce& Gabel, 2002), Juriosevic, Glazar, Pucko&Devetak, 2008). The present research study also agrees that subjects have similar misconceptions. For instance, ‘distilled water is not a pure matter but a mixture’. Similarly, ‘carbon dioxide gas is not a compound but mixture of some gases’. Thus, it is not surprising if secondary school students hold more than 90% alternative conceptions about this concept. The ACER report given by Adam, Doig& Rosier (1991) as cited in Skamp (2005) ‘when students were to explain how heat melts ice into water, 52% of the students gave uninterruptable responses’. Therefore, in this context some common ideas expressed by the subjects such as ‘air is not a matter,’ or ‘air is not a solution because it cannot be seen’ or solid things such as steel, spoons, cannot be called a solution because solid things are not solution. Similarly, many other common beliefs among such subjects were found. For instance, they hold a view that only ‘liquid’ substances can be called ‘solutions.’ Skamp (2005) cited ACER report by Adam, Doig & Rosier (1991) ‘when students were to explain how heat melts ice into water, 52% of the students gave uninterpretable responses’. Therefore, in this context some common ideas expressed by the subjects such as ‘air is not a matter,’ or ‘air is not a solution because it cannot be seen’ or solid things such as steel, spoons, cannot be called a solution because solid things are not solution. Similarly, many other common beliefs among such subjects were found. For instance, they hold a view that only ‘liquid’ substances can be called ‘solutions.’ Since, there were many such views which were not only far from scientific concepts but also had diversified opinions about the similar instances of chemistry concepts.

Such arguments can be traced in the review of literature about gender comparison in view of students understandings in which some authors favor male over female in physical sciences (Ann, 2003) and some authors like Cole (1997) noted that open-ended tests don't consistently show differences favouring males. Similarly, according to Osborne & Dillon (2010), the most significant factor influencing attitudes towards science and subject choice is 'gender'. Another research confirms the enduring low participation of girls in the study of physical sciences. Its reason pointed out by Thomas (1986) cited by Osborne & Dillon (2010) is that it is a consequence of cultural socialization which offers girls considerably less opportunity to tinker with new technologies. Kahle& Lakes (1983) contends that there is a gap between young girls desire to observe common scientific phenomena and their opportunities to do so. This leads to lack of experiences in science which ultimately leads to lack of understanding of science. However, such data are contradicted by more recent findings that there is no difference between girls and boys ability(Haworth et al, 2008).The present research study supports the later result and shows that girls are equally well or sometimes even doing better than boys in chemistry at secondary level. Table 4 clearly indicates that overall boys and girls in both control and experimental groups have equal frequencies of alternative conceptions or scientific responses. However, the performance of girls and boys does differ in the domain of reasoning. For instance, qualitative analysis of alternative conceptions indicated that girls were more self-centered as well as more bold to over generalize their statements as compared to boys. This is also evident in the categorical analysis where the alternative conceptions in all the five categories were not equally distributed and show gender difference in alternative ways of reasoning or thinking.

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