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Chapter 2

The Introduction of Formative Assessment Probes for Teaching the Mole Concept in Chemistry: A Small Study With High School Students

Mızrap Bulunuz[1]

Betül Kuralay[2]

Abstract

Mole, molar mass and the Avogadro number are used constantly to measure the amount of substance in chemical changes. However, students have difficulty in understanding these concepts because they are not familiar with measuring very small amounts of matter that cannot be seen and weighed in daily life, like atoms. The mole concept was developed to make the invisible and immeasurable atom visible and weighable. This research has three purposes: 1) To introduce the formative assesment probes on the teaching of the mole concept, 2) To evaluate the contribution of formative assessment techniques to understanding of the mole concept, 3) To reveal the students' knowledge about the application of the mole concept to problem solutions. The sample of the study consisted of 23 high school students. Four formative assessment probes were developed by the researchers. They were used as data collection tools. A formative assessment teaching technique "the agreement ring" was used for the teaching the mole concept. Students' answers to the formative assessment probes were analyzed by using the four-point scale. As a result of the study, it was found that formative assessment practices positively contributed to the conceptual understanding of high school students. In order to provide conceptual understanding in the teaching of the chemistry course, studies should be carried out to generalize formative assessment techniques and formative assessment probes.

1 Bursa Uludağ Üniversitesi, mizrap@uludag.edu.tr

2 Yenidoğan Anadolu Lisesi, Chemistry Teacher, kuralaybetul@gmail.com

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Introduction

In the teaching process, it is important to ensure that students learn meaningfully without having to memorize the basic science concepts (National Science Education Standards, 1996; Ministry of Education [MEB], 2018). In the Chemistry Curriculum (MEB, 2018), it is emphasized that measurement and evaluation practices are an integral part of teaching, that individual differences should be observed during the education process, and that measurement and evaluation practices should be carried out with the active participation of teachers and students. Teaching without taking into consideration the prior knowledge of students may prevent them from grasping new concepts or may cause them to return to their prior knowledge level (National Research Council [NRC], 1999). Formative assessment is defined as a process in which feedback is provided to students by teachers in order to increase student achievement towards curriculum attainment (Black & Wiliam, 1998a; McManus, 2008; Sadler, 1989). The nature of formative assessment is quite different from that of summative assessment. Summative assesment is used to measure and document students achievements; simply summing the results. Formative assessment isn't just a grading system, it's also a kind of assessment fused with teaching feeding back information into the teaching process (Black & Wiliam, 1998b; Keeley, 2008). Formative assessment is used in order to learn the information that students have, or do not have, and to teach accordingly (Black, Harrison, Lee, Marshall, & Wiliam, 2004; Won, Krabbe, Ley, Treagust, & Fischer, 2017). In an effective formative assessment process, data should be collected on how the learning process proceeds (Keeley, 2008). Thus, necessary educational arrangements should be made in order to close the gap between the students' current understanding and the desired objectives (McManus, 2008; Shepard, 2000). When formative assessment is not used in teaching, there is always a gap between teaching and learning outcomes. For example, this gap emerges in summative assessments such as PISA and TIMM tests, in which nationally and internationally students' achievement levels are determined (Bulunuz & Bulunuz, 2013).

Formative assessment allows students to develop cognitive and deep thinking skills, as well as providing feedback and shaping instruction (Keeley, 2008). Formative assessment helps teachers to teach in depth by focusing on conceptual understanding. Many books have been published about formative assessment probes that teachers can use to uncover students' prior knowledge during the lesson (Keeley, 2008, 2011, 2013; Keeley, Eberle, & Farrin, 2005; Keeley & Harrington, 2014; Keeley & Tugel, 2009). There are also guidebooks for formative assessment classroom techniques and their use in the teaching process (Keeley, 2008; Wiliam, 2011; Wiliam & Leahy, 2015). Formative assessment techniques enable the teacher to plan, monitor the teaching speed, identify possible misconceptions, become a "trampoline" for obstacles in the way of learning, and spend more time addressing students' ideas (Keeley, 2008). The nine benefits of using formative assessment techniques in the teaching process are listed as follows: 1) Students open up to each other and their teachers about their ideas, 2) It becomes an encourager for scientific discussions, 3) It also encourages students to ask better questions and give thoughtful answers, 4) It becomes the starting point for students to develop ideas and research, 5) It encourages the use of scientific language in science teaching, 6) Itives feedback and uses feedback in the learning process (between student-teacher, teacher-student, student-student), 7) It develops self-evaluation and peer assessment skills, 8) It enables thinking and engages the student in learning, 9) It contributes to concept development and transference (Keeley, 2008).

Black and Wiliam's (1998b) Inside The Black Box: Raising Standards Through Classroom Assessment is one of the leading studies on formative assessment. In this study, the characteristics of formative assessment in general and the positive effect of students on their conceptual understanding levels and attitudes towards the course are mentioned. International studies reveal that formative assessment contributes to students' conceptual understanding (Martinez-Gudapakkam, Mutch-Jones & Hicks, 2017; Trauth-Nare & Buck, 2011; Treagust, Jacobowitz, Gallagher & Parker, 2001; Yin, Tomita & Shavelson, 2013). The studies' results indicated that formative assessment may be important for increasing the academic achievement of students who fail level-determining examinations. Despite the interest in formative assessment internationally, in Turkey the lack of research that includes formative assessment examples is evident, especially in chemistry teaching. It is seen that researches are mostly aimed at introducing formative assessment probes in middle school science education (Bulunuz & Bulunuz, 2013; 2016), determining the level of conceptual understanding of students in various subjects by using formative assessment probes (Bulunuz & Bulunuz, 2017; Ayvacı & Candaş, 2017), and examining the effect of formative assessment-based teaching practices on student outcomes (Bulunuz, Kıryak, Tomaç, Karagöz, & Recepoğlu, 2017; Aydeniz & Pabuccu, 2011; Bala, 2013; Ozan, 2017; Yalaki, 2010).

In chemistry teaching literature, out of all the concepts that students have difficulty in understanding, the mole concept is the most difficult one (Özmen & Demircioğlu, 2003; Siswaningsih et al., 2017). Because an atom is not only invisible to the eye, but there is also not a scale precise enough to weigh it on Earth. The mass of an atom is now determined by mass spectrometry. The mole concept makes the atom visible and weighable, in a sense. Mole is the basic unit of measurement for the amount of material. The mole concept is defined by the IUPAC (2007) as the amount of matter of a system containing as many particles as the number of atoms in of 0,012 kilograms of the isotope carbon-12 (14th CGPM, 1971). The particle mentioned herein could be an; atom, ion, molecule or electron, so the particle must be specified. However, research has shown that the definition of moles in textbooks and most chemistry texts is not correct (Furió, Azcona, Guisasola, & Ratcliffe, 2000). In order to understand the mole concept, which is expressed as a unit of substance quantity, it is emphasized in the studies that "substance quantity" needs to be stated in a more understandable way. In their studies, Furió and his colleagues stated that the "amount of matter" does not have a clear meaning for students or teachers (Furió, Azcona, Guisasola, & Mujika, 1993; Furió et al., 2000). When the literature is examined, it is seen that students generally refer to the mole concept as mass, particle number, volume, or the Avogadro number (Furió, Azcona, & Guisasola, 2002; Staver & Lumpe, 1995; Tullberg, Strömdahl, & Lybeck, 1994).

In recent years, much research has been done to learn and teach the mole concept, which is one of the basic concepts in chemistry (Dierks, 1981; Furió et al., 2000, 2002; Larson, 1997; Padilla & Furió-Mas, 2008; Staver & Lumpe, 1995). In the studies, it was determined that students had alternative concepts related to mole, had difficulties in learning the mole concept, and also had various problems performing stoichiometric problem solutions (Özer, 2009). For example, a study in which high school students' level of understanding of basic chemistry concepts showed that the lowest correct to incorrect answer ratio related to the mole concept questions (Özmen & Demircioğlu, 2003). In a study on mole, molecule, solutions, solubility balance, acid-base, and redox, found that university students' success in solving conceptual problems was lower than their success in solving algorithmic problems (Morgil, Yılmaz & Özyalçın, 2002). According to Özer (2009), the mole concept serves as a bridge in defining concepts and solving algorithmic questions in many topics such as chemical reactions, stoichiometric calculations, and solution chemistry. Therefore, misconceptions about the mole concept can indirectly lead to students' difficulty in understanding or creating alternative concepts in other topics of chemistry. For example, in a study, it was found that the primary factor affecting students' failure to solve concentration problems was the superficial understanding of the mole concept (Chong, 2016). In addition, it has been stated that when the mole concept is not fully grasped, this leads to students trying to memorize formulas. The results of this research show that students have serious difficulties in conceptually internalizing the mole concept. However, there is a gap in the literature regarding studies about the meaningful teaching of the mole concept. In particular, no study was conducted to teach the mole concept in chemistry by using formative assessment classroom techniques and probes. This research has three purposes. The first one is to introduce the planned formative assessment probes related to the mole concept. The second is to reveal the knowledge of the fourth year high school students about mole and to examine the effects of formative assessment techniques on conceptual understanding. And, the third is to reveal students' knowledge about the application of the mole concept to real problem solutions. This study sought to answer the following questions:

1) What is the prior knowledge of high school fourth year students about mole?
2) Out of all the formative assessment practices, what is the effect of the agreement ring technique on students' conceptual understanding of mole?
3) What is the level of students' ability to explain a chemistry question from daily life using the mole concept?

Method

Research Model

This study is aimed at improving the teaching practices in the school. In this study, a practitioner and a researcher identified a possible problem areas in practice and possible causes and possible solutions to these problems (Cooper-Twamley, 2009; Yıldırım & Şimşek, 2013; Yuladur & Doğan, 2009). The study was conducted in four stages. The first stage examined literature on the science teaching approach based on the mole concept and on formative assessment. In the second stage, formative assessment probes about mole and colligative properties were prepared in line with the 12th grade curriculum of the Chemistry course. Then, the formative assesment probes were developed and used to the students. The research problems were determined based on the obtained data. The third stage used lesson plans based on the Formative Assesment Classroom Techniques in class. The last stage analyzed the data obtained from the teaching practice.

Study Group

The research study group consisted of 23, 12th grade high school students studying in the city center. The school where the research is conducted is an Anatolian High School which is in the list of secondary education institutions that accept students by the central examination of the Ministry of National Education. In general, the students' academic achievement is above average. Twelve of the students were female and 11 were male. In the study, the convenience sampling method was used in the selection of the group. This sample group was close and easy to access (Yıldırım & Şimşek, 2016). Due to the intensity of the students' program, only one class was allowed and only one formative assessment probe could be practiced as a pre- and post-test. The research was carried out in chemistry class with the necessary school administration permission.

Instructional Intervention Practices

In the study, the objectives related to "mole and colligative properties" were determined by examining 12th graders' chemistry curriculum. Four formative assessment probes were developed by researchers in line with the objectives. The first, second and third assessment probes related to the mole concept; the fourth was about the explanation of the freezing point depression in solutions that requires application of the mole concept to a real world problems. The second and third formative assesment probes are similar questions regarding the Avogadro's number. Feedback was received from a 24-year-old chemistry teacher for theformative assessment probes. The teacher stated that he liked the formative assesment probes developed and would be useful in teaching the mole concept. He also stated that students had a lot of problems with learning mole concept and that this problems caused prejudice against learning topics such as solution chemistry and equilibrium. He said that the formative assesment probes were about the chemistry concept that students confused very often, and they would probably give the wrong answer. He stated that the vast majority of students do not understand the mole concept and that this concept prevents them from loving chemistry courses because of the fact that it is mentioned in many chemistry topics.

While formative assessment probes were developed for the mole concept, pilot studies were also conducted with 11th grade students in a high school. Based on pilot data collected from the students, the questions were revised again in terms of content and grammar. The lesson plan was developed considering analysis of the students' answers. The formative assessment probes were practiced as pre-tests to reveal the 12th grade students' prior knowledge one week before the instruction.

One of the Formative Assessment Classroom Techniques (FACTs), the Agreement Circles, was used (Keeley, 2008). The agreement ring technique allows students to develop a critical perspective on their own learning by enabling them to discover and understand their ideas and to change their minds (Keeley, 2008). In this technique, students formed a large circle facing each other. The teacher started to read the statements in sequence and gave the students 5-10 seconds to think after reading. Some examples of the statements are presented below.

- The masses of different element atoms with equal moles are different from each other.
- 1 mole of H_2O molecules, contains 2 H atoms.

Then, she asked the students who didn't agree to remain in place, and those who did agree with the statement read, to take a step into the circle. Then, the teacher formed small groups of 3-4 people by matching the people who agreed and the ones who didn't. The students were given 2-3 minutes to express their ideas about the statement and to defend their own ideas. While students were discussing, the teacher observed through the groups and noted their ideas. It took about 10-15 minutes for the ideas of the students to surface. Then the teacher re-read the statement and asked the students to change their position in the circle depending on whether or not their ideas changed. Again, those who agreed with the statement remained inside of the circle and those who did not agree stayed outside. All changes in the process were noted by the teacher. Then, the students were re-formed and the same process was repeated for the other expressions. For the implementation of the agreement ring technique, researchers first developed conceptually correct and incorrect statements. While developing false expressions, researchers examined literature to find student misconceptions. Some of the probes' false expressions are taken from common misconceptions and some from pilot practices. In order to determine students' conceptual understanding of mole after the teaching instruction, only the third formative assessment probe (see below) could be used as a post-test 2-3 weeks later. The intensity of the school program did not allow to implement all the questions. This was a limitation for research.

Planned-Formative Assessment Probes about Mole Concept

In this study, planned formative assessment probes for the mole concept were developed. The first tier of questions was multiple-choice and the second tier was open-ended. In the first tier, there were different opinions about a question or proposed information. This stage aimed at revealing the knowledge and experience of the students, so students were asked to choose the opinion they agreed with. In the second tier, students were expected to explain the reasons for their selection in the first tier. In addition, a visual aid was added to each question to attract students' attention and interest to the subject. Three formative assessment probes for understanding the mole concept and one formative assessment probe about using mole concepts to solve chemistry questions from daily life are presented below.

Formative Assessment Probe 1

WHICH ONES' MASS IS HIGHER?

A group of students in the chemistry laboratory used iron (Fe) and naphthalene ($C_{10}H_8$) for experiments. There has been a discussion among students about whether 1 mole of iron or 1 mole of naphthalene has a higher mass. The students' views on this subject are as follows:

Aslı:"The mass of 1 mole of iron is higher. "

Deniz:"The mass of 1 mole of naphthalene is higher."

İpek:" Since both are 1 mole, their mass is equal."

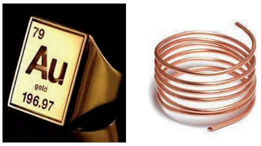
Which student do you agree with? Explain your answer scientifically.

The Correct Answer and Its Explanation: The answer given by Deniz, "1 mole of naphthalene has a higher mass," is correct. The molar mass is the mass of 1 mole of the compound in the molecular structure, 1 mole of the ionic compound as written in the formula, or one mole of the element (atom or molecule). The molar mass of iron atoms is 56 g/mole. In this case, when 1 mole of an iron atoms is taken, the mass will be 56 grams. Using the molar mass of the carbon and hydrogen atom, the molar-mass of the naphthalene molecule is calculated as (10 x 12 g/mol) + (8 x 1 g/mol) = 128 g/mole. Thus, the mass of one mole of naphthalene molecules is higher than the mass of one mole of iron atoms. One mole is defined as the amount of substance of the system containing the same number of particles as the number of atoms in the isotope carbon-12 that weighs 0.012 kilograms (= 12 grams). The number of atoms of 1 gram-mole of carbon-12 isotope was determined as $6.02x10^{23}$. Accordingly, 1 gram-mole of iron atoms and 1 gram-mole of naphthalene molecules both contain $6.02x10^{23}$ particles. However, since the mass of 1 naphthalene molecule is higher than the mass of 1 Fe atom, the naphthalene mass will be higher.

Formative Assessment Probe 2

WHICH ONE CONTAINS MORE ATOMS?

The chemistry teacher says that, 1 mole of copper (Cu) weighs 63,5 grams; 1 mole of gold (Au) weighs 197 grams. In this case, he asks the students questions about their opinions on the atomic numbers of gold and copper. After discussing for a while, the students' opinions are collected in three groups.



First Group: "Copper contains more atoms"

Second Group: "Gold contains more atoms"

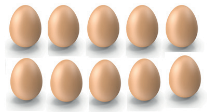
Third Group: "Both of them contain the same number of atoms"

Which group do you agree with? Explain your answer scientifically.

The Correct Answer and Its Explanation: The third group's answer, "Both contain the same number of atoms," is correct. In daily life, we sometimes use units like dozens, decks and pairs to make counting things easier. Dozens always represent 12. But not every dozen has the same mass. For example, the masses of a dozen eggs and a dozen grapes are not equal. The same logic applies to the mole concept. In this case, 1 mole of copper atoms and 1 mole of gold atoms both contain $6.02x10^{23}$ particles. Students may think that the one with the bigger mass should have the higher number of particles. However, different element atoms are different from each other, so their masses are different. Accordingly, when the atomic elements are taken into consideration, although 1 mole of the different elements contain the same number of atoms, the mass of 1 mole from each will also be different due to the fact that the masses of one atom from each are different.

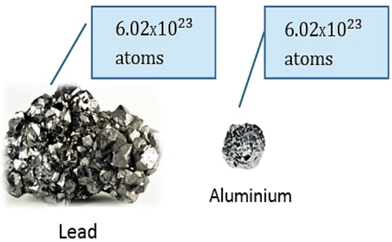
A dozen grapes

A dozen eggs



Formative Assessment Probe 3

MOLAR MASS



The teacher tells the students "The molar mass of lead (Pb) is 207 grams and aluminums' (Al) is 27 grams". "When we take the molar mass of these two elements, does it make sense that they contain the same number of atoms (6.02x1023)? Students' answers are as follows.

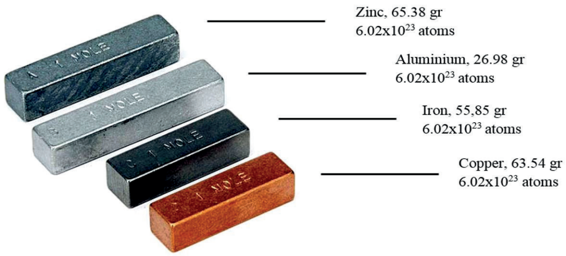
Elif: "No, because led (Pb) has a higher number of particles"

Aydan: "Yes it makes sense because 1 mole was taken from each one."

Özlem: "No, since the distance between molecules in each element is different, so is the number of atoms. "

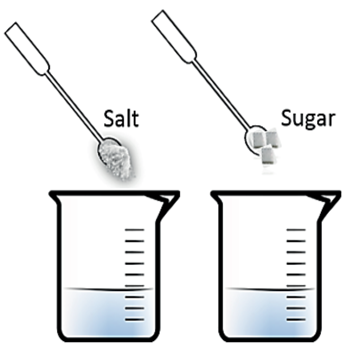
Which students' opinion do you agree with? Explain your answer scientifically.

The Correct Answer and Its Explanation: Aydan's answer, "Yes, it makes sense because one mole was taken from each element." is correct. Because, considering the atomic structures of elements, the masses of different element atoms with equal mole numbers are different from each other. Because the masses of each atom of different elements are different, the mass of 1 mole of different elements will also be different. However, one mole of both has the same number of particles and contains $6.02x10^{23}$ atoms. Mole can be thought of as a dozen units in daily life. This can be likened to a dozen oranges and a dozen watermelons being the same in number but different in mass. Below is an image of one mole taken from different element atoms.



Formative Assessment Probe 4

WHICH ONE'S FREEZING POINT IS LOWER?



Two beakers containing the same amount of water are mixed by adding 4 moles of sugar to one and 4 moles of salt to the other. Student views on the freezing points of the prepared solutions are as follows.

Ayse: "The freezing point of saltwater is lower."

Mehmet: "The freezing point of sugar solution is lower"

Ali: "The freezing points of the two solutions are equal."

Which students' opinion do you agree with? Explain your answer scientifically.

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The Correct Answer and Its Explanation: Ayse's answer, "The freezing point of salt water is lower," is correct. In a solution, properties that vary depending on the total number of particles per unit volume of the solution, which are not dependent on the chemical structure of the solute, are called colligative properties. When the saltwater solution and the glucose solution taken at the same concentration are compared, the saltwater solution freezes at a lower temperature. Because the salt solution contains more particles than the sugar solution. It should be noted that salt is ionically soluble and sugar is molecularly soluble. When 4 mols of salt are dissolved in water, it ionizes into sodium and chloride ions. That is, it contains a total of 8 moles of particles (ions). When 4 moles of glucose are dissolved in water, 4 moles of molecules are formed because of molecular solubility. The number of particles in sugar solution is less than salt solution. Therefore, the salt solution freezes at a lower temperature than the sugar solution.

$4NaCl_{(s)} \rightarrow 4Na^{+}_{(aq)} + 4Cl^{-}_{(aq)}$	$4\ C_6H_{12}O_{6(s)} \rightarrow 4\ C_6H_{12}O_{6(aq)}$
4 particles + 4 particles = 8 particles	4 particles

While the formative assessment probes and the agreement ring management were applied, the following information was also used in the feedback given about the mole issue at the end of each question application. The information in question is presented below, adapted from the Heath Science 3 book (Carle et al., 1996). The focus is on what is produced and how much is produced in chemical reactions. To calculate how much of a substance is produced, the number of atoms must be known. The Avogadro number ($6.02x10^{23}$) is used to express the number of atoms. Due to his work in the field, this number was named after the Italian chemist Amadeo Avogadro. The most important difficulty in understanding the mole concept is that the atoms are very small and the Avogadro number is very large. Because students do not have the experience of counting extremely small things that cannot be seen in daily life and using huge numbers such as Avogadro's, they have great difficulty in understanding / intuiting them. Instead of counting many things one by one in daily life, we count them by grouping them: dozens of pens (12), eggs in viol (30), paper in packeges (500). These units are quite useful in daily life to specify quantity. While people use concepts such as packages, dozens, and viols for shopping, chemists use the mole to count atoms, molecules, ions and electrons. But because an atom is so small, it is impossible to see or count a dozen or a pack. The Avogadro number is very large. In order for students to understand this number, they may need to associate it with something they know from everyday life. For example; if a grain of rice is $1.75x10^{-5}$ kg what is the mass of a one mole rice? When the mass of a grain of rice is multiplied by the Avogadro number ($1.75x10^{-5}$ kg x $6.02x10^{23}$), the result is $1.05x10^{19}$kg / moles. In order to relate this number to something more familiar, students may be asked the following question. How many cars would the mass of this much brass equal to? Assuming the average mass of a car is 1800 kg ($1.05x10^{19}$ kg: 1800 kg), the result is equal to 5.9 $x10^{15}$ cars. If this number is divided by (7.632,819,325) the total human population of the world, that means 800,000 cars per person. In other words, $6.02x10^{23}$ grains of rice mean 0.8 million cars for every woman, man and child in the world. Since $6.02x10^{23}$ is a very large number to count individually, the mass of the same number of atoms is determined by measuring. For example; payment for aluminium cans in recycling is made per box. However, the boxes are not counted individually. The mass of the aluminium cans is measured, then divided by the weight of the cans to calculate how many. This is called mass counting. A similar method is used to count very large atoms. The periodic table specifies the atomic mass units of atoms. For example aluminium is 26.98 akb. But since it is easier to measure the mass with scales, it is useful to know how to compare akb to grams. Since 1 akb = $1.66x10^{-23}$ g, the mass of an aluminium atom is 20.98 akbx$1.66x10^{-23}$ = $4.48x10^{-23}$ g Assuming that we have 26.98 g of aluminium, the number of atoms in it can be found by applying the method in the aluminium box calculation 20,98 g Al x 1 atom Al /$4.48x10^{-23}$g Al = $6,02x10^{23}$ Aluminium atoms. As you can see, this number is equal to the Avogadro number. This indicates that the mass of 1 mol ($6.02x10^{23}$) aluminium is 26.98 g. The mass of a mole in grams is the molar mass per element. The molar mass of aluminium is 26.98 g and the mass of one atom is 26.98 akb. The two numbers are equal. This relationship applies to all elements. Because of this relationship we use the periodic table not only to learn the mass (akb) of an atom, but also to learn the value in grams of the mass of a mole atom (Carle et al., 1996).

Data Analysis

The scoring key developed by Karataş, Köse and Coştu (2003) was used for the analysis of the formative assesment probes. In the first tier, students' predictions about the multiple choice part of the probe being correct or incorrect are assessed; and, in the second tier, the explanations of the students "right justification, partialy right justification, wrong justification and empty" were categorized. Below is the evaluation scale for the two-tired questions.

Table 1. Evaluation scale for two-tiered open-ended questions

Comprehension Levels	Explanation	Evaluation Criteria	Points
The Correct Justification	Answers containing all aspects of the valid justification	Correct Answer- The Right Justification **(D.C.-D.G.)**	**3**
Partially correct justification	Answers not containing all aspects of the valid justification	Correct Answer- Partially Correct Justification **(D.C.-K.D.G.)**	**2**
The Wrong Justification	Answers containing false information	Wrong Answer- The Right Justification **(Y.C.-D.G.)**	**2**
Blank	Irrelevant, unclear answer or blank	Correct Answer-The Wrong Justification **(D.C.-Y.G.)**	**1**
		Wrong Answer- The Wrong Justification **(Y.C.-Y.G.)**	**0**

A researcher and a chemistry teacher created evaluation criteria for the open-ended part of the questions. The answer key generated used in the evaluation was examined by the lecturer specialized in science education. The students'answers to the formative assessment probes were examined. The findings were presented in tables. In addition, students' answers before and after the intervention were examined and misconceptions were identified. Students'answers before and after the teaching were analyzed by the second author and a researcher who is a doctoral student. When the results of the two analyzes were compared, it was found that there was a 65% agreement before the teaching and 70% compliance after the teaching. Researchers came together to do an evaluation, and the answers they could not reach a consensus on were examined again. As a result, the percentages of inter-rater reliabilities agreement before and after the teaching increased to 86.90% and 82.60%.

Results

The research had two purposes. The first one was to reveal high school 12th grade students' knowledge about the mole concept by using planned formative assessment probes. The second one is to evaluate students' ability to apply their mole conputations in solving a chemistry problem from daily life (colligative properties). Finally, to evaluate the students' conceptual development on mole, a training intervention was planned and practiced based on the data obtained from students. The findings are presented below.

Evaluation of high school students' conceptual understanding of the mole concept

Three formative assessment probes were used to reveal the students' knowledge of the mole concept. The mass, mole, and particle-number relationships were questioned. Student views on three formative assessment probes were analyzed using a graded scoring key (Karataş, Köse & Coştu, 2003). The results of the analysis are presented in Table 2 by specifying the percentage and frequency values.

Table 2. Students' knowledge of the mole concept (N=23)

	First Question		**Second Question**		**Third Question**	
Category	**f**	**%**	**f**	**%**	**f**	**%**
Correct Answer (C.A.)-Right Justification (R.J.)	3	13,04	3	13.04	21	8.70
Correct Answer (C.A.)-Partially Correct Answer (P.R.J.)	6	26,09	5	21.74	5	21.74
Correct Answer (C.A.) -Wrong Justification (W.J.)	4	17,39	3	13,04	3	13.04
Wrong Answer (W.A.) - Wrong Justification (W.J.)	10	43,48	12	52,17	15	56,52

As shown in Table 2, approximately half of the students gave incorrect answers to the formative assessment probe related to the mole concept. For example, it is seen that most of the students (f = 10, 43.48%) answered the first question in the W.A.- W.J category. A small proportion of the students (f = 3, 13.04%) were found to be answering questions in the C.A – R.J. category, while some of them were answering questions in the C.A -P.R.J. (f = 6, 26.09%) and the C.A- W.J. category(f = 4, 17.39%). Examples of students' explanations are presented below.

"Since 1 mole was taken from both of them, their masses should be equal."

"Iron is heavier because it's a metal."

"Naphthalene has a higher mass because it contains more atoms."

When the comprehension levels of the students were examined according to the second formative assessment probe which questioned the mole concept, results were very close to those of the first question. It is seen that most of the students (f = 12, 52.17%) gave answers in the W.A.- W.J category. A small proportion of the students who answered correctly, in the

C.A – R.J. category (f = 3, 13.04%), while the majority of the respondents were C.A -P.R.J. (f = 5, 21.74%) and 3 students (13,04%) were in the C.A. W.J. category. The prominent statements of the students are listed below.

" 191 g of gold, 63,5 g of copper was taken. Therefore, gold has more atoms."

"There is no right proportion between the mass of the matter and the number of atoms it has."

"The difference in molar masses results from the intramolecular gap. The number of atoms is the same, but the mass increases with the gap."

"The matter with the higher mass has the higher number of particles."

On the other hand, it is seen that a higher proportion of students answered the third question in the W.A.- W.J category (f = 13, 56.52%). Only two (8.70%) of the students who answered correctly were in the C.A – R.J. It was seen that the majority of the students who answered correctly (f = 5, 21.74%) made explanations in the C.A.- P.R.J. category and three of the students (13.04%) responded appropriately to the C.A.-R.J. category. Examples of wrong answers that students wrote were as follows:

"Atomic structures and subatomic particles have different weights because of their structural differences."

"One mole represents the Avogadro number, it's not related to it's grams."

"It is related to the formula d = m / v, which we have seen in physics before. As the distance between molecules increases, the volume increases, the density remains constant, so the mass increases too."

"Even though the number of atoms is the same, the molar masses of these two elements are different because the gap between atoms causes mass and volume differences."

When the reasons given by the students to the open-ended part of the questions are examined, it is seen that they have a lot of incorrect preliminary information or misconceptions about the mole concept.

The effect of the formative assessment-based teaching practice on students' conceptual understanding of the mole concept

Instruction was implemented using The Agreement Circle Technique and the formative assessment probe. Then, students' views on the third formative assessment probe were analyzed in accordance with the rubric. Findings related to before and after instruction are presented in the frequency table in Table 3.

	First Practice			Second Practice		
Category	Student	Frequency	%	Student	Frequency	%
C.A.-R.J.	Ö20, Ö22	2	8.70	Ö1,Ö6,Ö14,Ö17, Ö20,Ö22	6	26.09
C.A.- P.R.J.	Ö1, Ö10, Ö17, Ö18, Ö19	5	21.74	Ö3,Ö8,Ö10,Ö11, Ö15,Ö18,Ö19,Ö21	8	34.78
C.A.- W.J.	Ö2, Ö3,Ö4	3	13.04	Ö2, Ö4,Ö13	3	13.04
W.A.- W.J.	Ö5,Ö6,Ö7,Ö8,Ö9,Ö11,Ö12,Ö13,Ö14,Ö15,Ö16, Ö21,Ö23	13	56.52	Ö5,Ö7,Ö9,Ö12, Ö16,Ö23	6	26.09

When the pre- and post- scores were compared, it was found that 8.70% of the students answered the question in the C.A.-R. J. category before teaching. In addition, 21.74% of the students answered the question at the C.A.-P.R.J. category, while this percentage increased to 34.78% after teaching. The percentage of students who responded in the C.A.-W.J. category fell from 56.52% to 26.09%.

The answers given by the student with the S6 code before and after formative assessment practices are presented below.

"One mole represents the Avogadro number, it's not related to it's grams" the answer in the W.A-W.J. category.

"The masses of atoms with equal moles are different from each other. Because they are different atoms and therefore have different atomic weights." the answer in the C.A.-R.J category.

S14 coded students gave the following answer before and after the teaching. The answer in the W.A.-W.J category: *"Although they have the same number of moles, their masses can be different."* The answer in the C.A.-R.J. category: *"The number of atoms they contain are the same, but since the mass of each atom is different from each other, lead and aluminum have different masses at the same moles."*

The level of students' ability to explain a chemistry question from daily life using the concept of mole

This exercise tried to evaluate the students 'skills for explaining a question about daily life by using the mole concept. Students were asked about the freezing point depression effect on solvents, such as water, when salt (ionic bound) and sugar (covalently bound) are dissolved in the solvent. Responses were analyzed by using the rubric. Percentage and frequency values of the findings are presented in Table 4.

Table 4. The percentage and frequency values of the study group students' answers to the fourth formative assessment probe "Which Ones' Freezing Temperature is Lower?"

Evaluation Criteria	**f**	**%**
Correct Answer -Wrong Justification	2	8.70
Correct Answer -Partially Correct Justification	10	43.50
Correct Answer -Wrong Justification	7	30.40
Wrong Answer - Wrong Justification	4	17.40

As can be seen in Table 4, the large group of students (f = 10, 43.48%) answered questions in the C.A.- P.R.J. category. It was seen that a small portion of the students who answered correctly (f = 2, 8.70%) were in the C.A. – R.J. category, the one-third of the students (f = 7, 30.43%) made statements in the C.A.-W.J. category and 4 students answered questions appropriate to the (17.39%) W.A.-W.J. category.

The students' explanations about answers are presented below:

"Salt, lowers the boiling point of water."

"When sugar dissolves in water, it ionizes. When the salt dissolves in water, the amount of ions formed is less than that of sugar. "

"The covalent bond is stronger than the ionic bond, therefore saltwater has a lower freezing point. "

Discussion and Conclusion

In this study, the conceptual comprehension levels of high school 12th grade students about the mole were examined by using three formative assessment probes. Students has been found that there are great deficiencies in their conceptual understanding levels. The majority of students prior to the teaching practice answered questions in the W.A.-W.J. category. It was seen that the students who made the right guess generally had difficulty in explaining the concept scientifically. The written explanations remained partially acceptable. This shows that the students do not reach a sufficient level of conceptual understanding in the lessons. The answers given to the open-ended part of the formative assessment probes show that the students have very serious misunderstandings or misconceptions about the mole concept. It was revealed that some of the students were wrong to define the concept of mole with Avogadro number and used synonyms rather than a unit. These results correspond to the research results that Tullberg and the others got (1994). Some students think that the mole concept corresponds to the mass concept, while others try to explain it by making a false connection with the density concept. This may be due to the fact that the terms molar mass and density all refer to the amount of matter in their definitions. In their 1993 study, Furió and his friends stated that the amount of substance had no clear meaning for either students or teachers. Similarly, studies by Furió et al (2002) and Staver & Lumpe (1995) showed that students expressed the term matter-quantity as the mass of the matter. Some of the students stated that the Avogadro number was the reason why particle numbers of substances that have different masses were the sameansBut he couldn't present a conceptually correct justification. This situation coincides with the inability to understand the mole concept, leading students to memorize formulas (Chong, 2016).

In the question about the effect of solute on the freezing point of water, more than half of the students were able to predict the correct option. However, the rate of students' scientific explanation of their predictions is below 10%. This is where the critical importance of formative assessment emerges. Because, skills such as being able to explain, giving examples, solving questions and establishing a connection with everyday life are necessary for conceptual understanding. If this question was asked as multiple choice, it would be accepted that the vast majority of students understood this topic conceptually, considering their correct predictions. However, when the explanation part of the problem was examined, it was determined that the students made the correct prediction, but there were important deficiencies in their explanations. For example, a student who estimated that sugar will lower the freezing point of the water more, wrote that the amount of ions in salt water is less than that of sugar as explanation. In addition, there are explanations such as *"sugar will ionize when dissolved in water"*; *"the covalent bond is stronger than the ionic bond and therefore the freezing point of the salt is low."* Misconceptions about the ionization of sugar in water have been revealed in many studies in the literature (Coştu, Ayas, Açıkkar & Çalık, 2007; Eyceyurt Türk, Akkuş, & Tuzun Nur, 2014)

After teaching the mole concept by using the formative assessment technique "The Agreement Circle", students' conceptual understanding levels were analyzed. As a result, the number of students giving correct answers and explanations increased. In addition to the increase in the number of correct answers, more meaningful explanations were obtained from the students. For example; Before teaching a student said, *"The* *number of Avagadro is the same for each atom and the atoms contain as many atoms as the number of Avagadro. This is also related to the mole. If the mole number is the same, they contain atoms in the same Avagadro number. But mass can be different."* After the instruction, he wrote, *"Although the number of moles is the same, since the atomic masses are different, the masses are different. But the number of particles is the same."* In the students' explanations, there were fewer misconceptions after the instruction. The formative assessment technique called Agreement Circle has been successful in improving students' understanding of moles, one of the basic concepts of chemistry. This result supports the results of other research showing that formative assesment supports conceptual understanding (Bulunuz & Bulunuz, 2017; Aydeniz & Pabuccu, 2011; Decristan et al., 2015; Yalaki, 2010). This study has two important limitations. The first is the small number of students, and the other is it had to be done in a limited time period. For these reasons, only one formative assessment probe regarding mole could be compared before and after intervention. Due to the busy schedule of the study school, the final test was given 2-3 weeks later. This increases the likelihood that students will remember the correct answers after the first test. By using the rest of the formative assesment probes further research can be conducted. For example, longer-lasting studies involving different grade levels can be conducted using these formative assesments probes.

Suggestions

Chemistry courses mainly include abstract concepts and topics. The content of the chemistry courses includes many algorithmic problem solutions related to these topics and concepts. The concept of moles is key in these algorithmic problem calculations. In order to save chemistry teaching from rote memorization, it is necessary to start from the concept of mole. In this context, formative assessment probes designed to teach the concept of moles should be disseminated. In the literature there are few formative assesment probes developed in the field of chemistry. Formative probes developed in this study can be inserted into chemistry textbooks. These questions can be videotaped and made available on Youtube and social media. Formative assessment techniques and probes can be disseminated by including chemistry teachers in in-service training. In today's education system, students usually take summative assessment and receive grades. While the applications of this research were being carried out, it was observed that the sample students expressed grade anxiety. Formative assessment practices go beyond grading and fuse assessment with teaching. This approach will also help reduce students' anxiety. In the study, it was seen that students generally had difficulty in justifying their correct answers. Formative assessment classroom techniques focus on exposing students' ideas to each other and their teachers. In this way, more opportunities can be provided for students to have the courage to think, create their own ideas, and share these ideas. This teaching can contribute to the development of students' explanation skills over time.

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