EduChemia
(Jurnal Kimia dan Pendidikan)

Vol.8, No.1, 2023
e-ISSN 2502-4787

ANALYSIS OF THE STUDENT'S ABILITY TO INTERCONNECT MACRO-SUBMICRO-SYMBOLIC REPRESENTATION ON ELECTROLYTE SOLUTION CONCEPT

Indah Langitasari*[1,3], Babang Robandi[2]

[1]*Doctoral Program of Science Education, FMIPA, Universitas Pendidikan Indonesia,*
Jl. Dr Setiabudi No.229, Isola, Kec. Sukasari, Bandung City, West Java – Indonesia

[2]*Pedagogic Program, FIP, Universitas Pendidikan Indonesia*
Jl. Dr Setiabudi No.229, Isola, Kec. Sukasari, Bandung City, West Java – Indonesia

[3]*Departemen of Chemistry Education, FPMIPA, Universitas Sultan Ageng Tirtayasa, Banten, Indonesia.*

E-mail: *indahlangitasari@upi.edu

Received: 22 Mei 2023. Accepted: 17 Juni 2023. Published: 31 Juli 2023

DOI: 10.30870/educhemia.v8i1.19974

Abstract: A comprehensive understanding of chemistry requires thinking using three levels of interconnected representation: macroscopic, submicroscopic, and symbolic. Electrolyte solutions are one of the concepts in chemistry that need to involve the interconnection of the three levels of chemical representation in studying them. This study aims to analyze the students' ability to interconnect the three levels of chemical representation in the electrolyte solutions concept. This research used a descriptive quantitative research design. The research instrument used The Multiple Representation of Electrolyte Test (MRET). The research data were analyzed descriptively based on the students' answer patterns. The results showed that the student's ability to interconnect the three levels of chemical representation in the electrolyte solutions concept is low. Students are only able to make interconnections between macroscopic and symbolic levels.

Keywords: Interconnection, representation, macroscopic, submicroscopic, symbolic, electrolyte solutions, MRET

Abstrak: Pemahaman kimia yang komprehensif memerlukan pemikiran menggunakan tiga level representasi yang saling berhubungan: makroskopis, submikroskopis, dan simbolik. Larutan elektrolit merupakan salah satu konsep dalam kimia yang perlu melibatkan interkoneksi tiga level representasi kimia dalam mempelajarinya. Penelitian ini bertujuan untuk menganalisis kemampuan siswa dalam menghubungkan tiga level representasi kimia dalam konsep larutan elektrolit. Penelitian ini menggunakan desain penelitian deskriptif kuantitatif. Instrumen penelitian yang digunakan adalah *The Multiple Representation of Electrolyte Test* (MRET). Data penelitian dianalisis secara deskriptif berdasarkan pola jawaban siswa. Hasil penelitian menunjukkan bahwa kemampuan siswa dalam menginterkoneksikan tiga level representasi kimia pada konsep larutan elektrolit rendah. Siswa hanya mampu membuat interkoneksi antara level makroskopis dan simbolik.

Kata kunci: Interkoneksi, representasi, makroskopik, submikroskopik, simbolik, Larutan elektrolit MRET

INTRODUCTION

Chemistry concepts have complex, abstract, concrete, and tiered characteristics. They often make students difficult to understand chemistry. Learning chemistry must consider the characteristics so students can easily understand chemical concepts. Understanding chemistry requires thinking using three levels of representation interconnected that are macroscopic, submicroscopic, and symbolic (Kelly et al., 2004). Chemistry can be well understood if learning it involves interconnecting the three levels of representation (Adadan, 2013). Macroscopic representation is a concrete level relating to real observations with the five senses to the facts or chemical phenomena. Submicroscopic representation is an abstract level that describes a chemical process that deals with the interactions of atoms, molecules, and ions. Symbolic representations involve using symbols to represent macroscopic and submicroscopic phenomena to be easily understood through reaction equations, mathematical equations, graphs, reaction mechanisms, and analogies analogy (Johnstone, 1982). Using three levels of representation in chemistry learning is essential to help students learn chemistry more meaningfully and remember chemical concepts more easily (Tuysuz et al., 2011).

One important concept in chemistry is the electrolyte-non-electrolyte solution. Electrolyte and non-electrolyte solutions are important fundamental concepts in chemistry taught in secondary schools. The characteristics of the electrolyte-nonelectrolyte solution are abstract, concrete, and tiered. Chemical material is abstract because concepts in chemistry, such as atoms, molecules, and chemical reactions, cannot be seen in plain view. In studying electrolyte-nonelectrolyte solutions, students cannot directly observe submicroscopic events that occur, such as interactions between solvent molecules and solutes when forming solutions, dissociation or ionization in strong electrolyte solutions and weak electrolytes, and electrical conductivity in electrolyte solutions.

Concrete chemical concepts can be demonstrated through experiments in the laboratory by observing the changes that occur. For example, the electrical conductivity of an electrolyte solution can be observed through the flame of a gas lamp and bubble using an electrolyte tester. Chemical material is tiered, meaning that one material with another material is interrelated. One material is the basis for learning the next material. If understanding the basic concept is lacking or incorrect, it will affect an understanding of the higher-level concept. As with electrolyte-nonelectrolyte solutions and redox reactions, it is the basis for studying electrochemical concepts. The lack of understanding of the electrolyte-nonelectrolyte solution concept and redox reactions causes students to experience difficulties in studying electrochemical concepts. Therefore, the electrolyte-nonelectrolyte solutions and redox reactions concepts must be well understood to study the electrochemical concept easily.

Electrolyte and non-electrolyte solutions are a chemical topic that has high generalization and abstraction concepts, so in understanding this topic, students must be able to build and interconnect their understanding macroscopically, submicroscopically, and symbolically (Aulia & Andromeda, 2019; Fitriyani et al., 2019). These three levels' macroscopic, submicroscopic, and symbolic representations and interconnections are very important and needed to understand the electrolyte-nonelectrolyte solutions concept. The interconnection of the three levels of representation is very petrifying for students to build the structure of understanding chemical phenomena (Chittleborough, 2004). Macroscopic, symbolic, and submicroscopic representations complement each other in explaining chemical phenomena. Explanation of chemical phenomena will not be well understood using only one or two levels of representation. However, the facts show that learning the electrolyte solutions concept in schools generally involves macroscopic and symbolic levels only, whereas submicroscopic levels tend to be ignored. This condition causes students difficulty in studying the electrolyte solution concept at the submicroscopic level. Garnett & Treagust (1992) reported that some students were confused about the nature of electric currents in metal conductors and electrolyte solutions.

Chemical learning which only emphasizes symbolic level and problemsolving, causes students to have difficulty developing a conceptual understanding of chemistry (Chandrasegaran et al., 2007). The inability of students to connect these three levels of representation can result in difficulty connecting chemical concepts to everyday life (Jansoon et al., 2009), so students tend to memorize concepts. As a result, learning becomes less meaningful (Siew et al., 2014). Therefore, it is important to analyze the students' ability to interconnect three levels of chemical representation in the electrolyte solutions concept.

METHOD

This research used descriptive quantitative research methods with one group of subjects. Descriptive research was used to describe the students' interconnection skills of the three levels of representation in the electrolyte solutions concept. This research was conducted in one of the high schools in Malang. The study involved one group of subjects in the first grade of senior high school with 37 students.

This interconnection study of three levels of representation used the Instrument The Multiple Representation of Electrolyte Test (MRET). MRET is a test of the ability of interconnection of three levels of student representation, which includes: (1) macroscopic tests in the form of inferring the results of experiments that are experiments on electrolyte and nonelectrolyte electrical conductivity, (2) interconnection tests to symbolic levels in the form of dissolution reaction equations to determine particles in the electrolyte-nonelectrolyte solutions based on the results of experiments on macroscopic tests, and (3) interconnection tests to the submicroscopic level where students are asked to make submicroscopic images of electrolyte-non-electrolyte solutions and submicroscopic images of electrical conductivity of electrolyte solution based on experimental results. Three expert validators in chemical education have validated the MRET instrument.

Students' answers are then analyzed by classifying the number of students who gave the correct answers to the test. The following equation calculated the percentage of students who answered correctly:

$$\text{Percentage} = \frac{n}{N} \times 100\%$$

n = number of students who answered correctly
N = number of all students

The student's ability to interconnect the three levels of representation is categorized based on the criteria for the level of understanding contained in Table 1. Based on the percentage of students who answered correctly, then described the interconnection pattern of three levels of chemical representation that students have in understanding the electrolyte solutions concept.

Table 1. Criteria for students' ability levels

P Value	Ability Levels
80 - 100%	Very high
66 - 79%	High
56 - 65%	Moderate
31 - 55%	Low
0 - 30%	Very low

RESULTS AND DISCUSSION

MRET begins with an experimental activity about the electrical conductivity of a solution. In this experiment, students were asked to determine the type of electrolyte and the degree of solution ionization. Determination of the type of electrolyte and the degree of solution ionization were analyzed from the student's ability to determine the type of strong electrolyte, weak electrolyte, and nonelectrolyte electrolytes and the degree of ionization of each solution tested based on the light intensity of the light bulb. Solutions tested in the experiment were $CaCl_2$ 0.5M and 0.5M KOH solution, which represents a strong electrolyte, 0.5M HCOOH solution and a solution of H_3PO_4 0.5M, representing a weak electrolyte, and C_2H_5OH representing nonelectrolytes. The percentage of students who can determine the type of electrolyte and the degree of ionization solution correctly is given in Figure 1. Figure 1 shows that the macroscopic ability of students in determining the type of electrolyte and the degree of ionization solution based onzexperimental results are classified as very high.

In the next stage, students were asked to transfer the conclusions from macroscopic observations in the form of symbolic representation by writing the dissolution reaction equation and determining the particles contained in the solution. Symbolic understanding of students in writing dissolution reactions was analyzed based on the student's ability to write the dissolution reaction equations correctly and completely: correctly writing the substances formed, the phase of the substances formed, and the reaction signs, and correctly equating the dissolution reaction. The percentage of students who can write the dissolution reaction equations and the particles formed in the solution correctly and completely is given in Figure 2.

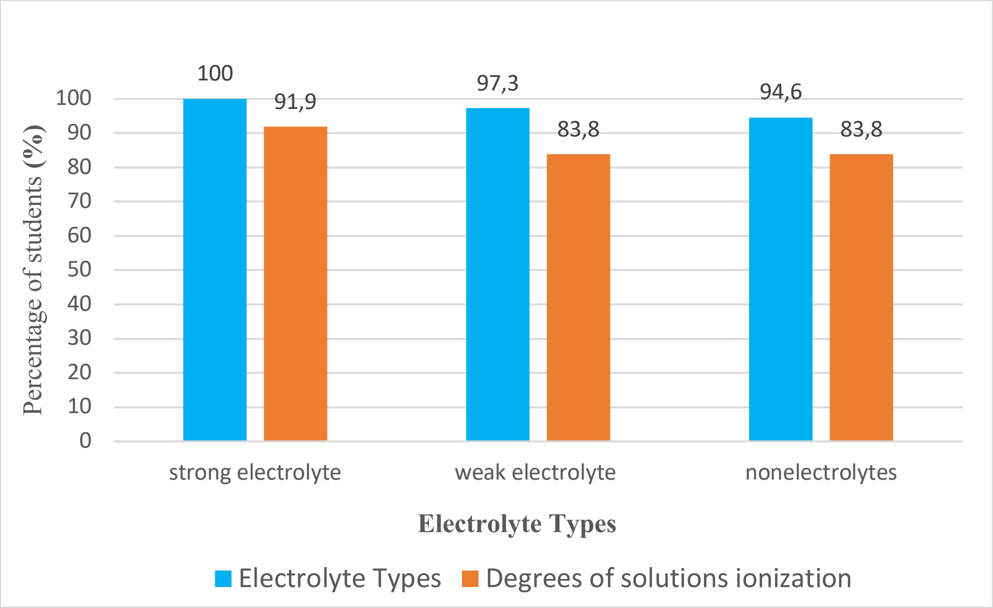

Figure 1. Percentage of students who are able to determine electrolyte types andzdegrees of solutions ionizationz

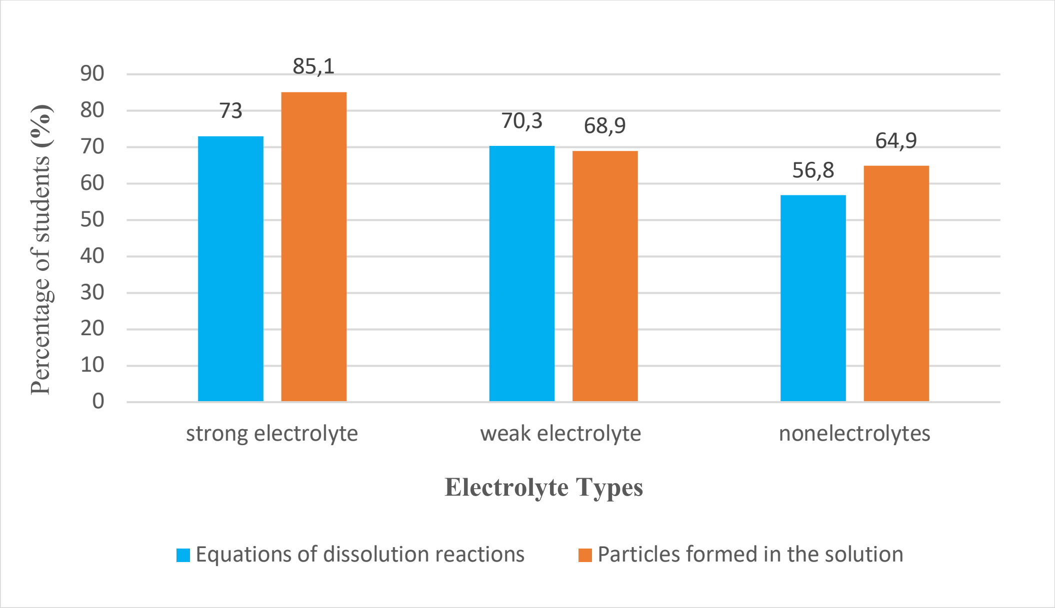

Figure 2. Percentage of students who are able to write equations of dissolution reactions and particles formed in the solution correctly and completely

Figure 2 shows that not all students were able to interconnect macroscopic understanding into symbolic representation. In determining the type of electrolyte, 94-100% of students were able to determine the type of electrolyte correctly based on the light of the experiment, but only 56.8 - 73% of students could write the dissolution reaction equation correctly. Likewise, the determination of species in solution only some students can determine the species in the solution.

In the final stage of the MRET, students are asked to interconnect the results of macroscopic observations and symbolic understanding into submicroscopic representations. At this stage, students were asked to make a submicroscopic picture of each solution tested and a submicroscopic description of the solution's electrical conductivity. The interconnection ability of students in describing the submicroscopic condition of the solution correctly and completely is analyzed based on the student's ability to describe the submicroscopic solution by criteria: correctly giving the symbol cation, anion, or molecule, and the image is randomly distributed. Meanwhile, students' interconnection ability in providing a submicroscopic picture of the solution's electrical conductivity correctly and completely must meet two criteria: correctly describing the direction of ions in solution and the direction of electron flow in conductive wires. A percentage of students could interconnect macroscopic observations and symbolic understanding in the submicroscopic description of the solution and the electrical conductivity of the solution given in Figure 3.

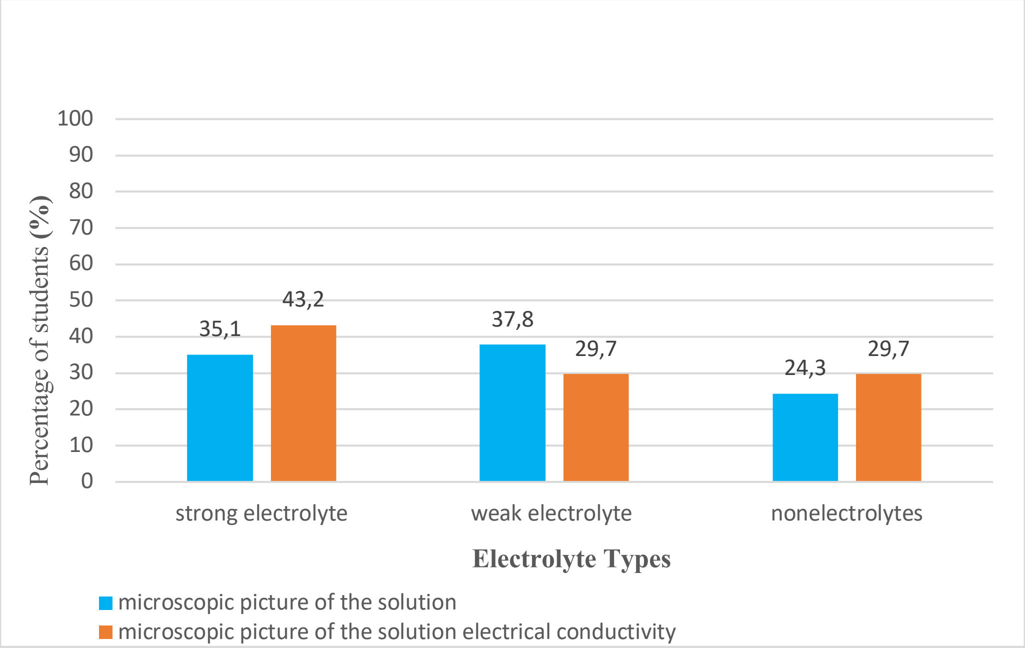

Figure 3. Percentage of students who are able to interconnect macroscopic observations and symbolic representation into the submicroscopic picture of the solution and the electrical conductivity of the solution correctly

Figure 3 shows that only a small proportion of students can make a submicroscopic picture of the solution and the process of the electrical conductivity of the solution. This indicates that the interconnection skills of students from the macroscopic and symbolic levels to the submicroscopic level are still low.

The ability to interconnect three levels of student representation is relatively low, especially to connect the macroscopic and symbolic understanding at the submicroscopic level. The macroscopic level is a concrete level associated with sensory observation of chemical phenomena. In the macroscopic ability test in MRET, students easily determine the type of electrolyte based on the light bulb that can be observed in plain view. In this case, the students' macroscopic abilities are high.

The student interconnection ability from the macroscopic to the symbolic level is moderate. Not all students who can conclude the type of electrolyte based on the experimental results can correctly write the dissolution reaction equation. Based on the results of the identification of student answers, obtained answers to errors of students so that the dissolution reaction equation is incomplete or wrong, namely: 1) wrong in writing the results of the reaction substances, 2) wrong in writing the phase of the reaction results, 3) in writing the reaction signs, and 4) wrong in equalizing the dissolution reaction. Student's difficulties in writing the reaction equation will affect their ability to determine the particle contained in the solution. Species formed in solution as a result of dissolving substances can be identified from the dissolution reaction equation. Based on student answers' identification results, students who can write the dissolution reaction equation correctly can also determine the species formed in the solution. Conversely, students who have yet to correctly write the dissolution reaction equation will find it difficult to determine which species are formed in the solution.

The interconnection ability of students from macroscopic and symbolic levels to submicroscopic levels is relatively low. Most students still have difficulty making submicroscopic images of solutions. Based on the results of the identification of student answers, obtained answers to errors students make submicroscopic images of solutions: 1) wrong in giving anion, cation, and molecular symbols, 2) true anion, cation, and molecule symbols, but the submicroscopic picture given is not distributed randomly, and 3) true anion, cation, and molecule symbols, micro-submicroscopic images are distributed but not random. Skills to make submicroscopic images of chemical phenomena can be obtained if students understand the concepts of the chemical phenomenon and practice a lot in making submicroscopic images of processes and chemical reactions.

The weak interconnection of students to the submicroscopic level is also indicated by the students' difficulty in making submicroscopic images of the process of the solution's electrical conductivity. The ability of students to make submicroscopic images of the solution's electrical conductivity process is relatively low. Based on the results of the identification of student answers, obtained answers to errors of students in making a submicroscopic description of the solution's electrical conductivity process: 1) wrong in determining the direction of ion flow in the solution, positive ions move to the anode and negative ions move to the cathode and 2) wrong in determining the direction of flow of electrons in the conductive wire, electrons flowing from cathode to anode.

The low ability to interconnect three levels of student representation, especially at the submicroscopic level, because, in general, learning electrolyte solutions only emphasizes macroscopic and symbolic levels. Submicroscopic levels tend to be ignored. Even if studied, the submicroscopic level is studied separately without any interconnection with macroscopic and symbolic levels (Nastiti et al., 2012 Herawati et al., 2013). When submicroscopic explanations are ignored, students cannot directly observe submicroscopic phenomena, such as interactions between solvent and solute molecules when forming solutions, dissociation or ionization in strong electrolyte solutions and weak electrolytes, and electrical conductivity in electrolyte solutions. These conditions often cause students to be unable to visualize structures and processes at the submicroscopic level, which can hinder their understanding of chemical concepts and even lead to misconceptions (Sunyono et al., 2015; Tasker & Dalton, 2006). Research conducted in several decades also mentions that students experience difficulties in understanding submicroscopic and symbolic representations because both levels of representation are abstract and cannot be observed (Chandrasegaran et al, 2007). Student's difficulties in understanding the material in submicroscopic representations can make it difficult to relate their understanding to other representations (Herman et al., 2021). Even though the three levels of representations are interrelated and must be connected in explaining chemical phenomena. Explanation of chemical phenomena will not be well understood if it is only explained using one level of chemical representation (Langitasari, 2016). The inability of students to connect the three levels of representation makes chemistry learning ineffective, so most students prefer to memorize concepts rather than understand concepts (Andrianie, Sudarmin, & Wardani, 2018).

Meaningful learning in chemistry requires students' thinking skills simultaneously at the macroscopic, submicroscopic, and symbolic levels (Gkitzia et al., 2019). Therefore, learning chemistry requires learning strategies and teachers who can direct students to understand and connect the three levels of chemical representation. Teachers need to select and involve several representations and adopt several visualization approaches to support students learning of chemical phenomena (Ferreira & Lawrie, 2019). One strategy that can be done is to use submicroscopic modeling, such as dynamic animation media. Animation media can help students build strong relationships between the three levels of representation, which can ultimately improve students' representational interconnection skills [Levy (2013); Langitasari (2018)]. A learning environment that integrates three levels of chemical representation can support students in making connections between the three levels of chemical representation and make learning more meaningful (Baldwin & Orgill, 2019; Rau, 2015; Sunyono & Meristi, 2018; Talanquer, 2018; Tuysuz et al., 2011; Upahi & Ramnarain, 2019). Thus, the students' interconnection ability of the three levels of chemical representation will increase, and it will be easier for students to understand chemical concepts.

CONCLUSION

The ability to interconnect macroscopic levels to the symbolic level of students in the concept of electrolyte solutions is classified as moderate. However, the ability to interconnect the three levels of student chemical representation (macroscopic, submicroscopic, and symbolic) is low. This condition makes students' understanding incomplete and less meaningful. One implication of this research is the need to use submicroscopic modeling, such as animation media, to help students understand electrolyte solutions using three levels of representation. Using three levels of representation and the relationship between the three in chemistry learning can make learning more meaningful and the concept of chemistry easier to understand.

REFERENCES

Adadan, E. (2013). Using multiple representations to promote grade 11 students' scientific understanding of the particle theory of matter. *Research Science Education*, 43: 1079-1105.

Andrianie, D., Sudarmin, & Wardani, S. (2018). Representasi Kimia Untuk Mereduksi Miskonsepsi Siswa Pada Materi Redoks Melalui Penerapan Model Pembelajaran Inkuiri Terbimbing Berbantuan LKS. *Chemistry in Education*, *7*(2).

Aulia, A., & Andromeda. (2019). Pengembangan E-Modul Berbasis Inkuiri Terbimbing Terintegrasi Multirepresentasi dan Virtual Laboratory pada Materi Larutan Elektrolit dan Nonelektrolit untuk Kelas X SMA / MA. *EduKimia Journal*, 1(2), 94–102.

Baldwin, N., & Orgill, M. (2019). Relationship between teaching assistants' perceptions of student learning challenges and their use of external representations when teaching acid–base titrations in introductory chemistry laboratory courses. *Chem. Educ. Res. Pract.*, 20 (4), 821-836. doi:10.1039/c9rp00013e

Chandrasegaran, A.L., Treagust, D.F., & Mocerino, M. 2007. The Development of two-tier multiple-choice diagnostic instrumen for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practise*, 8 (3): 293-307.

Chittleborough, G. D. (2004). *The Role of Teaching Models and Chemical Representation in Developing Students Mental Models of Chemical Phenomena*. Tesis Doktor. Curtin University of Technology.

Ferreira, J. E. V., & Lawrie, G. A. (2019). Profiling the combinations of multiple representations used in large-class teaching: Pathways to inclusive practices. *Chem. Educ. Res. Pract.* 20

(4): 902-923. doi:10.1039/c9rp00001a.

Fitriyani, D., Rahmawati, Y., & Yusmaniar. (2019). Analisis Pemahaman Konsep Siswa pada Pembelajaran Larutan Elektrolit dan Non- Elektrolit dengan 8E Learning Cycle. *Jurnal Riset Pendidikan Kimia*, *9*(1), 30–40.

Garnett, P.J. & Treagust, D.F. 1992. Conseptual Difficulties by Senior High School Student of Electrochemistry: Electric Circuit and Oxidation-reduction Equations. *Journal of Research in Science Teaching*, 29 (2): 121-142.

Gkitzia, V., Salta, K., & Tzougraki, C. (2019). Students' Competence in Translating Between Different Types of Chemical Representations. *Chem. Educ. Res. Pract.*, 21, 307-330. doi:10.1039/c8rp00301g

Herawati, R. F., Mulyani, S., Redjeki, T. (2013). Pembelajaran Kimia Berbasis Multiple Representasi Ditinjau Dari Kemampuan Awal Terhadap Pretasi Belajar Laju Reaksi Siswa SMA Negeri 1 Karangayar Tahun Pelajaran 2011/2012. *Jurnal Pendidikan Kimia (JPK)*, 2(2): 38-43.

Herman, H., Nurhadi1, M., & Gunawan, R. (2021). Development of Multiple Representation Based Module with PowerPoint Assisted On Electrolyte and Non Electrolyte Solutions. *Jurnal Zarah*, *9*(1), 1–7.

Jansoon, N., Cool, R.K., & Samsook, E. (2009). Understanding Mental Models of Dilution in Thai Students. *International Journal of Environmental & Sciense Education.* 4 (2): 147-168.

Johnstone, A. H. (1982). Macro-and Micro-Chemistry. *School Science Review*, 227 (64): 377-379.

Kelly, R.M., Phelps, A.J., & Sanger, M.J. 2004. The effects of a Computer Animation on Students' Conceptual Understanding of a Can-Crusing demonstration at the Macroskopic, Microskopic, dan symbolic levels. *The Chemical Educator*, 9 (3): 184-188.

Langitasari, I., Effendy, Fazaroh, F. (2018). Dynamic and Static Modeling Embedded in Inquiry Learning to Improve Student's Multiple Representation Ability. *Jurnal Penelitian dan Pembelajaran IPA*, 4 (1): 1-13.

Langitasari, I. (2016). Analisis Kemampuan Awal Multi Level Representasi Mahasiswa Tingkat I Pada Konsep Reaksi Redoks. *Jurnal Kimia Dan Pendidikan*, *1*(1), 14–24.

Levy, D. (2013). How Dynamic Visualization Technology can Support Molecular Reasoning. *Journal of Science Education and Technology*, 22 (5): 702-717. DOI 10.1007/s10956-012-9424-6.

Nastiti, R.D., Fadiawati, N., Dan Kadaritna N. (2012). Development Module Of Reaction Rate Based On Multiple Representations. *Jurnal Pendidikan dan Pembelajaran Kimia*, 1 (2).

Rau, M. A. (2015). Enhancing undergraduate chemistry learning by helping students make connections among multiple graphical representations. *Chem. Educ. Res. Pract, 16(3), 654–669.* doi:10.1039/c5rp00065c

Siew, W.S., Mohammad Yusof Arshad. (2014). Application of Multiple Representation Levels in Redox Reactions among Tenth Grade Chemistry Teachers. *Journal of Turkish Science Education*, 11 (3): 35-52.

Sunyono, S., Meristi, A. (2018). The Effect of Multiple Representation-Based Learning (Mrl) To Increase Students' Understanding of Chemical Bonding Concepts. J*urnal Pendidikan IPA Indonesia*. 7 (4): 399-406 DOI: 10.15294/jpii.v7i4.16219.

Sunyono, Yuanita L., Ibrahim, M. (2015). Supporting Students in Leearning with Multiple Representation to Improve Student Mental Models on Atomic Structure Concepts. *Science Education International*, 26 (2): 104-125.

Talanquer, V. (2018). Chemical rationales: another triplet for chemical thinking, International *Journal of Science Education,* 40:15, 1874-1890, DOI: 10.1080/09500693.2018.1513671

Tasker, R. & Dalton, R. 2006. Research Into Practise: Visualisation of the Molecular World Using Animations. *Chemistry Education Research and Practise*, 7 (2), 141-159.

Tuysuz, M., Ekiz, B., Bektas, O., Uzuntiryaki, E., Tarkin, A., & Kutucu, E.S. 2011. Pre-service Chemistry Teachers' Understanding of Phase Changes and Dissolution at Macroscopic, Symbolic, and Microskopic Levels. *Procedia Social and Behavioral Sciences,* 15: 152-455.

Upahi, J., & Ramnarain, U. (2019). Representations of Chemical Phenomena in Secondary School Chemistry Textbooks. *Chem. Educ. Res. Pract*. 20 (1): 146-159. doi:10.1039/c8rp00191j