A DIAGNOSTIC ASSESSMENT OF EIGHTH GRADE STUDENTS' AND THEIR TEACHERS' MISCONCEPTIONS ABOUT BASIC CHEMICAL CONCEPTS

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ABSTRACT

Even though many students at all levels struggle to learn chemistry and feel its exact essence, they are often unsuccessful. In this regard, most studies identified that the key cause of such failure to succeed especially in post primary and college education is formations of misconceptions towards basic chemistry/science concepts from the very beginning in primary education. However, what these studies couldn't exactly figure out is all about the possible source and cause of such misconceptions. Hence, in this study, it was aimed to diagnose both teachers' and students' misconceptions about five basic chemistry concepts (particulate nature of matter, physical state of matter, distinguishing differences of chemical and physical changes, phase changes and stoichiometry) and to examine the relevance and consistency of areas and intensity of students' misconceptions with that of their teachers. As a result, a survey research method comprising of multi-tier chemistry misconception test (MTCMT) and an interview as data gathering instruments were employed by which eighth grade students and chemistry/science teachers from four second cycle primary schools found in Mettu Administrative Town were purposely selected as target populations. In the mean time, the MTCMT was administered for 64 students and 4 teachers as a pilot test, for 192 students and 6 teachers as a final version, and 32 students were finally interviewed to get detail information on their existing conception. As a result, many set of suspected and new misconceptions were found, and finally from the Pearson's correlation, it was found that 90% of students' misconceptions has a significant correlation with teachers misconceptions implying that teachers are responsible for most (90%) of their students' misconceptions. *[AJCE, 3(1), January 2013]*

INTRODUCTION

Even though many students at all levels struggle to learn chemistry and feel its exact essence, they are often unsuccessful (1). Findings of many studies including (2) reveal that students' performance on national and regional chemistry examinations had alarmingly been declining from year to year. In this regard, what findings of most studies identified is that the key cause of such failure to succeed especially in post primary and college education is formations of misconceptions towards basic chemistry/science concepts from the very beginning in primary education (3). It is clear that students use pre-existing conceptions constructed from reflection on previous experiences to reason about newly presented science concepts, and to make sense of their instructional science experiences (4).

If children could not develop the necessary understandings in basic scientific/chemical concepts from the very beginning, they couldn't entertain more advanced concepts in a desired way later in high school and college (5). Because preconceptions are often incorrect from a scientific point of view they can interfere with students' latter learning of science/chemistry concepts (6-7). Once misconceptions are created in students' mind, they become very resistant to change and some of these students persist in giving answers consistent with their misconceptions even after large amounts of instruction (1). What a student learns results from the interaction between what is brought to the learning situation and what is experienced while in it (7). As a result, this aspect of chemical education has been given more emphasis in recent studies.

Basic and fundamental chemistry and science concepts, which are susceptible to misconceptions and misleading applications, have been considered in recent studies. More specifically, particulate nature of matter, physical state of matter, distinguishing chemical and physical changes, phase changes and stoichiometry are among the most frequent set of

Chemistry concepts studied (8-10), even though there is shortage of studies in our context. Still some researchers, based on their findings, argue that primary school science and chemistry teachers were also found to have such naïve ideas and misconceptions about basic chemical concepts (11).

However, what these studies couldn't exactly figure out is all about the possible source and cause of such misconceptions. In this regard, it was hypothesized in this study that teachers could significantly be possible cause of students' misconceptions. As a result, it was aimed to diagnose students' and teachers' misconceptions towards selected chemistry concepts, and correlate intensity and areas of students' and teachers' misconceptions

METHODOLOGY

In this study a survey research method was employed. The study comprised of two types of diagnostic tests which served as data gathering instruments. These are multi-tier chemistry misconception tests (MTCMT). The subjects of the study were 8th grade students and their chemistry/science teachers from four second-cycle primary schools in Western Ethiopia, Ilu Abba Bora Zone. From this zone second-cycle primary schools found in Mettu Administrative Town was selected using purposive sampling. These schools are Abuna Petros, Kidus Gebreal, Bubu and Nicholas Bohme Higher Primary School. In the first two schools there were respectively 146 (of which about 52% of them are females) and 280 (of which about 54% of them are females) eighth grade students. In the third and fourth schools there were respectively 135 (of which about 46% of them are females) and 146 (of which 52% of them are females) eighth grade students. On the other hand, there are 8 teachers teaching chemistry and basic science in the schools.

Three test groups were formed: pilot multi-tier chemistry misconception tests, revised multi-tier chemistry misconception tests and interview test groups. The purpose of the earlier was to examine standard of each item, while the last was employed to obtain in-depth information on students' prior knowledge, logical reasoning, mental representation and confidence level.

In the course of the study, related literatures were exhaustively consulted to find existing students' misconceptions towards the selected concepts. Next, a pilot multi-tier chemistry misconception test comprising of 14 main items was accordingly prepared and administered for 64 students and three teachers. Then its results were analyzed and some items were accordingly re-written, and the revised version was administered for 192 students and six chemistry/science teachers. Finally a semi-structured interview was prepared and administered for 32 students.

To simplify the task of data analysis, respective responses and answer were assigned in to three categories. These categories are responses showing correct or desired conceptions, alternative conceptions and missed understandings. Based on the respective values of these categories, proportions of students' scores and teachers' misconceptions were computed in terms of each concept, topics and sub-topics. Finally comparison of status and intensity of students' and their teachers' misconceptions was carried out to check consistency in terms of both frequency and areas of diagnosed misconceptions.

Regarding the drawing-based interview, categories of students' responses and drawings were used. These categories are mostly assigned to five levels. The first category, level one, is only concerned with yes-or-no responses. The second level is all about non-representational drawings, while the third one represents drawings with misconception. The fourth and the fifth

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levels are respectively concerned with partial drawings and comprehensive representational drawings.

According to these categories, drawings were evaluated. Based on this evaluation, students sketching drawings with misconception were additionally asked to give detailed descriptions on their own drawings. This was carried out to check validity of the interpretation of the drawings. Finally, obtained descriptions were compared with respective drawings.

RESULTs AND DISCUSSIONs

Diagnosed misconceptions and their categories

Information and data on students' and teachers' alternative conceptions were gathered through multi-tier chemistry misconceptions test (MTCMT) and interview. The MTCMT was employed for the matter of diagnosing, figuring out and computing existing alternative conceptions in a more quantitative manner, while the interview aimed at digging out in-depth qualitative information regarding mental representation, prior knowledge and logical reasoning with respect to selected chemical concepts. Anyway, data gathered through both instruments were categorized to and presented under the respective concepts, topics and sub-topics.

In addition, some new or unexpected misconceptions were also diagnosed in the course of this study. These misconceptions were said to be "new" or "unexpected" for being either completely new or ever appear in the addressed age, context and grade range of this study.

Particulate nature of matter

Regarding the nature and structure of an atom, about 72.9% of students perceive an atom as some kind of billiard object fully filled throughout by some other particles, while 66.67% of their teachers think so. Still about 58.33% of students and 50% of their teachers believe that an atom of an element can be seen through microscope, have physical state and color like any other form of matter. From these students about 39.06% of them think physical state of an atom as it was liquid.

Physical state of matter

Regarding this chemical concept three multi-tier questions consisting of 9 items were employed to diagnose respective students' and teachers' misconceptions. The first question examines students' and teachers' conception of shape and structure of a single H_2O molecule. As a result, more than 41.17% of students and 16.67% (1 from 6 teachers) believe a single H_2O molecule has different shape and structure in solid, liquid and gaseous states. In their response to the second tier of this question, about 82.29% of students and 33.33% of their chemistry teachers inferred that river water and ice water are different in their chemical composition. Once again, 64.6% of students were found to think that molecules (particles) of water can experience motion only in liquid state; while still 17% of them think only gaseous particles or molecules can experience motion. However, most of their respective (about 83.3% of) teachers were found to have the desired conception. This implies students were led to such kind of misconception due to "flowing nature" of liquids.

Many recent studies shows that children usually think as a single molecule can have different shape, size, structure and even mass in different physical states. These children are of 9-12 years old. However, what makes this study special is that older students (aged 14 – 15 years) were found to share such alternative conceptions. From 32 eighth grade interviewed students, only 13 of them were found to think that the mass of a single H_2O molecule is constant in all three physical states, while the rest believe that a single H_2O molecule could be heavier in solid state (9 students) and in liquid state (10 students). In addition, in their response about the mass of collected gaseous product from an engine of a car, about 21 of them inferred that it is less than that of liquid fuel found in the tanker of the car before burning. In their reasoning, more than 85% of them said something like ". . . because, gases are less heavy than liquids".

Regarding size, all interviewed students believe that size of a single molecule, H_2O for example, will change as its physical state changes. From these students, 16 of them think a single H_2O molecule is larger in liquid state, while 12 and 4 of them respectively were found to believe that a single H_2O molecule is larger in solid and gaseous state.

Moreover, it was attempted to compare and contrast students' diagrammatic representation of all the three states of water from their respective teachers' drawings taken informally. In this comparison, it was found that among drawings of 32 interviewed students and 18 teachers, 17 of students' and 16 of teachers' belong to the following category. Drawings indicating correct and alternative conceptions are presented as follows.

Figure 1: Teachers' drawing showing correct conceptions

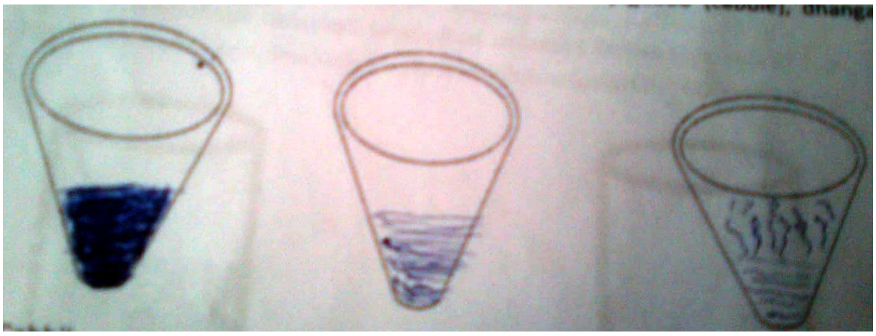


Figure 2: Students' drawing showing correct conceptions

Figure 3: Teachers' drawing showing alternative conceptions

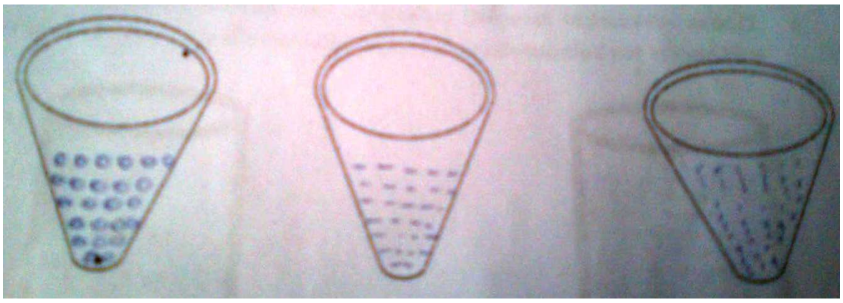


Figure 4: Students' drawing showing alternative conceptions

For the matter of simplicity density related differences were deliberately ignored during evaluation of these for being unique for water. Interviewees were also informed during interview session to assume the amount of sample water as constant in all three states and all three containers as closed.

Figures 1 and 2 represent categories of students' and teachers' drawings showing desired conception. On the other hand, figures 3 and 4 represent teachers' and students' drawings indicating alternative conceptions, respectively. First, the size of corresponding circles or dots placed in an ice-representing one are larger than those of liquid water and vapor representing drawing. Second, these circles and dots in the first ice-representing drawing are larger than those of liquid water and vapor representing drawing. Such kind of representations could have two chemical implications-as H_2O molecule in ice could be broken in to some kinds of other smaller molecules or particles and as number of molecules of water could increase in changing to liquid and gaseous states.

Change of state, physical and chemical changes

In this regard, different chemical events were given emphasis. Evaporation, cooling and heating of gaseous molecules, dissolving, rusting and burning of candle are among these events. Besides, some biased ways of lesson presentation and resulting conceptual perceptions were also entertained. Ways of explaining chemical compositions of simple molecules and compounds, for example, are among commonly miss-presented chemical topics. In this study too, about 48% of students and 16% of their teachers were found to use explanations like ". . . it [water] contain H_2 and O_2 in it", as if oxygen and hydrogen molecules could independently exist in water.

i. Evaporation

Water was taken as first example and its change from liquid to gas (vapor) was given more emphasis. In the first tier of the diagnostic question, the entire respondents were found to be able to easily figure out this change as physical. However, on their response to what really happens to water during evaporation (in the second tier) a wide range of perceptions were found.

For example respondents believe that:

- The bond between O and H breaks (23.44% of students and 16.67% of teachers)
- Water changes to air (50% of students and 33.34% of teachers)
- Water disappears during evaporation (6.77% of students)
- Only intermolecular forces break during evaporation (18% of students)

From this distribution, it's tangible that about 82% of students, except the last category were found to have set of misconceptions towards physical process of evaporation. The interview also revealed that more than 75% (24 out of 32) of students have such alternative conceptions. According to these students, water changes to hydrogen and oxygen gas on evaporation. The third tier of this question gives respondents the change to imagine a water sample being evaporated and think about chemical compositions of the bubbles formed in the mean time. As a result they think of the forming bubbles as:

- Dust particles (6.25%)
- Gases like O_2, CO_2 and H_2 (79.16% of students and 50% of teachers)
- Just water (12.5%)

On the other hand, it should be noted that such kinds of naïve ideas are deep-rooted in that interview shows that about 65% (21 out of 32) of students believe spaces between molecules like H_2O in a water sample are filled with hydrogen, oxygen, carbon dioxide gases, dust and even germs and bacteria.

ii. Heating and cooling of gases

This aspect of chemistry/science education seems to be among hardly understood topics. Different studies revealed that children were mostly found to think mechanically about most of scientific phenomena. Especially in earlier age, they were found to be led by what they have been seeing rather than by what they have been taught. They usually tend to think and feel macroscopically. As a result, for chemical process like diffusion, expansion, weakening of intermolecular attraction or repulsion they were found to use bursting, shrinking, growing, reproduction and so on.

In this study, too, more than 60% of students were found to have missed conceptions rather that alternative conceptions. However, about 18.23% of students and 16% of their teachers think that volume of gases increase up on heating because of the swelling of their molecules. Conversely, almost the same proportion of students and their chemistry teachers (respectively 21.35% and 16.67%) think volume of a gaseous sample decrease up on cooling because of shrinking of its molecules. No one seems to figure out the impact of temperature on intermolecular interaction, namely, attraction and repulsion between molecules of gas. In interview session also, when students were asked to remaining gaseous molecules in a partially evacuated cylinder, only about 12.5% (4 out of 32) of them were able to figure out and explain the spontaneously diffusing nature of gases. Students' drawing showing desired conceptions (DC) and alternative conceptions (AC) are presented below (Figures 5 and 6).

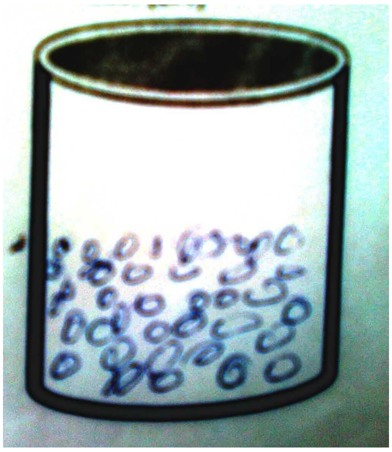


Fig 5: Students' drawing showing AC

Fig 6: Students' drawing showing DC

iii. Dissolving

Among the total 192 students who took the multi-tier chemistry misconception test (MTCMT), about 87.5% of them agreed that dissolving some crystal of sugar as a physical change. In proceeding to the second tier of the respective question, which expose them to think about what really happens to the sugar during dissolving, most of them were found to raise different naïve ideas. As a result about 26.56% of students and 16.67% of teachers believe that the sugar is lost or disappeared up on dissolving, while 60.42% of students and 50% of teachers believe sugar will be changed or transformed to water up on dissolving. Still 5.5% of students think sugar will decompose to its elements up on dissolving in water. Only 13.02% of students and 16.67% teachers were found to have the desired conception. From these students, in their response to the third tier which brings the events of dissolving to concept of conservation of mass and stoichiometry, about 49.47% of them were found to think that the mass of water remains constant whatever the mass of the sugar is, as the sugar is just disappeared or lost. Moreover, this figure reached 71% in the interview session. These students, in their reasoning said ". . . the mass of the solution will exactly equal to that of pure water because the sugar has just disappeared".

iv. Rusting

Almost all students were found to have no problems of figuring out a chemical event happened when a nail is exposed to moisture and air. Because, only 5.2% and 2.6 of students and teachers respectively think the nail will melt and dissolve when exposed to moisture and air. However, different set of alternatives conceptions were found when this rusting issue is brought to the concept of conservation of mass or stoichiometry in the second tier. In this regard, only

30% of them were able to point out that the mass of the rust is greater than that of the nail due to combination of oxygen with the iron of the nail. The rest think the mass of the rust is:

- Greater than that of the nail due to addition of soil (12.5%)
- Less than the mass of the nail, because the nail itself is being eaten up (36.46% of students and 33.34% of teachers)
- Equal to the mass of the nail (35.42% of students and 16.67% of teachers)

v. Burning of a candle

Here the overall event of burning and lightening of candle was entertained as two separate processes. These are burning of the central part and the changes occur on the external part. More than 78% of students and 66.67% of their teachers identified the melting part of the candle as a physical change. The second tier of the question issued on this event offers students and respective teachers to think about the composition of the flame formed during burning of a candle. As a result, they were found to think it as:

- Just a flame (64.3% of students and 66.67% of teachers)
- Dust particles (5.22% of students)
- Right Conception; Hydrocarbon particles (13.02% of students and 16.67% of teachers)
- Oxygen and hydrogen gas (13.01% of students and 16.67% of teachers)

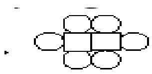
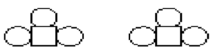
Stoichiometry

Under this chemical concept; balancing of chemical equations, analysis of reactant consumption and product formation proportion, the concept of limiting reactant and diagrammatic representations of atoms reacting and forming elements, molecules and compounds were given more emphasis to diagnose alternative conceptions regarding conserving mass and difference between subscripts and coefficients. Most students and teachers have no problems of choosing the most possible numbers that kept a given chemical equation balanced. Significantly most of them were found to be unaware of the chemical meanings and implications of coefficient and subscripts, though they exactly know operational meanings of these terms.

Among the 156 students who were able to choose the right set of numbers of coefficients of simple chemical equation, such as reaction of oxygen and hydrogen to form water and reaction of nitrogen and hydrogen forming ammonia, only about 11.46% of them were found to be able to figure out the proportion of consumption of oxygen and hydrogen in the formation of water. About 50% of them think as all the reactant combine together whatever the proportion of reactant and ignoring the impact of limiting reactants. The rest 40% of them were found to have missed-understanding rather than missed conceptions.

Regarding diagrammatic representations of reacting and forming species, most teachers and students were found to have no clear mental representations of what they are teaching and learning, respectively. This is most probably missed-conceptions (lack of understanding) rather than alternative conception. For about 56.25% of students and 16.67% of teachers, for example, the following pictures are the same in every chemical and physical aspect. Moreover, this figure of students' misconceptions and missed-understanding rose to 96.67% in the interview session. For instance,

 and  as H_4 and $2H_2$ were considered the same

 and  as N_2H_6 and $2NH_3$ were considered the same.

Such findings can be best amplified by the following attempts (drawings) of numerical and diagrammatical representation of balanced chemical equations of simple reactions.

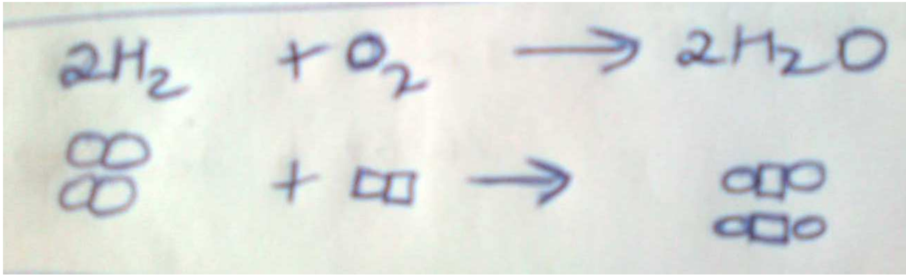


Figure 7: Category of teachers' drawing showing desired conceptions

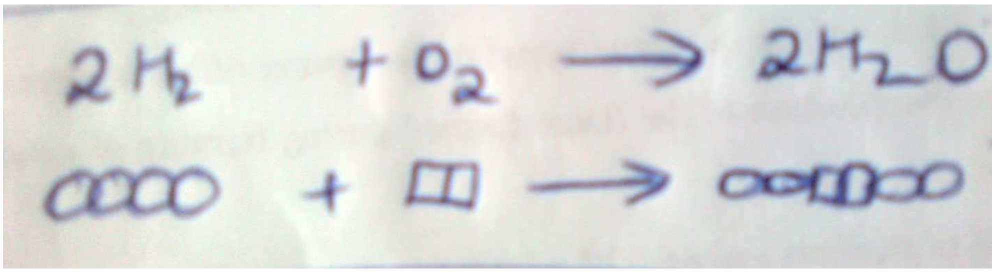


Figure 8: Category of drawings (attempted only by teachers) showing alternative conceptions

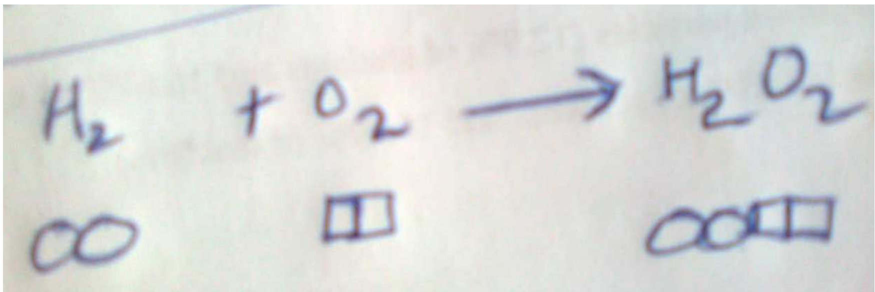


Figure 9: Category of drawings (attempted by both teachers and students) showing alternative conceptions

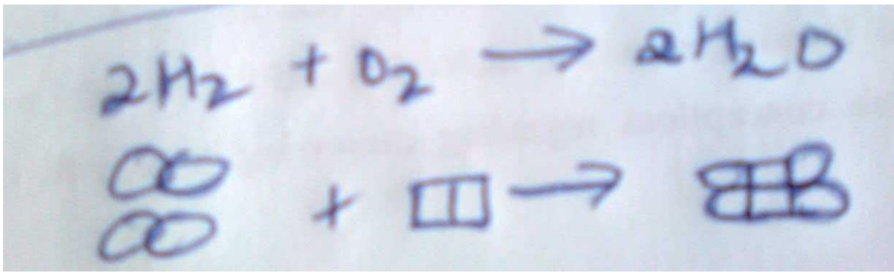


Figure 10: Category of drawing showing alternative conceptions

Figure 7 from the above list represents a balanced and correctly represented chemical equation of a reaction by which water is formed. Unfortunately, none of the students attempted to represent such a balanced chemical equation using drawing. From the rest interviewed students, only one of them balance the chemical equation correctly and attempted to represent it using drawing, though the drawing falls to the alternative conceptions category of figure 9. As a result, only two students attempted to balance both numerically and diagrammatically. This implies that most students have no understanding in this regard, rather than alternative conceptions. Regarding teachers' drawings informally obtained, 22%, 11%, 11% and 66% of them respectively fall to the figure 7, 8, 9 and 10 categories.

The next theme of stoichiometry brings students' and their teachers' attention to an event of burning a piece of wood. In the first tier of this theme, about 60.42% of students and almost all teachers have the desired conception in inferring that burning of wood can result in the formation of ash, soot, smoke and so on. The rest students were found to think only ash (9.89%), smoke (5.3%) and soot (19.79%) could be formed. However, surprisingly, about 68.23% of students think as the mass of all the products of a burning wood is less than that of the wood.

This implies that most of students have alternative conceptions and naive ideas about the stochiometric meaning of burning of wood. Similarly, during the interview, almost all students were able to figure out fuel burns in a car engine resulting release of gases. They were able to indentify this change as combustion reaction, a kind of chemical change. However, what these students respond differently on is the mass of collected gas. In this regard, about 62.5% (20 out of 32) of them think the overall mass of resulting gases will be less than that of the fuel. From these 62.5% of students, still about 18 of them believe that the mass of collected gases would be less than that of liquid fuel. In their reasoning, they said ". . . because gaseous molecules are lighter than that of liquid molecules".

On the other hand, about 83.33% of teachers didn't agree with their students' ideas. They believe the total mass of all products of a burning wood will exactly be equal to the mass of the wood. Still, such conceptions fall to the misconceptions categories because these teachers seem to forget the role, mass and addition of oxygen in the burning process.

Correlation of students and their teachers' misconceptions

For better comparison, categories of alternative conceptions in terms of each concept and specific topic are presented below in table 1 with their respective frequencies.

Table 1: Correlations of frequencies of students' and teachers' misconceptions

Concept	Specific topics	Category of Misconceptions	Frequencies Students (%)	Teachers (%)	Pearson's Correlation Value
Particulate nature of matter		1. Atom is like some kind of billiard object fully filled throughout by some other particles	72.91	66.67	0.944
		2. atom of an element can be seen through microscope,	58.33	33.33	
		3. atom of an element have physical state and color like any other form of matter	68.75	**50**	
		4. Atoms of elements exist in liquid state	39.06	16.67	
Physical State of matter		1. a single H_2O molecule has different shape and structure in solid, liquid and gaseous state	**69**	**16**	0.964
		2. river water and ice water are different in their chemical composition	**82.92**	**32**	
		3. molecules (particles) of water can experience motion only in liquid state;	64.6	16.66	
	Evaporation	1. The bond between H and O breaks during evaporation	23.44	16.67	0.991
Change of State		2. Water is changed to air during evaporation	50	33.34	
		3. Water disappear during evaporation	6.77	-	
	Composition of bubble, water	1. The chemical compositions of bubbles formed during evaporation of water are dust particles	6.25	-	0.960
		2. The chemical compositions of bubbles formed during evaporation of water are gases like hydrogen, oxygen, carbon dioxide and so on	78	**50**	
		3. Water contain H_2 and O_2 molecules in it	48	**16.67**	
	Heating and Cooling of Gases, properties of gases	1. volume gases increase up on heating because of the swelling of their molecules	18.23	16.66	1.00
		2. volume of a gaseous sample decrease up on cooling because of shrinking of its molecules	21.35	16.67	
Physical and Chemical Change	Dissolving	1. the sugar is lost or disappeared up on dissolving	**26.56**	**16.67**	0.998
		2. sugar will be changed or transformed to water up on dissolving	**60.42**	**50**	
		3. sugar will decompose to its elements up on dissolving in water	**5.2**	-	
	Rusting	1. A nail will be melted when exposed to moisture and air	**5.2**	-	0.863
		2. A nail will be dissolve when exposed to moisture and air	**2.5**	-	
		3. The mass of the rust is greater than that of the nail because of addition of soil	**12.5**	-	
		4. The mass of the rust is less than that of the nail because the nail is just eaten up	**39.56**	**16.67**	
		5. The mass of the rust is equal to that of the nail	**35.42**	**33**	
	Burning of Candle (Composition of flame formed by a burning candle)	1. Just flame	**64.59**	**66.67**	0.993
		2. Dust particles	**5.2**	-	
		3. Gases like Oxygen, hydrogen, carbon dioxide and so on	**13.02**	**16.67**	
Stoichiometry	Subscripts and coefficient	1. $2H_2$ and H_4 are the same in every aspects	56.35	16.67	1.00
		2. $2NH_3$ and N_2H_6 are the same too!	55.72	16.66	
	Limiting reactant and Stoichiometry	1. All the reacting species combine together whatever their proportion is	50	16.67	-0.873
		2. The mass of all products of burning wood is less than that of the wood	70.83	16.67	
		3. The mass of all products of burning wood is equal to that of the wood	28.12	83.33	

As can be understood from table 1, intensity or frequencies of students' and teachers' misconceptions have significant (and even perfect) correlation for most concepts and specific topics. Only the correlation of diagnosed alternative conceptions of students' and teachers' about one concept (stoichiometry, specifically the concept of limiting reactants) shows negative correlation. As a result, frequencies of students' and teachers' alternative conceptions towards 9 specific topics categorized under selected five concepts were found to have significant correlations. This implies that teachers are responsible for almost all (90%) of their students' misconceptions. From all specific topics, rusting was found to be less susceptible to misconceptions or alternative conceptions. On the other hand, particulate nature of matter, physical state of matter and stoichiometry were found to be the most alternatively perceived concepts.

New or unexpected alternative conceptions

For seven up to nine years children, as revealed by recent diagnostic studies, physical states could not only be three. For these children, being powder, jelly-like, soft moisture and hard are perceived as separate physical states (10). Such alternative conceptions were found to be vanished in late primary and junior education, though about 12.5% (4 out of 32) of interviewed eight grade students were still found to think so in that they inferred physical state of cotton as soft, flour as powder and so on. This is one aspect of unexpected alternative conceptions. The other concern soot formed from burning of different substances considering the gaseous nature of smoke which latter changes to soot. More than 19% (6 out of 32) of interviewed participants perceived physical state of soot as gas.

CONCLUSIONS AND RECOMMENDATIONS

Concepts and specific topics with the most frequency of students' and teachers' misconceptions were identified. Simultaneously, topics which are less subjected to misconceptions were also identified. From ten topics categorized under selected five concepts, only one (rusting) was found to be less susceptible to misconceptions implying that the rest topics are highly susceptible to both teachers' and students' misconceptions.

Generally, it was found that most of diagnosed students' misconceptions have significant correlation with that of teachers. These correlations are significant for 90% (9 out of 10) of specific topics, while correlations are insignificant for the rest10% (1 out of 10) of topics and concepts.

It is already found that teachers are responsible for most (90%) of students' misconceptions with respect to specific topics, 80% with respect to selected concepts implying that most of these concepts were found to be highly susceptible to alternative conceptions. In such cases, challenging students' conceptual change is highly dependent on teachers' respective conceptual change. Therefore, it is recommended to give a direct, specific, applied and continuous training to chemistry teachers, focusing on subtopics on which significant correlation of students' and teachers' misconceptions were found.

However, such training could not independently bring promising solutions since other challenges related to ways of delivery, content nature and organization could have hindering impacts. For this matter, training sessions should be planned and implemented in such a way that appropriate ways and art of content delivery and materials organization will be simultaneously worked on.

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