IS TEACHING-LEARNING OF MOLE CONCEPT REALLY DIFFICULT?

Alka Mehrotra and Anjni Koul

Department of Education in Science and Mathematics
National Council of Educational Research and Training
Sri Aurobindo Marg, New Delhi.

'Mole' concept is very simple, but it is generally the most feared and misunderstood concept. It is usually considered to be difficult to teach. In this article an attempt has been made to explore the answers to the following questions –

i) Why do teachers usually find teaching-learning of mole concept difficult?

ii) Why are teachers unable to design the activity for teaching the mole concept?

A common perception is that, since it is an abstract concept, it cannot be taught by activity based method. Therefore, making concrete to abstract link is not possible. This article provides suggestions to design activity to simplify the teaching-learning process of mole concept.

Introduction

National Council of Educational Research and Training (NCERT) conducts training programmes to develop master trainers so that improvement in teaching-learning process of Science and Mathematics can be brought about. These programmes are conducted with the hope that the master trainers will organise similar training programmes for the teachers belonging to their respective organisations and to the schools of nearby areas. In 2011-12 a need-based training programme in Science at Secondary Stage was planned. A questionnaire was developed to identify training needs and sent to different stake holders. Teachers identified some topics/ concepts which they felt were difficult to teach. One of these was *Mole Concept*. Feedback received from teachers showed that students do not easily understand the mole concept. However, this topic finds place in NCERT textbooks of secondary stage science[1] and higher secondary stage chemistry[2]. The mole concept is abstract and students find it difficult to learn; therefore, they develop a kind of fear for it. We think that, if proper transactional strategies are adopted, the problem can be solved to some extent. Therefore, teachers participating in the orientation programme conducted for Master Trainers in Science at Secondary Stage in 2012 were involved in the process. Written responses of the teachers on the transactional strategies that they usually follow to deliver the mole concept were collected. The collected responses of the teachers helped us to find out the reason for the difficulty arising in teaching- learning of the mole concept. To

solve the difficulty, teachers were assigned an activity related to the mole concept. They were given freedom to modify the activity if required.

Methodology

Before starting the discussion on transaction of mole concept, teachers were asked to write their responses about the following questions :

- What are the *key concepts* that should be dealt in the class to make the students understand the mole concept?
- What *previous knowledge* should students have before learning the mole concept?
- What *strategy* do you usually adopt for teaching the mole concept?
- Which *activity/activities* do you demonstrate in the class or ask the students to perform either individually or in groups during the teaching – learning process of mole concept?

The responses (in original) obtained from the teachers about the key concepts, previous knowledge and teaching strategies are tabulated in Table 1.

Table -1: Responses of Teachers about Key Concepts, Previous Knowledge and Teaching Strategies

S.No.	Key Concepts	Previous Knowledge	Teaching Strategy
1.	• What is a mole? • Why mole (terminology) is used? • How is mole related to Avogadro number? • How the value varies when the matter is taken in grams, moles and atom?	• Students are only aware of atoms, molecules, elements and compounds. • Students know that every element is made of their own type of atoms. • Students are also aware that atoms are very tiny particles and we cannot weigh them by either spring balance or physical balance, so some method is required to weigh the atoms.	**Activity** Examples of (A) No of bricks, (B) 1 dozen of Bananas (C) 1 kg Sugar Start with an activity that above things can be weighed but not the atoms so we need to know mole concept which is measurement for weighing the atom 1 mole = 6.023×10^{23} number then explain the concept.
2.	• Mole • Mole number • Molecular mass • No. of electrons, protons and neutrons in mole	• Students know small particles of substance. • Teachers give knowledge about mass of substance	Demonstration and lecture method. Teacher is teaching sub particles constituted by small particle atom. Mole of the sub particle prepared atomic mass of the substance or element e.g. H_2O - 1 mole Oxygen - 2 mole Hydrogen CO_2 - 1 mole Carbon - 2 mole Oxygen

3.	• What is mole? • Where we use the concept of mole in school in life. • Formulas to calculate (a) mole (b) number of particles in mole (c) weight in grams in mole. • Scientific importance of mole in chemistry laboratory	• How many articles are there in one dozen? • How many grams are there in one kg? • Knowledge about other S. I. units and their relation with other C.G.S. units	• To make them understand the concept of mole, first discuss the other SI units. • Some examples • Formulas • Numericals
4.	What is atom, proton?	Daltons Theory, previous structure of atom	• By drawing energy level shell of atom it can be compared with the solar system • Avogadro no of atom • Molecular mass-atomic mass • Mass and weight difference.
5.	Known to unknown : • Concept of atomic mass • Number atoms in one gram atomic weight is called one mole • Concept of gram atomic mass.	• Concept of unit • Unit of mass • Concept of one gram • Concept of atom • Concept of atomic mass • Concept of gram atomic mass • Number of atoms in gram atomic mass.	• Project method • Heuristic method
6.	• Mole concept— no. of moles present in an atom of an element/ compound/ ion • Avogadro number	Concept of atom, element, compound, ion	Heuristic method—from known to unknown
7.	• Definition • Inter-relationship between amount of matter (mole), mass of the substance • (molar mass), number of particles constituting that amount and mass of substance	Students know about different materials/substances.	• Provide an insight on mole concept by emphasising on important concepts on mole concept. • Demonstrate that substances appearing different in size and volume are of same mole through–theory, experiment

8.	• Mole a collection of 6.023×10^{23} particles of atom / molecules. • A mole of an atom =1 atom of that element = gram atomic mass = atomic number	Mole a collection of a) Atom, molecule b) Symbol of atom, formula of molecule c) Atomic number, atomic mass.	Mole = number of particles. I II III IV 4 Oranges 4Bananas 4Apples 4 Figs Number in all containers is same=4, but the item is different, its mass is different so 1 mole of O = 16u = 6.023×10^{23} O So 1 mole of O_2 = 6.023×10^{23} O_2
9.	• What is mole? • Avogadro number • What is n,N,m,M,N_0? • Formulas to solve problems • Why Avogadro number is called magic number?	• How to calculate atomic mass/molar mass? • What does the different symbols (n, N, m, M,N_0) mean?	• Blackboard work done by students while solving the problems. • Interaction
10.	Mole of any element means the amount of number elements present in 1 atomic weight in grams or molecular weight in gram is called mole. Previous knowledge required.	Students must know the molecular / atomic weight of few elements like for C=12, O = 16.	Suppose the atomic weight of O = 16 and molecular weight = 32 Therefore, 32g of O_2 = 1 mole of O_2.
11.	• Concept of mole as a number. • Relation between mole of an atom / molecule • Relation between the number and mass • Molar mass.	• Concept of atom and molecule. • Atomic and molecular mass.	• Clearing the concept of mole as a number (Avogadro number) • Using atomic structure models (kit) to clear that molecule has atoms in it. • Atomic mass – not measurable for practical purposes. • Concept of molar mass • Relation of Avogadro no with molar mass. • Numerical relations – Students try to derive the mathematical relations for each calculation
12.	• Mole concept • Number of atoms or molecules or ions in an element or compounds	• It is equal to number of atoms or molecules or ions present in an element or compounds	

	• Equivalent of Avogadro number i.e. 6.023×10^{23} atoms. • It is like measurement of other matter like 1 dozen =12, 1 gross = 144. • Number of atoms equivalent to C-12 (Carbon -12) molecule. • It is the unit for measurement of number of atoms / molecules present in an atom.	• It is used for the measurement of number of atoms with C-12 as standard unit for measurement.	
13.	—	—	• We know elements are made by group of atoms, but how many atoms grouped together. • During chemical reactions how many elements or molecules react to form how many element or molecules. • This know form mole concept – each element or molecules contain fix number of atoms or element or molecules known as mole constant $\text{No. of moles} = \frac{\text{Given mass}}{\text{Atomic mass (Molecular mass)}}$
14.	States of matter and examples	States of matter and examples	• Take the examples from children and divide with the help of children and explain the definition of different types of matter with arrangement of particles. • Definition of building blocks of particles: By using above concept we explain how the particle is formed with drawing figure • Atomic number: By using above concept we can explain with figure • Mass no: By using above concept we can explain with figure

			Mole: By using all above can give conclusion of the mole concept with definition.
15.	• Weight in grams – interconnection with mole. • Molar mass interconnection with mole. • Difference between weight in gram and molar mass.	Knowledge of using the balance	—

Expected Responses

Key Concepts

- Mole is the method of 'counting' items and finding the mass of items that cannot be seen.
- Analogy between mole concept and familiar counting units such as dozen, gross, rim, etc.
- Relationship between:
  (a) Mass of a Mole of an item and mass of single item.
  (b) Inter-conversion of mass of the substance into number of moles
- Application of mole concept to measure a given substance.

Previous Knowledge Required for Teaching Mole Concept

Before learning about mole concept students should have :

- knowledge of basic mathematics,
- understood concept of atomic mass, molecular mass, formula mass,
- knowledge about calculation of formula mass
- knowledge of using the chemical balance.

Table-1 indicates that most of the teachers are not clear about the relationships that need to be developed while teaching mole concept. Discussion on the methodology reported by them (Table-1) also shows that they are not focusing on child-centred method of teaching-learning process. In general, they use chalk and talk method only. Almost all of them are neither performing any activity nor are they motivating the child to perform any activity. To motivate the teachers to use child-centred method of teaching and to suggest strategies for removing the difficulty they face in teaching the mole concept, teachers were asked to carry out the following activity.

Activity

Teachers were advised to work in groups, in order to give them feel of collaborative learning which also leads to learning of time management.

Three packets of different types of seeds were provided to them – Green gram (*Moong dal*), Kidney beans (*Rajma*), Gram(*Channa*). The activity was performed in the following steps.

Step-1: Each group was asked to choose the packet of seeds of their own choice.

Step -2: Groups were told to look for the new unit^3 for counting the seeds in the packet. They discussed and decided to make the unit of eight

items. The new unit was given the name 'ASHTAK'. The word ASHTAK means eight in Hindi, which is appropriate for eight items. This means if we have a packet of one ASHTAK pencils, the packet will have eight pencils. To make them more familiar with the new unit 'ASHTAK', they were given following exercise to solve.

Exercise

1. Two ASHTAK of pencils will have _____ pencils.

   (Answer – 16 pencils)

2. Three ASHTAK of pencils will have _____ pencils

   (Answer – 24 pencils)

3. One ASHTAK of water molecules means _____ molecules.

   (Answer – 8 water molecules)

4. One ASHTAK of particles means _____ particles.

   (Answer – 8 particles)

5. One and a half ASHTAK particles means _____ particles.

   (Answer – 12 particles)

6. One ASHTAK of sodium atoms means _____ atoms.

   (Answer – 8 sodium atoms)

7. Six ASHTAKS of sodium atoms have _____ sodium atoms.

   (Answer – 48 sodium atoms)

8. Two and a half ASHTAKS of sodium atoms have _____ atoms.

   (Answer – 20 sodium atoms)

9. One ASHTAK of formula units of a salt has _____ formula units.

   (Answer – 8 formula units)

10. One fourth ASHTAK of formula units of a salt has _____ formula units of a salt.

    (Answer – 2 formula units)

11. How many molecules are present in 800 ASHTAKS?

    (Answer – 6400 molecules)

12. How many formula units are present in 600 ASHTAKS?

    (Answer – 4800 formula units)

13. How many oxygen molecules are present in 0.5 ASHTAK?

    (Answer – 4 molecules)

14. How many chlorine atoms are present in 0.25 ASHTAK molecules of chlorine?

    (Answer – 4 atoms)

16. 64 atoms of chlorine are equal to how many ASHTAK molecules?

    (Answer – 4 ASHTAK molecules)

Through this exercise it was emphasised that we are proceeding towards the counting of the number of particles which we are unable to see. It was highlighted that since one cannot see eight water molecules, sodium atoms or chlorine molecules etc. with the naked eye, therefore, scientists use bigger unit for counting the small

particles like atoms, molecules and ions etc. so that one can see the bulk of these small particles. This unit is named as **mole. It contains 602,200,000,000,000,000,000,000 particles or 6.022 × 10 ^{23} particles.** This number is called Avogadro number. In other words we can say- 'one mole contains Avogadro number of particles'.

Step-3: Each group was asked to fill Table-2 by weighing the required number of seeds.

Table 2 : Name of the seed

S. No.	Number of seeds	Mass of seeds	Mass of one seed
1.	Eight (one ASHTAK)		
2.	16 (two ASHTAK)		
3.	Any number of seeds picked up without counting (Random Number)		

Step -4: The teachers were asked to count the number of seeds picked up randomly (S.No.3, Table 2) and find out how many ASHTAKS it contains. They were asked to find out the mass of one seed and complete the Table 2. Once the activity was over, they were asked to answer the following questions.

1. Do you find any relationship between mass of one ASHTAK and two ASHTAK?
2. Do you find any relationship between the mass of one ASHTAK and the number of ASHTAKS in random sample?
3. Is there any similarity in the mass of one seed obtained from each observation of Table 2?
4. Compare your results with the results of other groups having the same seeds.
5. Is the activity useful for explaining the relationships-
   (a) Mass of a Mole of an item and Mass of single item
   (b) Inter-conversion of mass of the substance into Number of Moles

Table 3 (Group-1) : Observations and Data submitted by groups

S. No.	Name of the seed	Number of seeds	Total Mass of seeds/g	Mass of one seed/g
1.	*Moong Dal* (Green Gram)	8	0.2984	0.0373
		16	0.5553	0.0347
		Randomly picked number (62)*	2.2205	0.0358
2.	*Rajma Seed* (Kidney Bean)	8	2.5892	0.3237
		16	5.1237	0.3202
		Randomly picked number (19)*	5.7603	0.3032
3.	*Chana Seed* (Gram)	8	5.0576	0.6322
		16	8.4990	0.5312
		Randomly picked number (21)*	11.5135	0.5483

* Number in the brackets shows actual count of seeds in the random sample

Table 4 (of Group-2)

Group-2 worked with only *Channa* seeds

S. No.	Name of the seed	Number of seeds	Total Mass of seeds/g	Mass of one seed/g
1.	*Chana Seed*	8	4.8260	0.6032
		16	10.2045	0.6378
		24	12.9245	0.5385
		Randomly picking (21)*	13.1790	0.6278

* Number in the brackets shows actual count in the random sample

Explanations Given by Teachers Using Data Tables- 3 and 4:

1. Mass of one seed calculated from the mass of one ASHTAK seeds, two ASHTAK seeds of same kind etc. is approximately same since mass of seeds of the sample is approximately same.
2. Mass of different kind of seeds is different therefore, mass of one ASHTAK of different kind of seeds differs.
3. Mass of a mole of substance depends on the abundance of different isotopes present in the sample.

It can be seen from the Tables-3 and 4 of Group-1 and 2 respectively that mass of one seed calculated from the mass of one ASHTAK, two ASHTAK etc. is very close but not the same. Teachers highlighted that mass of all seeds in the sample of same kind of seeds may not be same; therefore, there may be slight difference in the mass of one ASHTAK of seeds. Teachers could also explain that slight difference in the calculated mass of one seed may be observed because all the seeds in an ASHTAK may not have same mass. Similarly, mass of a mole may differ depending upon the abundance of heavy or lighter isotopes present in the sample. Mass of one mole of a substance depends on the abundance of different isotopes of atoms present in the sample.

(4) Relationship between Mass of a Mole of an item and Mass of single item.

Number of seeds in the given mass of seeds can be calculated by dividing the given mass of the seeds by average mass of one seed as follows;

(*Only close readings were used for calculating the average mass of one seed in all cases)

Calculations from Table 3 (Data of Group-1)

Average mass of one *Moong Dal* seed

$$= \frac{0.0373 + 0.0347 + 0.0358}{3} = 0.0359$$

Average mass of one *Rajma* seed

$$= \frac{0.3237 + 0.3202}{2} = 0.3219$$

Average mass of one *Channa* seed

$$= \frac{0.5312 + 0.5483}{2} = 0.5398$$

Calculation of number of seeds in randomly picked up sample from the total mass of sample

Number of seeds in randomly picked up *Moong Dal* $= \frac{2.2205}{0.0359} = 62.02514$ (Actual count 62)

Number of seeds in randomly picked up *Rajma* seeds $= \frac{5.7603}{0.3219} = 18.99835$ (Actual count 19)

Number of seeds in randomly picked up *Channa* seeds $= \frac{11.5135}{0.5483} = 20.99854$ (Actual count 21)

Calculations from Table 4 (Data of Group-2)

Average mass of one channa seed

$$= \frac{0.6032 + 0.6378 + 0.6278}{3} = 0.6229$$

Number of seeds in randomly picked up *Channa* seeds $= \frac{13.1790}{0.6278} = 20.99235$ (Actual count 21)

Now, it can be explained very easily that if we know the mass of a substance we can calculate the number of atoms present in the sample by dividing the given mass by the average mass of single atom.

4. Inter-conversion of mass of the substance and number of Moles

Mass of two ASHTAK seeds of same kind is approximately double the mass of one ASHTAK seeds of that kind as can be seen from the following calculations.

Calculations from Table-3 (Data of Group-1)

$$\frac{\text{Mass of two Ashtak } \textit{Moong Dal}}{\text{Mass of one Ashtak } \textit{Moong Dal}} = \frac{0.5553}{0.2984} = 1.8609$$

$$\frac{\text{Mass of two Ashtak } \textit{Rajma Seed}}{\text{Mass of one Ashtak } \textit{Rajma Seed}} = \frac{5.1237}{2.5892} = 1.9789$$

$$\frac{\text{Mass of two Ashtak } \textit{Channa Seed}}{\text{Mass of one Ashtak } \textit{Channa Seed}} = \frac{8.4990}{5.0576} = 1.6804$$

Calculations from Table 4 (Data of Group-2)

$$\frac{\text{Mass of two Ashtak } \textit{Channa Seeds}}{\text{Mass of one Ashtak } \textit{Channa Seeds}} = \frac{10.2045}{4.8260} = 2.1145$$

$$\frac{\text{Mass of three Ashtak } \textit{Channa Seeds}}{\text{Mass of one Ashtak } \textit{Channa Seeds}} = \frac{12.9245}{4.8260} = 2.6780$$

Therefore, we can find the number of moles in a sample of substance by dividing the total mass of that sample by mass of one mole of that substance. As can be seen from the following calculations, we can calculate the number of ASHTAKS in the randomly picked up seeds by dividing the mass of the seeds by mass of one ASHTAK of seeds and compare it with the actual number of ASHTAKS in the randomly picked up sample.

Calculations from Table 3 (Data of Group-1)

$$\frac{\text{Mass of randomly picked up } \textit{Moong Dal seeds}}{\text{Mass of one Ashtak } \textit{Moong Dal seeds}} = \frac{2.2205}{0.2984} = 7.43$$

Actual value of ASHTAKS $= \frac{62 \text{ seeds}}{8 \text{ seeds}} = 7.75$

$$\frac{\text{Mass of randomly picked up } \textit{Rajma seeds}}{\text{Mass of one Ashtak } \textit{Rajma seeds}}$$

$$= \frac{5.7603}{2.5892} = 2.2247$$

$$\text{Actual value of ASHTAKS} = \frac{19 \text{ seeds}}{8 \text{ seeds}} = 2.38$$

$$\frac{\text{Mass of randomly picked up } \textit{Channa seeds}}{\text{Mass of one Ashtak } \textit{Channa seeds}}$$

$$= \frac{11.5135}{5.0576} = 2.2784$$

$$\text{Actual value of ASHTAKS} = \frac{21 \text{ seeds}}{8 \text{ seeds}} = 2.63$$

Calculations from Table 4 (Data of Group-2)

$$\frac{\text{Mass of randomly picked up } \textit{Channa seeds}}{\text{Mass of one Ashtak } \textit{Channa seeds}}$$

$$= \frac{13.1790}{4.8260} = 2.7308$$

$$\text{Actual value of ASHTAKS} = \frac{21 \text{ seeds}}{8 \text{ seeds}} = 2.63$$

- Teachers reported that they were not aware of any such activity and responded that they would like to use such activities in their teaching-learning process.
- They suggested that average mass of several single seeds of same kind can be compared with the mass of one seed calculated from the mass of an ASHTAK of seeds.
- They found that the activity is very useful for explaining the mole-mass and item- mass relationship and they could explain that, how mass could be converted into mole and mole number could be converted into mass.
- They could explain that, mass of one mole of a substance depends on the types of isotopes of the substance present in the sample.

Using mass of one seed, they explained that mass of all seeds in the sample of same kind of seeds may not be same, therefore, there may be slight difference in the mass of one ASHTAK of seeds. Similarly, mass of a mole may differ depending upon the abundance of heavy or lighter isotopes present in the sample.

Same activity was tried with another group of 24 teachers. This time four kinds of seeds were taken for the activity. Again similar results were obtained. Data obtained by different groups for different seeds are given in Tables 5, 6, 7 and 8

Table 5 : Name of seed: *Moong dal* (Green Gram)

Group Number	Average mass of one seed	Mass of random sample	Calculated number of seeds in random sample	Actual number of seeds in the sample
1.	0.0416	0.8736	21.0	21
2.	0.0417	1.5430	37.0	37
3.	0.0431	2.2976	53.3	54
4.	0.0456	1.3413	29.4	31

Table 6 : Name of seed: *Channa* (Gram)

Group Number	Average mass of one seed	Mass of random sample	Calculated number of seeds in random sample	Actual number of seeds in the sample
1.	0.5954	11.9978	20.20	20
2.	0.5560	11.4816	20.70	20
3.	0.5536	11.5047	20.80	20
4.	0.6127	9.1769	14.97	15

Table 7 : Name of seed: *Rajma* (Kidney bean)

Group Number	Average mass of one seed	Mass of random sample	Calculated number of seeds in random sample	Actual number of seeds in the sample
1.	0.3186	7.3322	23.01	24
2.	0.3199	3.4286	10.70	11
3.	0.3223	6.9991	21.70	22

Table 8 : Name of seed: *Urad Dal* (Black lentils)

Group Number	Average mass of one seed	Mass of random sample	Calculated number of seeds in random sample	Actual number of seeds in the sample
1.	0.0505	1.8408	45.60	41
2.	0.0438	2.3172	52.90	53
3.	0.0469	2.4378	51.97	52

CONCLUSION:

We worked with a very small group of teachers. Hence, any kind of generalisation is not possible, but one can surely conclude that teachers find difficulty in recognising the key concepts and the essential previous knowledge required by the students to understand the mole concept. This may be the cause of the difficulty in learning of mole concept by students. Therefore, in order to find out the cause of difficulty arising in teaching-learning of some topics, it is important to carry out some kind of research for finding out the capability of teachers in recognising the key concepts. It is also important to know how far teachers need training for understanding and using the child-centred strategies for teaching–learning process. This paper also highlights how understanding of a difficult topic can be simplified by activity based teaching–learning process, which is one of the concerns of National Curriculum Framework – 2005[4]

References

1. Science Textbook of Class IX, National Council of Educational Research and Training, New Delhi, 2006.
2. Chemistry Textbook of Class XI, National Council of Educational Research and Training, New Delhi, 2006.
3. Introduction to mole concept, Golda Steiner, Park Ridge High School, Park Ridge, NJ, Developed through the National Science Foundation – funded, Partnership for the Advancement of Chemical Technology (PACT) (www.terrificscience,org/lesson pdfs/MoleIntro.pdf)
4. National Curriculum Framework-2005, National Council of Educational Research and Training, New Delhi, 2005.