

## **Gender Disparity in Misconceptions about the Concept of Solution at Secondary Level Students in Pakistan**

**Ahmed Sher Awan\***  
**Tariq Mahmood Khan\***  
**Tahseen Mahmood Aslam\***

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### **Abstract**

The major objective of this research study is to look into gender disparity in misconception of science students in learning concept about solution at secondary level in Pakistan. An equal sample of 60 male and 60 female students of 10<sup>th</sup> class were included in randomly selected sample that has learnt chemistry for two years through traditional text book approach. Seven instances or non-instances were used to explore misconceptions of each subject. To determine the reliability of the instrument (IAI), Inter-rater reliability Cohen Kappa cross tab statistics was used. Content validity of the instrument was established through experts' judgemental procedures. Overall high proportion of gender misconceptions in girls and boys at secondary level pointed out a big problem for science educationalist. Further, categorical analysis revealed five categories of misconceptions. In which many alternative ideas 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. It is notable that their ideas were not improved despite teaching for two years through traditional textbook approach. Thus, this study will guide to create awareness of the misconceptions into scientific conceptions in learning chemistry at secondary and higher secondary level.

**Key Words:** Gender disparity, Learning, Misconception, Instances, Non-instances, Inter-rater reliability, Content validity, Alternative ideas.

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### **Introduction**

Gender differences are found in students' emotions and behaviour, physical performance, technology use, cognitive abilities and achievement. The differential

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

treatment of boys and girls at home and in the classroom can have a strong impact on students' gender role, identity, academic development and specifically learning of chemistry. Therefore, in Pakistan, the curriculum reforms and teachers training at elementary and secondary level has been launched to discourage the traditional methodology. But the main problem is implementation due to non-availability of trained man power to cater the students' misconceptions in teaching of chemistry. Similarly, gender disparity is prominent in teaching and learning of science concepts. Moreno (2010) stated that learning differences between males and females are useful to consider whether the gender differences found in education originate in biological/nature differences or social/nurture influences. But in the teacher centered instruction, the teacher may have gender, cultural or other biases that will delimit learning of chemistry for some students. For instance, if the teacher unconsciously believes that boys are better suited for learning chemistry than girls, he may call on boys often to answer a question or to assist in a demonstration. This behaviour reinforces the cultural disadvantage girls have in the learning of chemistry (Peters & Gega, 2002).

The word '**gender**' refers to traits and behaviours that a particular culture believes to be appropriate for men and women, and the word '**sex**' refers to the biological differences of men and women. Sex differences are almost immediately obvious and controlled by nature whereas, gender differences are psychologically and socially controlled differences related to how individuals express their biological sex in their behaviour. Sex hormones affect the development of gender differences in the brain (Bronstein, 2006). Males and females are mostly indistinguishable in their brain anatomy with only few exceptions. However, all cultures have gender-specific roles and treat males and females differently in many respect; so different societies display quite different gender roles. Additional support comes from a sociocognitive theory of gender, which emphasize on the role that observation, imitation, rewards and punishment play in children's development. For instance many parents encourage different activities, traits, and toys for boys and girls (Bronstein, 2006).

Although boys are more likely to have self-confidence in their ability to control the world and solve problems; but teachers may show girls that they have just as much potential for learning chemistry, physics and mathematics as boys do. Because research indicates that boys tend to attribute their success to an enduring ability (e.g. they are smart or naturally athletic and their failures to a lack of effort (they didn't try hard enough). In contrast, girls attribute their success to effort and their failure to a lack of ability. Therefore, to accommodate girls' more affiliative nature, provide opportunities for cooperative group work and frequent interaction with classmates. As girls demonstrate slightly higher verbal performance than boys,

which may compensate males dominance in physical activities. As teachers, we should hold equally high expectations for both boys and girls and make sure that both genders have equal educational opportunities (Wigfield, Eccles, Schiefele, Roser, & Devis-Keen, 2006). Therefore, all these issues of gender differences have much impact in teaching/learning of chemistry.

Sirhan (2007) stated that Chemistry by its very nature, is highly conceptual while much can be acquired by rote learning in a non-meaningful way. Although students show some evidence of learning and understanding in examination papers, researchers find evidence of alternative conceptions and abuses of rote learning and of certain areas of basic chemistry which are not understood even at degree level.

Students' alternative conception is a universal phenomenon and research in science education has identified a vast catalogue of such beliefs held by students which are at odds with orthodox science (Novak, 1978; Zafar Iqbal, 2003; Taber, 2000). Thus, it is not only imperative to uncover the students' alternative conceptions of chemistry at secondary level but the change of their views, is the main challenge for science educators. It is clear that without assessing the gravity of this task, the process of conceptual change cannot become successful. It is the need of the time to adopt and devise an effective methodology of teaching and learning which should have the potential to meet the challenge. In this situation, the constructivist approach of teaching and learning would be the most appropriate. This approach has received much attention by the science educators that is why its literature in all popular textbooks of science education and educational psychology has been exploded exponentially (Nasir & Iqbal, 2002). It seeks to explain the origins of students' alternative conceptions, and to use this information to guide more effective teaching. Constructivism is the belief that all knowledge is constructed in the minds of the learners, not passed on from the teacher to the students. Therefore, learning builds on the existing ideas in the students' mind (Peter & Gega, 2000; Ausubel, 1978).

## **Methodology**

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 in Pakistan.

Random selection of students of 10<sup>th</sup> class to explore the students' misconceptions was made from a represented equal sample of 60 male and 60 female students from four public high schools was randomly selected. The selected students of class 10<sup>th</sup> had studied this concept during their academic session for two years. Therefore, it was assumed that all the students had no problem in the understanding of this concept.

### **Development of Research Instrument**

As a research instrument, IAI (Interview about Instances) seven instances were developed to explore students' misconceptions about the concept solutions in chemistry. These instances are given below.

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

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.

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 solution?
- (iii) Why do you think so?

### **Reliability of the Instrument**

Reliability of the instrument IAI and IAE was determined. Female and male students' understanding was 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 appendix C and its values are given in following table:

**Table 1 - Inter-rater reliability of the instrument**

	Value	SE(a)	SE(a)	SE(a)
Measure of AgreementKappa	.823	.019	.019	.019
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 research instrument which was developed by Osborne & Gilbert (1979), 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:	Composition of Matter	
Name of the Instance (I)	Knowledge Responses (II)	Reasoning Responses (III)	Name of Category (IV)
Air			

All the misconceptions identified about all instances of the concept solution 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); Zafar Iqbal (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 about misconceptions in tables in the form of frequency and percentage was interpreted through typical statements of the subjects about each instance.

Histograms and overall summary of misconceptions about this concept with the help of tables are also given.

### **Exploration of boys' sample**

#### **(i) Incorrect Use of Scientific Term**

The boys subjects of class 10 hold 93 frequencies of misconceptions in category-1. For example white of an egg is not a solution but a 'compound or element'. It is a concentrated liquid – insoluble in water, particles can be filtered (26). Oil in water mix to form 'solution.' There is some change in energy (10). Air is 'not a solution' but a unification of different gases. 'Liquid is essential for making solution' (6). Steel spoon is a metal formed by 'metallic bond'. Solvent is necessary for solution which is not the part of steel (12). NaCl in water is a concentrated solution, formed by solute and solvent. It is a good electrolyte, by increasing temperature, it gets dissolved easily (12). IM alcohol in water is a 'concentrated' solution or liquid type. There is no hydrogen bonding. It is not a good electrolyte (13). Soda water is a solution – unsaturated solution. It is a type of liquid (14).

In the above mentioned responses, mostly subjects considered incorrectly that only 'liquids' are solutions, whereas 'air' and 'solids' cannot be called solutions in any case. They under-generalized the term 'solution.'

#### **(ii) Self-Contradictory Views**

The boys subjects of class 10 hold 24 frequencies of misconceptions in category-2. For example 'white of an egg' is a colloidal solution and mixture but it's more like a 'compound'. Its particles cannot be filtered because it is a compound (10). Oil in water is apparently not soluble but actually it is a solution (9). Air is a mixture of gases...yes, it is a solution but, air is a mixture of gases. It is not a solution but some components like  $\text{CO}_2$  and  $\text{H}_2\text{O}$  are present in it (5). Since, subjects used the term 'compound or solution' but contradicted their views at the same time by another term.

**(iii) Self-centered/Human-centered Views**

The subjects of class 10 hold the highest frequencies of 160 misconceptions in this category-3. For example, white of an egg is a solution – a viscous solution. The colour of an egg is white due to white hens or naturally white as made by Almighty Allah (21). Both oil and water form separate layer because, oil is slippery and does not mix with water (4). Air is a mixture of gases, ‘not a solution’. Liquid is essential for making a solution (23). Steel spoon is solid, not a solution at all. It cannot be dissolved in anything. Solvent is essential and chemical bonding makes it stronger (38). NaCl in water is a salty solution. Energy absorbs because salts dissolve in water. It is not a good electrolyte (24). I Molar (IM) alcohol in water is also salty taste water, a solution which changes into ions. A strong ionization process occurs (20). Soda water is a solution of Pepsi Cola. Gas evolved when heated or added salt. No effect of pressure (20). Thus, all these self-centered views are superficial observations without deep understanding about the environment.

**(iv) No Scientific Term but Correct Explanation**

No statement by class 10 in this category.

**(v) Scientific Term but Incorrect Explanation**

The boys subjects of class 10 hold frequencies of 115 misconceptions in category-5. For example oil in water is not a solution. Energy is not changed but there is hydrogen bonding. Similarly oil and water have different chemical nature, so do not dissolve (33). Air is a solution – gas into gas. Liquid is essential for making solution. Pressure has no effect (8). Steel spoon is a solution solid into solid but solvent is essential for solution. There is carbon bonding in it (10). NaCl in water is solid into liquid solution. There is some chemical reaction between positive and negative ions. Temperature ‘effects’ its solubility (17). IM alcohol in water is a solution – liquid into liquid. Physical reaction occurs. This is not a good electrolyte (24). Soda water is a solution of water and carbon dioxide – liquid into gas.  $\text{CO}_2$  mixed with water through a chemical reaction and hydrogen bonding (23). So, the subjects used the scientific terms like, gas into gas solution or liquid into gas etc. but could not explain further, in a scientific way.

**Table 2 Exploring Students' misconception (Boys 10 Class) about Major Concept 'Solutions'(N = 60)**

Instances/ Events		White of an Egg	Oil in Water	Air	Steel Spoon	NaCl in Water	IM Alcohol in Water	Soda Water	Total Frequency & Average %
Incorrect use of scientific term	f	26	10	6	12	12	13	14	93
	%	43.33	16.67	10	20	20	21.67	23.33	22.14
Self-contradictory views	f	10	9	5	-	-	-	-	24
	%	16.67	15	8.33	-	-	-	-	5.71
Self-centered or human centered views	f	21	4	33	38	24	20	20	160
	%	35	6.66	55	63.34	40	33.34	33.34	38.09
No scientific term but correct explanation	f	-	-	-	-	-	-	-	-
	%	-	-	-	-	-	-	-	-
Scientific term but incorrect explanation	f	-	33	8	10	17	24	23	115
	%	-	63.33	13.34	16.66	28.34	40	38.34	27.38
Total alternative conceptions	f	57	56	52	60	53	57	57	392
	%	95	93.33	86.67	100	88.34	95	95	93.33
Total scientific responses	f	3	4	8	-	7	3	3	28
	%	5	6.66	13.33	-	11.66	5	5	6.67

### Exploration of girls sample

Sixty girls of class 10 of two public schools were selected and presented the same seven instances/non-instances of 'solution' which were used for boys with same sequence. The same criteria was applied for identification of alternative conceptions which was used for boys and 378 alternative conceptions were classified into five categories of alternative conceptions and 42 responses about seven instances were scientific in nature in the following way:

#### (i) Incorrect Use of Scientific Term

The subjects of class 10 hold 102 frequencies of misconceptions in this category-1. For example, white of an egg is 'heterogeneous solution', as there are undissolved chemicals which may be filtered (19). Oil in water is 'concentrated solution'. As, both are solution. Energy released due to heavy particles. Of course,



heavy particles are not fully dissolved (9). Air is concentrated solution of gases. Due to rise in temperature air absorbs heat and high pressure made air heavier (10). Steel spoon is 'heterogeneous solution' made up by iron and other metals through bondings(73). NaCl in water is 'heterogeneous solution' – a type of acid – base formation energy is released, good electrolyte (16). IM alcohol in water is an 'electrolytic colloidal solution'. Hydrogen bonding has no role in it (148). Soda water is a 'non-standardized molar solution'. High pressure increases solubility of  $\text{CO}_2$  (21). The girl subjects overemphasized the terms like, 'heterogeneous' solution, concentrated solution or electrolytic colloidal solution.

#### **(ii) Self-Contradictory Views**

The subjects of class 10 hold 36 misconceptions as self-contradictory view. For example, white of an egg is solution – 'super saturated'. Although, it is also called colloids (7). Oil in water is not a solution, but it's a type of solution. Water is a polar solvent. Hydrogen bonding has no role in this event (6). Air is 'concentrated solution' of gases. Due to rise in temperature, air absorbs heat and high pressure made air heavier (4). Steel spoon is not a solution. It is made up by two substances like iron and silver (Ag). It is a type of concentrated solution (7). Soda water is mixture of  $\text{CO}_2$  and water but  $\text{CO}_2$  reacts chemically with water and  $\text{H}_2\text{CO}_3$  acid is formed which is a compound (6). Here, views of girl subjects were seemed to be more self-contradictory as compared to boys in both quality and quantity.

#### **(iii) Self-centered or Human-centered Views**

The subjects of class 10 hold highest 143 frequencies of misconceptions in this category-3. For example, white of an egg is solution, made up of two substances. It is not a simple type of solution but a unique solution with rich protein and energy (13). Oil in water floats on the surface of water and become like a sponge. Of course, oil is partially mixed with water. Oil is lighter and water is heavier(8). Air is not a solution but a gas. How it could be solution without liquid? There is no effect of heat on air(38). Steel spoon is not a solution – used in houses for making utensils. It is very strong made by Uranium metal. It is chemically formed and not separated (23). NaCl in water is a solution. By shaking salt mixes and electricity can pass through it. So it may be named as 'electrical solution' (21). IM alcohol in water is a liquid and alcohol for drinking can be prepared. There is no hydrogen bonding in this system (20). Soda water is a solution or liquid solution. Its molecules move freely by increasing temperature (20). In this category, boys were more self-centered in frequencies (164) as compared to girls (143) but in the quality of responses, girls are more human centered than boys.

#### **(iv) No Scientific Term but Correct Explanation**

Only two subjects of class 10 replied in this category. For instance, carbon dioxide gas dissolves in water and does not mixed chemically but only pressure is involved(2).

**(v) Scientific Term but Incorrect Use of Scientific Term**

The subjects of class 9 hold frequencies of 95 misconceptions in this category-5. For example, white of an egg is a colloidal solution, transparent solution and can be easily filtered (15). Oil in water is not a solution – as oil does not mix at all in water – so a heterogeneous mixture. Fats hinder to mix with water (25). Air is a gas into gas solution. Pressure and temperature have slight effect on it properties(52). Steel spoon is a solution of carbon and iron, made up chemically by a chemical bond. Liquid is essential to make solution (10). NaCl in water is a solution –solid into liquid. Mixing is only due to shaking by spoon (15). IM alcohol in water is liquid into liquid solution and if one mole of alcohol is added then IM solution. It is not a good conductor of electricity (19). Soda water is a mixture – gas into liquid solution. Co<sub>2</sub> mixes ‘chemically’ with water (6). Since, girls use the correct scientific terms like ‘colloidal solution’ solid into liquid etc. but explained these terms non-scientifically.

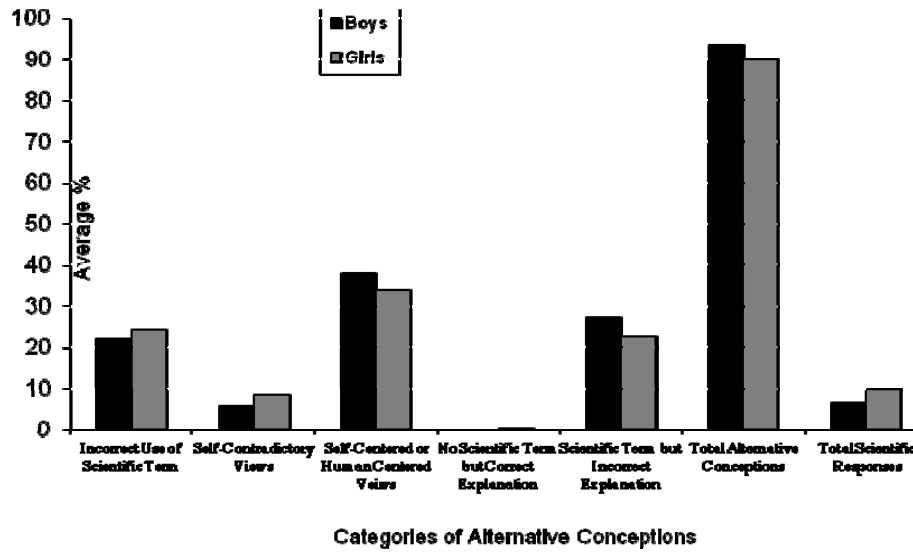
**Table 3 - Exploring Students’ misconceptions (Girls 10 Class) about Major Concept ‘Solutions’ (N = 60)**

Instances/ Events		White of an Egg	Oil in Water	Air	Steel Spoon	NaCl in Water	IM Alcohol in Water	Soda Water	Total Frequency & Average %
Categories of Alternative Concept									
Incorrect use of scientific term	f	19	9	10	13	16	14	21	102
	%	31.67	15	16.66	21.67	26.66	23.33	35	24.30
Self-contradictory views	f	7	6	4	7	3	3	6	36
	%	11.67	10	6.67	11.67	5	5	10	8.57
Self-centered or human centered views	f	13	8	38	23	21	20	20	143
	%	21.66	13.33	63.34	38.34	35	33.33	33.34	34.02
No scientific term but correct explanation	f	-	-	-	-	-	-	2	2
	%	-	-	-	-	-	-	3.33	0.47

Scientific term but incorrect explanation	f	15	25	5	10	15	19	6	95
	%	25	41.67	8.33	16.66	25	31.67	10	22.64
Total alternative conceptions	f	54	48	57	53	55	56	55	378
	%	90	80	95	88.34	91.67	93.33	91.67	90
Total scientific responses	f	6	12	3	7	5	4	5	42
	%	10	20	5	11.66	8.33	6.66	8.33	10

**Table 4 - Gender comparison of exploring 10<sup>th</sup> class Students' Understandings about Major Concept 'Solutions' N = 120**

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



### Conclusion

1. Majority of the subjects of both boys and girls were of the view that liquid should be an essential component of the solution.

2. Majority of the subjects both boys and girls could not distinguish between mixture and solution e.g. about air or among the solutions, colloids and suspensions.
3. In the instance 'white of an egg' subjects both boys and girls have misconception in it in many forms such as solution (like liquid-liquid, saturated or unsaturated solutions), colloids, and suspensions mostly without logical reasons.
4. 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, girls 18% and boys only 4 % correctly replied that it was not a solution.
5. 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.

It may be concluded that girls were slightly better in holding scientific views and boys hold relating more misconceptions about the concept solution.

## **Discussion**

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 research study some common misconceptions expressed by the subjects were found 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.

Similarly 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 like Muijs & Reynolds (2005) confirms the enduring low participation of girls in the study of physical sciences. Its reason pointed out by Thomas (1986) as cited by Osborne & Dillon (2010) is that it is a consequence of cultural socialization which offers girls considerably less opportunity to think with new technologies. Kahale &

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 misconceptions or scientific responses. However, the performance of girls and boys does differ in the domain of reasoning. For instance, qualitative analysis of misconceptions indicated that girls were more self-centered as well as 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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