International Journal on Advanced Science Engineering Information Technology

Vol.12 (2022) No. 6
ISSN: 2088-5334

The Development of Structured Inquiry Based Module on Chemistry Learning: Its Impact on Students' Mental Models

Hidayati [a,*], Hilma Suryani [b]

[a] State Islamic University of Raden Fatah, Palembang, 30126, Indonesia
[b] State Islamic University of Sulthan Thaha Saifuddin, Jambi, 36363, Indonesia
Corresponding author: *hidayati.hhidayati@gmail.com

***Abstract*—Mole concept is an essential part of chemistry learning and has been the prerequisite to learning other chemistry concepts. The learning source has not yet completely connected the three representations levels. The inability to connect the three levels of representations might affect students' learning outcomes and mental models. This study aims to determine the effect of structured inquiry-based modules on students' mental models of the mole concept. The design of a study is *Randomized Control Group Postest Only Design*. There were 141 students from two Senior High Schools in Padang recruited as the samples of the study. The instruments are *two-tier* mental diagnostic tests and semi-structured interviews. The model category of students' mental model on mole concept in experimental group I demonstrates that the level target was 34.29%, Intermediate 3 was 60%, and Intermediate 2 was 5.71%. Control group I shows that the target level was 28,57%, Intermediate 3 was 45.71%, and Intermediate 2 was 25.71%. Meanwhile,experimental group 2 shows that the level target was 22.86%, Intermediate 3 was 71.43%, and Intermediate 2 was 5.71%. Control group II had the following categories, the level target was 14.29%, Intermediate 3 was 62.86%, and Intermediate 2 was 22.86%. The result of the t-test on hypotheses reveals that the mental model of the mole concept in the experimental group was higher than the control group of both schools. Hence, it can be said that the module affects students' mental models of mole concepts in both schools.**

***Keywords*—Mental model; module; mole concept; structured inquiry.**

Manuscript received 7 Aug. 2021; revised 12 Jan. 2022; accepted 21 Mar. 2022. Date of publication 31 Dec. 2022.

I. INTRODUCTION

Chemistry is a branch of science that involves several abstract concepts that students might misinterpret. A chemistry material that most students might find difficult to learn as it deals with the abstract concept is the mole concept. [1] Students could not connect the mole concept with mass and the number of particles. Besides, teachers had a low conceptual understanding of relationships between relative atomic/formula mass and molar mass as connecting ideas between atomic theory and mol concept [2].

A textbook is a learning resource that a teacher frequently uses in teaching and learning [3]. The learning component has the highest level of interaction for students. In other words, students develop their paradigms and get the information from the textbook. A teacher prepares, carries out, and evaluates the teaching and learning activity by referring to the textbook's content [4]. The difficulties in understanding the learning material might be due to the textbook used by the teacher in the learning process [5]. Most teachers only use symbolic representations and focus on calculating the stoichiometry teaching process without developing an understanding of the concept [6]. Hence, a textbook used in the teaching and learning process that aims to direct students to understand the concept may mislead the students. In some cases, it can also cause the students to misinterpret the concept.

The textbook used at schools has not yet comprehensively presented chemistry materials, teaching chemistry through interconnection among three levels of representations. The representations consist of macroscopic (concrete), submicroscopic (illustrated by models related to the structure of the atom, molecule, and ion), and symbolic (symbols, formulas, stoichiometry reaction, graphs, etc), which are fruitful in understanding and chemistry instructions [7]. Most textbooks used in the learning process have not connected the three levels of representation as a whole [7], [8], [9].

In the teaching and learning process, a teacher uses concrete and visual teaching aid as a diagram of representation, oral and verbal description, symbolic representation, and physical model to convey the meaning of new concepts and terms. The three levels of representations demonstrate that students must know macroscopic, submicroscopic, and symbolic to learn and understand chemistry [10], [11], [12], [13].

Understanding chemistry depends on representation since it assists the mental model development. Three levels of chemistry representations are connected and reflected in students' mental models [14], [15]. One of the urgencies of exploring mental models is to master chemical concepts, and this is intended to improve the chemistry learning process [16], [17]. A teacher should know how students develop their mental model to ensure they do not do it mistakenly because a mental model is essential to constructing a theory and chemistry practices [18], [19].

Students must be actively involved in using the teaching material. It is suggested to have teaching material that allows the students to formulate problems, collect and organize the data to prove hypotheses, and make the conclusion. Those steps are done in sequence, so the students can find the concept of learning material by themselves under learning objectives. In collecting and organizing data, teaching material should present and connect three levels of chemistry representations. The mental model will develop as the students know and connect the three levels of chemistry representations well. The order of those steps is the phase in structured inquiry learning.

II. MATERIALS AND METHOD

The design of the study is a randomized control group posttest-only design. The design is as follows:

TABLE I
RESEARCH DESIGN

Group	Treatment	Post-test
Experimental	X	T
Control	Y	T

Note: X is the instruction with the module, Y is the instruction without the module, and T is Post-test

This study was conducted at two Senior High School Padang, SMA N A Padang and SMA N B Padang. The sampling technique used in the present study is cluster purposive sampling. The experimental group is Science Class 2, and the control group is Science Class 3 in SMA N A Padang. Meanwhile, in SMA N B Padang, the experimental group is Science Class 1, and the control group is Science Class 5. The experimental groups were taught by using the structured inquiry-based module, while the control groups were taught using the textbook used at school.

The instruments used in the study are a *two-tier* diagnostic test and a structured interview. The students' answers are grouped into four categories: correct on both levels, correct on the first level but wrong on the second level, wrong on the second level but correct on the second level, and wrong on both. The diagnostic instrument used in the current study was adapted from the *Two-tier* test developed by Yang [20] applies the scoring system that the answer is correct if both statements are correct. However, the scoring system can be developed as follows:

TABLE II
SCORING SYSTEM OF TWO-TIER DIAGNOSTIC TEST

Answer	**Score**	**Level of Understanding**
Correct answer, correct reason	2	A lot
Correct answer, wrong reason	1	A little
Wrong answer, correct reason	1	A little
Correct answer, correct reason	0	None

Moreover, the data were analyzed concerning understanding macroscopic, submicroscopic, and symbolic levels and possible misunderstandings. The data were then grouped into five categories and analyzed using the formula below:

$$\text{percentage} = \frac{\text{n}}{\text{N}} \text{ x } 100\% \quad (1)$$

n: The number of students on the indicator of the mental model

N The total number of students

100: Fixed number, Zafri [21]

TABLE III
THE CATEGORY OF MEAN SCORES TWO-TIER DIAGNOSTIC TEST, PARK [22]

Number.	Score	Category	Mental Model
1.	<25	Very poor	Initial Model
2.	25-49	Poor	Intermediate 1
3.	50-74	Moderate	Intermediate 2
4.	75-99	Good	Intermediate 3
5.	100	Excellent	Target Model

From Table 3, the initial model is the model an individual carries since birth, or it is the model formed because of the wrong environment or concept and image structure unaccepted in science, or students are unable to find the concept. Intermediate 1 mental model is the model which has been formed or concept and explanation given is close to the truth of science and image structure generated cannot be accepted or vice versa. Intermediate 2 mental model is students' mental model which is indicated by the concept owned by students and image structure created is close to the truth of science. Intermediate 3 mental model is marked by the student's explanation/concept, which is acceptable in science, and structure image created is close to the truth, or explanation/concept is not well accepted in science, yet the image structure is correct. A target mental model is a mental model marked by the concept/explanation and image structure created by the students is acceptable in science [22].

The data were analyzed descriptively and quantitatively. The effectiveness of structured inquiry-based modules can be seen through the experimental and control group's hypotheses of students' learning outcomes. Prior to hypotheses testing, normality and homogeneity tests were carried out.

III. RESULT AND DISCUSSION

The study results reveal the effect of the structured inquiry module on students' mental models of the mole concept. It is shown in Table 4. Table 4 shows that the significance value of SMA NA Padang is 0.011 on the significance level (α = 0.05), and the significance value is smaller than 0.005, suggesting that H_0 is rejected. Similarly, at SMA NB, the significance value is 0.000, suggesting that H_0 is rejected. It indicates that there is an effect of the module on students' mental models.

TABLE IV
THE RESULT OF HYPOTHESES TESTING OF STUDENTS' MENTAL MODEL

School	Group	N	Mean	S	Sig.	
SMANA Padang	Experimental	35	84.89	9.427	0.011	H_0 is rejected
	Control	36	79.11	9.282	0.011	
SMANB Padang	Experimental	35	81.06	9.362	0.000	H_0 is rejected
	Control	35	68.91	12.030	0.000	

Hypotheses:
H_0: There is no effect of the module on students' mental model
H_1: There is the effect of the module on students' mental model

The questions were developed by involving three levels of representations. The levels are connected in order to avoid misunderstanding. Three of the four questions involve mathematical calculations requiring the students to connect three levels (macroscopic, submicroscopic, and symbolic). The result of a *two-tier* diagnostic test is as follows:

TABLE V
STUDENTS' MENTAL MODEL OF MOLE CONCEPT

School	Mental Model	Students' mental model	
		Experimental	Control
SMAN A Padang	Target Model	34.29%	28.57%
	Intermediate 3	60.00%	45.71%
	Intermediate 2	5.71%	25.71%
	Intermediate 1	-	-
	Initial Model	-	-
SMAN B Padang	Target Model	22.86%	14.29%
	Intermediate 3	71.43%	62.86%
	Intermediate 2	5.71%	22.86%
	Intermediate 1	-	-
	Initial Model	-	-

Table 5, students' answer analysis on a *two-tier* diagnostic test, demonstrates that students of SMA NA Padang in the experimental group (34.29%) and control group (28.75%) are in the category of target mental model. Meanwhile, students of SMA N B Padang in the experimental (22.86) and control group (14.29%) are in the category of target mental model. The mental model suggests that students' concept in the form of picture and explanation is precise scientifically.

At SMA N A Padang, most students in experimental group (60%) and control group (45.71%) are in the intermediate 3. It means that a student's mental model in the form of a picture and explanation is acceptable scientifically. Students of SMA N B Padang in the experimental (71.43%) and control group (62.86%) are in the intermediate 3. There are more students in both control groups at SMA N A and SMA N B in the category of intermediate 2 than in the experimental groups. This mental model shows that students' concept in the form of structured figure is close to the truth of science. The category of students' mental model indicates students' understanding of the mole concept. The category of students' model mental describes how students understand each test item of the mole concept. The analysis of students' mental model of the mole concept based on the question number is illustrated in Table 6.

A previous study used *two-tier* diagnostic tests to determine students' understanding of a particular topic. The series of *two-tier* diagnostic tests is administered to determine students' understanding, and later, the questions and test items are confirmed through interviews to determine the types of students' mental models [23].

TABLE VI
STUDENTS UNDERSTANDING OF MOLE CONCEPT

School	Item	Experimental			Control		
		Max	Min	None	Max	Min	None
SMAN A Padang	1	77.14	22.85	-	61.1	38.9	-
	2	82.86	11.43	5.71	75	22.22	2.78
	3	57.14	40	2.86	50	50	-
	4	97.14	2.86	-	88.9	11.1	-
Total Percentage		78,57	19.29	4.29	68.75	30.56	2.78
SMAN B Padang	1	65.71	34.28	-	48.57	42.86	8.57
	2	77.14	22.86	-	62.86	37.14	-
	3	65.71	31.43	2.86	28.57	20	14.29
	4	88.57	8.57	2.86	100	-	-
Total Percentages		74.28	24.29	2.86	60.00	33.33	11.43

Table 5 demonstrates that the students from both schools, experimental and control groups, had the highest understanding level as they answered question number 4, molar mass. It suggests that most of the students knew how to solve the calculation of mass 1 mole of substance which involves conversion from atomic mass in the atomic mass unit (macroscopic) to mass 1 mole of a substance in gram unit and to decide the total mole of a substance (atom, molecule or ion) (submicroscopic). Students could connect the three levels (macroscopic-submicroscopic-symbolic) once they answered correctly and determined the correct reason.

The little understanding category was found when the students of both schools answered question number 3, deciding the mass of 1 atom in the gram unit. In this question, students could not connect submicroscopic and symbolic levels well. Due to the calculation of the completion process, students first knew the number of particles (atom, molecule, or ion) of 1 mole of a substance. It is proven that in experimental and control groups, SMA N A Padang students' mental model of mole concept is in the intermediate 2 (5.71% and 25.71%). Meanwhile, students' mental model in experimental and control groups SMA N B Padang is in the intermediate 2 (5.71% and 22.86%). The mental model of the mole concept in intermediate 2 would affect students' understanding of the problem solving concerning the number of particles due to students' inability to connect the three levels of representation, especially transformation from a submicroscopic level to a symbolic level.

Students' inability to connect the three levels is due to misunderstanding at the submicroscopic level. It occurs when students answer question 1, discussing the number of particles in 1 mole of a substance. Students of experimental groups (22.85%) and control groups (39.9%) at SMA N A Padang are in the category of little understanding. On the other side, students of SMA N B Padang in the experimental groups (34.28%) and control groups (42.86%) are in the category of little understanding. It indicates that some students still got confused with the definition of 1 mole of substance either in two-tier diagnostic test (level one), or level two and even the students made mistakes in two levels.

Having analyzed the students' answers, students' misunderstanding is in the category of submicroscopic level in which the students did not understand that 1 mole of substance expresses the number of substances containing the number of similar particles to the number of particles in 12 grams C-12. The comparison between mole and particle in the sample is defined as a means to enumerate atomic particles/molecules of substances through the amount of mass macroscopically [24].

The definition of mole indicates that mole has a concept and quantitative calculation. Researches in science education show that the mole concept provides a window through which students understand the quantitative aspects of substance at the microscopic level through understanding the relationship between the amount of substance, the number of elementary particles, mass, and other topics [2]. Meanwhile, the understanding of mole conceptually, the student should be able to perceive the macroscopic world, which they see in the real context as the number, and connect it to the world of the particle [25]. So it is hoped that the teacher will be able to facilitate chemistry learning with three levels of representation that are taught comprehensively [26], [27].

Based on the data in Table 4 concerning students' mental model of the mole concept and Table 5 demonstrates that the students in experimental groups of both schools outperformed the students in control groups. The difference might be caused by using a structured inquiry model in the experimental group.

The textbook used in control groups discussing the mole concept still presents the formulae in solving the mole concept. Mole is written as the comparison between mass (gram) and Relative Atom mass (A_r) or Relative Molecule mass (M_r). In addition, mole is defined as the multiplication equation between molar volume and volume number 22.4 liters. It is inappropriate in chemistry instruction because it can cause misunderstanding. This is in line with the study conducted by Pekdag [28], that $n = m/M_A$ is presented as the equation used to calculate "the total mole." This approach in the textbook neglects the basic quantity of the number of substances. The study conducted by Mweshi [2] shows that the chemistry teachers were perplexed by the description of "the number of substances, " which some considered as mass and/or the number of basic entities.

The learning of the mole concept by using a structured inquiry-based module affected students' understanding and model mental. The module presents the steps of structured inquiry activities supplemented with the interconnection of three levels of representations as well as conversion factors used to discover the concept. As a result, students could develop a mental model of the mole concept and enhance their understanding. By taking into account the teaching and learning process and learning source, the problems that might occur during teaching and learning activities can be minimized. [29], [30], [31] showed that students taught using inquiry with three levels of representation showed greater scientific understanding of matter's particulate nature than students taught with conventional learning.

Having undertaken *a two-tier mental diagnostic test to determine* students' understanding and mental model of the mole concept, the authors interviewed the students to clarify the answers and reasons chosen. The authors selected one experimental group student in each category (target, intermediate 3, and intermediate 2) and one control group student in the same categories. The interview result shows that teaching and learning are one-factor affecting students' mental models. Numerous mental model sources include instruction, language, words, daily experience, social environment, and intuition. The textbook used by the teacher in the teaching and learning process is one of the teaching subcategories [23]. The study by Lin [17] shows that students' mental model in learning the topic of acids and bases belongs to the mental model phenomena category. Students' mental models developed into scientific mental models.

The module can be used in chemistry instruction in highly accredited and moderate schools. Graph 1 shows the statistical analysis of the interactions between school criteria teaching and learning activities conducted using a module, and students' mental model of the mole concept indicates two straight lines that do not intersect. It shows an interaction between school criteria and teaching and learning using the module and students' mental models. Regardless of the school criteria (high and moderate), the teaching and learning using structured inquiry-based modules affect students' mental models of the mole concept. Therefore, teaching and learning using structured inquiry-based modules can be undertaken in all school criteria. The structured inquiry model is also effective and significantly influences students' mental models.

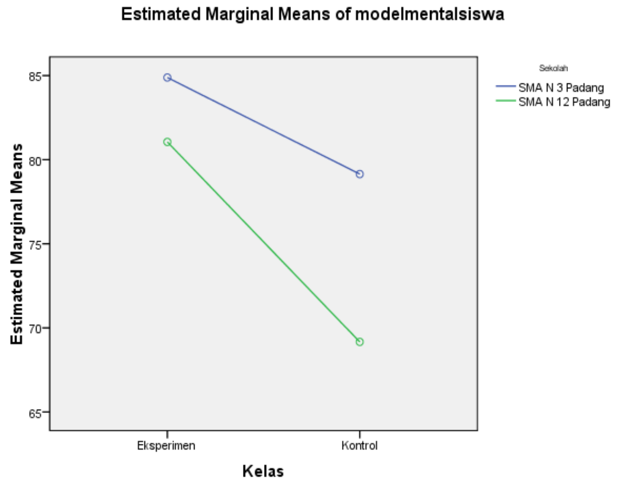

Fig. 1 Graph of interaction between school criteria and learning using the module on students' mental model of concept mole

The structured inquiry model is appropriate to be applied in a module of the mole concept. This is accomplished by considering that the material of the mole concept is mostly abstract, and the teacher's guide is needed to consider students' thinking abilities based on the regular stages.

IV. Conclusion

Concerning the result of the research, it can be concluded that a structured inquiry-based module could promote students' mental model of the mole concept. Students' mental model in the experimental group was higher than those of the control group (in both schools whose students were at average and high proficiency level). The improvement of the mental model was indicated by the results of both schools' hypotheses testing (t-test). The significance value of both schools was lower than 0.05, indicating that students taught using the developed model outperformed those taught without the module. This might be due to the stages of the structured inquiry learning process, which have led the students to comprehend the concept. The authors recommend that other researchers analyze the effectiveness of another inquiry-based module (such as guided inquiry) to determine the effect of the developed module on students' mental models. Furthermore, other researchers could use the structured inquiry module to figure out students' mental module on the chemical equation to compare the results

References

[1] S. H. Chong, N. Goolamally, and K. E. Leong, "Post-secondary science students' understanding on mole concept and solution concentration," *Univers. J. Educ. Res.*, vol. 7, no. 4, pp. 986–1000, 2019, doi: 10.13189/ujer.2019.070410.

[2] E. Mweshi, O. Munyati, and K. Nachiyunde, "Teachers' Understanding of the Link between the Atomic Theory and the Mole Concept," *African J. Res. Math. Sci. Technol. Educ.*, vol. 24, no. 3, pp. 411–422, 2020, doi: 10.1080/18117295.2020.1845462.

[3] K. Vojíř and M. Rusek, "Of teachers and textbooks: lower secondary teachers' perceived importance and use of chemistry textbook components," *Chem. Educ. Res. Pract.*, vol. 23, no. 4, pp. 786–798, 2022, doi: 10.1039/D2RP00083K.

[4] B.P.Sitepu, "Memilih Buku Pelajaran," *J. Pendidik. Penabur*, no. 4, pp. 113–126, 2005.

[5] A. Bergqvist and S.-N. Chang Rundgren, "The influence of textbooks on teachers' knowledge of chemical bonding representations relative to students' difficulties understanding," *Res. Sci. Technol. Educ.*, vol. 35, no. 2, pp. 215–237, Apr. 2017, doi: 10.1080/02635143.2017.1295934.

[6] S. A. Malcolm, E. Mavhunga, and M. Rollnick, "The Validity and Reliability of an Instrument to Measure Physical Science Teachers' Topic Specific Pedagogical Content Knowledge in Stoichiometry," *African J. Res. Math. Sci. Technol. Educ.*, vol. 23, no. 2, pp. 181–194, 2019, doi: 10.1080/18117295.2019.1633080.

[7] X. Chen, L. F. de Goes, D. F. Treagust, and I. Eilks, "An analysis of the visual representation of redox reactions in secondary chemistry textbooks from different chinese communities," *Educ. Sci.*, vol. 9, no. 1, 2019, doi: 10.3390/educsci9010042.

[8] J. E. Upahi and U. Ramnarain, "Representations of chemical phenomena in secondary school chemistry textbooks," *Chem. Educ. Res. Pract.*, vol. 20, no. 1, pp. 146–159, 2019, doi: 10.1039/c8rp00191j.

[9] F. . Goes, X. Chen, C. K. . Nogueira, C. Fernandez, and I. Eilks, "An analysis of the Visual Representation of Redox Reactions," *Sci. Educ. Int.*, vol. 3, no. 1, pp. 313–324, 2020.

[10] K.-D. Su, "Enhancing Students' High-Order Cognitive Skills for Hierarchical Designs in Micro and Symbolic Particulate Nature of Matter," *J. Balt. Sci. Educ.*, vol. 19, pp. 842–854, Oct. 2020, doi: 10.33225/jbse/20.19.842.

[11] A. Berg, D. Orraryd, A. J. Pettersson, and M. Hultén, "Representational challenges in animated chemistry: self-generated animations as a means to encourage students' reflections on sub-micro processes in laboratory exercises," *Chem. Educ. Res. Pract.*, vol. 20, no. 4, pp. 710–737, 2019, doi: 10.1039/C8RP00288F.

[12] C.-Y. Lin and H.-K. Wu, "Effects of different ways of using visualizations on high school students' electrochemistry conceptual understanding and motivation towards chemistry learning," *Chem. Educ. Res. Pract.*, vol. 22, no. 3, pp. 786–801, 2021, doi: 10.1039/D0RP00308E.

[13] L. Wang, G. Hodges, and J. Lee, "Connecting Macroscopic, Molecular, and Symbolic Representations with Immersive Technologies in High School Chemistry: The Case of Redox Reactions," *Educ. Sci.*, vol. 12, no. 7, 2022, doi: 10.3390/educsci12070428.

[14] A. Praisri and C. Faikhamta, "Enhancing students' mental models of chemical equilibrium through argumentation within model-based learning," *Int. J. Learn. Teach. Educ. Res.*, vol. 19, no. 7, pp. 121–142, 2020, doi: 10.26803/ijlter.19.7.7.

[15] T. M. Derkach, "The origin of misconceptions in inorganic chemistry and their correction by computer modelling," *J. Phys. Conf. Ser.*, vol. 1840, no. 1, 2021, doi: 10.1088/1742-6596/1840/1/012012.

[16] A. C. Wardah and A. Wiyarsi, "A systematic review: How are mental model of chemistry concepts?," *Univers. J. Educ. Res.*, vol. 8, no. 2, pp. 332–345, 2020, doi: 10.13189/ujer.2020.080202.

[17] F. R. Amalia, S. Ibnu, H. R. Widarti, and H. Wuni, "Students' mental models of acid and base concepts taught using the cognitive apprenticeship learning model," *J. Pendidik. IPA Indones.*, vol. 7, no. 2, pp. 187–192, 2018, doi: 10.15294/jpii.v7i2.14264.

[18] J. E. V. Ferreira and G. A. Lawrie, "Profiling the combinations of multiple representations used in large-class teaching: pathways to inclusive practices," *Chem. Educ. Res. Pract.*, vol. 20, no. 4, pp. 902–923, 2019, doi: 10.1039/c9rp00001a.

[19] A. Derman, N. Koçak, and I. Eilks, "Insights into components of prospective science teachers' mental models and their preferred visual representations of atoms," *Educ. Sci.*, vol. 9, no. 2, pp. 1–19, 2019, doi: 10.3390/educsci9020154.

[20] Y. Xiao, J. Han, K. Koenig, J. Xiong, and L. Bao, "Multilevel Rasch modeling of two-Tier multiple choice test: A case study using Lawson's classroom test of scientific reasoning," *Phys. Rev. Phys. Educ. Res.*, vol. 14, no. 2, p. 20104, 2018, doi: 10.1103/PhysRevPhysEducRes.14.020104.

[21] Zafri, *Penelitian Pendidikan*. Padang: Padang: Universitas Negeri Padang, 1999.

[22] E. J. Park, G. Light, S. Swarat, and D. Denise, "Understanding learning progression in student conceptualization of atomic structure by variation theory for learning," *Learn. Progress. Sci. Conf.*, 2009.

[23] J. W. Lin and M. H. Chiu, "Exploring the characteristics and diverse sources of students' mental models of acids and bases," *Int. J. Sci. Educ.*, 2007, doi: 10.1080/09500690600855559.

[24] J. R. Staver and A. T. Lumpe, "Two investigations of students' understanding of the mole concept and its use in problem solving," *J. Res. Sci. Teach.*, 1995, doi: 10.1002/tea.3660320207.

[25] J. Claesgens and A. Stacy, "What are students' initial ideas about 'amount of substance'?:"Is there a specific weight for a mole?"," *Annu. Meet. Am. Educ. Res. Assoc. (Chicago, IL, April. 2003)*, p. 26, 2003.

[26] S. W. Locatelli and B. Davidowitz, "Using metavisualization to revise an explanatory model regarding a chemical reaction between ions," *Chem. Educ. Res. Pract.*, vol. 22, no. 2, pp. 382–395, 2021, doi: 10.1039/D0RP00339E.

[27] K. S. W. GRM and I. Devetak, "The influence of active learning and submicrorepresentations on 14-year-old students' understanding of the alkaline earth metal concepts," *J. Serbian Chem. Soc.*, pp. 1–16, 2021.

[28] B. Pekdağ and N. Azizoğlu, "Semantic mistakes and didactic difficulties in teaching the 'amount of substance' concept: A useful model," *Chem. Educ. Res. Pract.*, 2013, doi: 10.1039/c2rp20132a.

[29] C. Mamombe, K. C. Mathabathe, and E. Gaigher, "The Influence of an Inquiry-based Approach on Grade Four Learners' Understanding of the Particulate Nature of Matter in the Gaseous Phase: A Case Study," *Eurasia J. Math. Sci. Technol. Educ.*, vol. 16, no. 1, pp. 1–11, 2020, doi: 10.29333/ejmste/110391.

[30] J. Dunn and U. Ramnarain, "The effect of simulation-supported inquiry on south african natural sciences learners' understanding of atomic and molecular structures," *Educ. Sci.*, vol. 10, no. 10, pp. 1–12, 2020, doi: 10.3390/educsci10100280.

[31] D. N. L. Laksana, W. Dasna, and N. Degeng, "The Effects of Inquiry-Based Learning AND Learning Styles on Primary School Students' Conceptual Understanding in Multimedia Learning Environment," *J. Balt. Sci. Educ.*, vol. 18, pp. 51–62, Feb. 2019, doi: 10.33225/jbse/19.18.51.