JPII 12 (2) (2023) 187-198

Jurnal Pendidikan IPA Indonesia

http://journal.unnes.ac.id/index.php/jpii

DIFFERENCES IN THE *TRIPLECHEM* LEARNING MODEL WITH BALINESE LOCAL WISDOM AND THE DISCOVERY LEARNING MODEL IN INFLUENCING STUDENTS' VISUAL LITERACY AND MENTAL MODELS ABOUT ACID-BASE SOLUTIONS

I. W. Suja*[1], I. M. G. Jayadiningrat[2], I. N. S. Ardiyasa[3]

[1]Universitas Pendidikan Ganesha, Bali, Indonesia
[2]Universitas Hindu Negeri I Gusti Bagus Sugriwa, Bali, Indonesia
[3]Sekolah Tinggi Agama Hindu Negeri Mpu Kuturan, Bali, Indonesia

DOI: 10.15294/jpii.v12i2.44456

Accepted: May 22nd, 2023. Approved: June 09th, 2023. Published: June 10th, 2023

ABSTRACT

This study intends to investigate the differences in the effect of the *TripleChem* learning model with Balinese local wisdom and the Discovery Learning model on students' visual literacy and chemical mental models about acid-base solutions. The research was designed using a quantitative approach and classified as quasi-experimental. The research design used was a pretest-posttest non-equivalent control group design. The population of this study was 206 junior high school students with Balinese cultural backgrounds with various beliefs (religions), namely Hindus, Muslims, and Christians. Cultural content will cause learning to be more contextual, more interesting, and bring students closer to their own culture. The sampling was done using a simple random sampling technique, and obtained two sample classes, one class as the experimental group, and the other as the control group. The experimental group was taught using the *TripleChem* learning model containing Balinese local wisdom, while the control group was taught using the Discovery Learning model. The dependent variable in this research was visual literacy and students' mental models of chemistry. Data collection was carried out using a visual literacy test (10 items in total; item validity between 0.520 – 0.893; and test reliability coefficient of 0.895) and a chemical mental model test (8 items in total; item validity between 0.669 – 0.878; and test reliability coefficient of 0.922). Data analysis was carried out descriptively and MANCOVA. The results show that the *TripleChem* learning model is more effective to be applied to improve students' visual literacy and mental models about acid-base solutions compared to the Discovery Learning model. This condition is caused by the syntax of the *TripleChem* learning model which is more sequential and structured to build students' visual literacy and chemistry mental models. The application of the *TripleChem* learning model in chemistry learning needs to be supported by laboratory facilities to display chemical macroscopic phenomena and animated media to explain these phenomena at the level of matter particles.

Keywords: acid-base solution; mental model; visual literacy

INTRODUCTION

Before learning, educators must choose a suitable learning model to make the teaching and learning process fun, meaningful, and sustainable (MacVaugh & Norton, 2012; Franco-Mariscal et al., 2015; Rahmawati et al., 2019; Coman et al., 2020). Meaningful learning in chemistry education is not only interpreted as success in associating newly received information with students' prior knowledge but as success in building a complete mental model of chemistry, covering three levels of chemistry (macroscopic, submicroscopic, and symbolic) and the interconnection of these three levels (Tsaparlis & Finlayson, 2014; Supriadi et al., 2021; Yulianti et al., 2022). The macroscopic level is real, covering various chemical phenome-

***Correspondence Address**
E-mail: wayan.suja@undiksha.ac.id

na that can be directly observed or measured in everyday life and the laboratory. The submicroscopic level is abstract and requires theory to explain phenomena that occur at the molecular level. The symbolic level represents matter particles, including atoms, molecules, and ions, in pictures, formulas, or forms resulting from computer processing. The chemical mental model formed in students' minds about the interconnection of the three chemical levels can describe, explain, and predict chemical phenomena based on their molecular structure (Mayer, 2020; Supriadi et al., 2021; Siregar & Kurniawati, 2022; Nagel & Lindsey, 2022).

The learning models applied by educators in the classroom are usually classified as general models, which are only sometimes compatible with the characteristics of the teaching materials that must be delivered to students. The 2013 curriculum standard process (*Permendikbud* No. 65 of 2013) reveals that science/chemistry learning in schools uses a scientific approach using discovery/inquiry learning models, problem-based learning, and project-based learning. Applying these models to chemistry learning can improve student learning outcomes, science process skills, critical thinking skills, and students' creative thinking skills (Permatasari & Laksono, 2019; Suradika et al., 2023; Yerimadesi et al., 2023), but there is no guarantee that learning is carried out by targeting the three levels of chemistry and their interconnections as a whole (Suja, 2018a; Dewi et al., 2021; Yulianti et al., 2022; Cunha, 2023).

To provide a clear direction regarding the target of recognizing the three chemical levels and their interconnections, previous findings have developed a specific model for learning chemical concepts (Sartika & Hadi, 2015; Dewi et al., 2021). The learning model is labeled as the *TripleChem* learning model (Suja, 2018a). The development of a special *TripleChem* model for learning chemistry is based on links and matches between chemistry content, which consists of three levels and their interconnections, with ways to study it according to the epistemology of *Catur Pramana*, which includes *Anumana Pramana* (reasoning), *Pratyaksa Pramana* (observing), *Upamana Pramana* (modeling), and *Sabda Pramana* (explanation).

Testing the advantages of the *TripleChem* learning model as a specific model for learning chemical concepts, especially in forming visual literacy and chemical mental models, compared to general learning models, needs to be carried out further. This action is needed to assist teachers in choosing the right learning model to introduce chemistry concepts that cover three levels to students. If this is not done, the teacher will only use the general learning models suggested in the curriculum without considering the characteristics of the concepts to be taught to students and their learning objectives. The application of the discovery learning model that is commonly practiced by teachers in teaching chemistry concepts according to the 2013 Curriculum is proven to be able to improve learning outcomes, science process skills, and students' higher-order thinking skills (Permatasari & Laksono, 2019; Azhara et al., 2020; Mahdian et al., 2022;.Yerimadesi el al., 2023). However, no research has compared the advantages of this learning model with the *TripleChem* model for teaching chemistry concepts.

In this study, the researchers compare the effects of the *TripleChem* learning model with the Discovery Learning model on learning acid-base concepts in junior high schools. The selection of the acid-base concept in junior high school is based on the following considerations. First, the concept of acids and bases is essential in learning science in the seventh grade of junior high school. This concept will continue to be used by students while studying chemistry, even up to university. On that basis, the mental models of junior high school students about acids and bases must be scientifically correct, and that can happen if they are taught with the right learning strategies. Second, the concept of acids and bases taught in junior high schools includes understanding aqueous solutions, macroscopic properties of acid-base solutions, ionization/dissociation reactions at the molecular level, and reaction equations at the symbolic level. Thus, learning the concept of acids and bases in junior high school provides space to introduce the three chemistry levels fully. Third, students' first impressions of learning chemical concepts will influence their acceptance of chemical material in subsequent lessons, whether at junior high school, senior high school, or university. Thus, the availability of suitable and effective learning models for chemistry is necessary for every teacher who teaches chemistry material. These actions are intended to make chemistry learning interesting and meaningful in forming students' mental models and visual literacy.

On the other hand, learning chemistry (science) concepts in schools should not uproot students from their cultural roots (Parmiti et al., 2021; Pujawan et al., 2022). For this reason, learning the acid-base concept in this study is complemented by the local wisdom of the community in the form of indigenous Balinese knowledge that applies acid-base principles, such as the habit of eating betel (*nginang*), treatment of drug-addicted patients using a concoction of starfruit and tamarind, treatment of wasp bites with kitchen vinegar, treatment of bee stings with whiting, and others (Suja, 2017; Rizaldi et al., 2021). Various previous research results show that the integration of culture or local wisdom into learning chemistry (science) is proven to be able to increase learning interest, scientific attitude, learning outcomes, science process skills, student activity during the learning process, empower students as preservers of the nation's culture, and develop student character (Nuralita et al., 2020; Hikmawati et al., 2021; Parmiti et al., 2021; Suciyati et al., 2021; Mudjid et al, 2022; Yulianto et al., 2023; Rahmawati et al., 2023; Sunyono et al., 2023).

Concerning the problems above, this research is conducted to describe and explain the profiles of students' mental models regarding acid-base solutions, as well as differences in visual literacy and chemical mental models between students who learn using the *TripleChem* learning model containing Balinese local wisdom and students who learn using the Discovery Learning. Teachers can use the findings of this study to develop appropriate learning models for improving students' visual literacy and chemistry mental models.

METHODS

The population of this study was 206 junior high school students with Balinese cultural backgrounds with various beliefs (religions), namely Hindus, Muslims, and Christians. Cultural content will cause learning to be more contextual, more interesting, and bring students closer to their own culture. The sampling was done using a simple random sampling technique and obtained two sample classes: the experimental group and the control group. The number of students in each sample class was 34 people. The experimental class used the *TripleChem* learning model with Balinese local wisdom. Learning by applying the *TripleChem* learning model in the experimental class consists of four stages. Stage 1 Observing, to introduce the macroscopic level of chemistry. At this stage, students observed chemical macroscopic phenomena taken from local Balinese wisdom, such as the use of lime for betel nut (nginang) and the treatment of wasp bites with kitchen vinegar. Learning had been done by observing videos about nginang, and direct observation of the properties of lime, lime solution, and vinegar as examples of acid-base solutions. Stage 2 Reasoning, to introduce the submicroscopic level. At this stage, students discussed in their groups why a lime solution is alkaline, whereas vinegar is acidic. The discussion was directed so that students built their arguments based on the types of dissolved compound particles and their presence in the solution. Stage 3 Modeling, to introduce the symbolic level. At this stage, the student group visualized the particles of the acid-base solution in the form of an image or molecular model and wrote down the complete chemical formula with the ionization/dissociation reaction of the particles of the acid-base compound in water. Stage 4 Explanation, to build a complete mental model of chemistry. At this stage, students reported the results of their group discussions in class discussions, followed by observing a video about acid-base solutions, which displays the macroscopic properties of compounds and acid-base solutions, the particles that make up acid-base compounds, and the ionization/dissociation processes that experienced when dissolved in water. The video was also equipped with ionization/dissociation reaction equations. At the final stage of explanation, students explored various acidic or basic compounds used in their daily life and those in the laboratory. In contrast, the control class was taught using the Discovery Learning model commonly applied at the school. This research was designed with a quantitative approach and classified as quasi-experimental research (Fraenkel & Wallen, 2006; Palys & Atchison, 2014; Creswell & Creswell, 2017). The research design used was a pretest-posttest non-equivalent control group design, as shown in Table 1. Before learning, the two groups were given a pretest. Furthermore, the experimental group was given a learning treatment using the *TripleChem* learning model containing Balinese local wisdom, while the control group was taught using the Discovery Learning model. After learning, both groups were given a posttest.

Table 1. Research Design

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2
Control	O_3	Y	O_4

The dependent variable in this study was students' visual literacy and mental models of chemistry about acid-base solutions. Each data was collected using a visual literacy test (10 items; item validity 0.520 – 0.893; test reliability coefficient 0.895) and a chemical mental model test (8 items; item validity 0.669 – 0.878; test reliability coefficient 0.922). The following shows an example of each question used to measure students' visual literacy and mental models. Item about visual literacy: "One water molecule is formed by two hydrogen atoms and one oxygen atom. If the hydrogen atom is represented by a small black ball, and the oxygen atom by a white ball that is larger in size, draw the visual shape of the water molecule. The position of the two hydrogen atoms is about 104° to one another." Item about chemical mental models: "Andi was given the task of determining the nature of the solution the teacher had prepared. Two solutions are available, each containing a solution labeled ammonia (NH_3) and hydrogen formate (HCOOH). (a) Which of the two solutions can change the color of red litmus paper to blue? (b) Explain what causes a solution to change the color of red litmus paper to blue? (c) Write the ionization reaction of this compound in the water!" The three questions above successively measure students' understanding at the macroscopic, submicroscopic, and symbolic levels. The test outlines used for data collection are shown in Table 2.

Table 2. Research Instruments

Variable	Dimension/Indicator	Number of Items	Items
Visual Literacy	Visual thinking	3	1, 2, 3
	Visual difference	2	4, 5
	Visual association	2	6,7
	Reconstruction of meaning	3	8, 9, 10
Mental Models	Describe the properties of an acid-based solution	2	1, 2
	Analyze acid-base solutions	2	3, 4
	Identify a neutralization reaction	2	5, 6
	Identify the properties of salt solutions	2	7, 8

Data analysis was carried out descriptively related to the student's mental model profile, general description of the research results, and multivariate analysis of covariance (MANCOVA) for hypothesis testing. The profile of the student's chemistry mental model was identified based on the student's ability to connect the three levels of chemistry. Students' answers to each item were grouped into an answer and no answer (No Response). Only students who give answers could determine their mental model. Students' mental models were generally grouped into conceptual and alternative mental models. The conceptual model was owned by students who show a correct (scientifically correct) understanding of the three chemical levels. Alternative mental models were divided into partially correct and specific misconceptions mental models. Partially correct mental models were characterized by incomplete mastery of all three chemistry levels, but one or both were correctly understood. Finally, mental models of special misconceptions occur if students do not understand the three chemistry levels (Sendur et al, 2010).

RESULTS AND DISCUSSION

The purposes of data analysis describe the results of the research data. This action aims to provide an overview of the distribution of data. The research data includes 1) a profile description of the chemical mental model, 2) a general description of the research results, 3) an analysis prerequisite test, and 4) hypothesis testing.

The data for this study are obtained from each group's pretest and posttest scores, including visual literacy scores and chemical mental model scores. Before learning, the two groups of students have been assigned to study the acid-base solution material. The pretest was given before the learning process, then different treatments between the experimental and control groups, and finally given the posttest. Thus, the pretest results show student learning outcomes independently before class; meanwhile, the posttest results show the impact of the instructional implementation of learning in the experimental and control classes.

In this study, the covariate variable is students' mental models of chemistry about the concept of acid, base, and salt solutions before learning. Students' mental models are built from their understanding of the three chemical levels related to acid, base, and salt solutions before and after learning, as shown in Table 3.

The data in Table 3 shows the percentage of students' understanding achieved for each level of chemistry (ideal value for each level = 100%).

Table 3. Understanding of Three Levels of Chemistry

Chemical Levels	Experimental Group		Control Group	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
Macroscopic	79.41	98.90	85.66	90.81
Submicroscopic	8.82	46.32	0.92	16.54
Symbolic	29.96	76.29	44.12	63.60

The data shows that students' understanding of the macroscopic level of chemistry before learning has reached the minimum completeness criteria (MCC) for science subjects of 60. With independent study, students can understand the macroscopic level of chemistry through books or other learning resources. On the other hand, students' understanding of the submicroscopic level of chemistry is classified as very low, the lowest compared to understanding the other two chemistry levels. Visually, students' understanding of the three chemistry levels in the experimental and control group is shown in Figure 1.

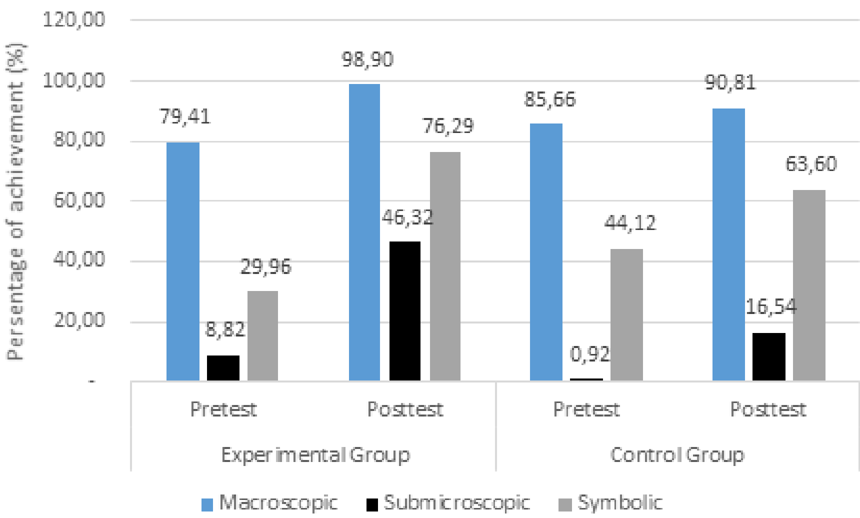

Figure 1. Comparison of Understanding of Three Levels of Chemistry

The data in Figure 1 shows that students' understanding of the submicroscopic level before and after learning is lower than that of the other two chemical levels. The data in Figure 1 also shows an increase in understanding at the submicroscopic level in the experimental class (taught with the *TripleChem* model) higher than in the control class (taught with the Discovery Learning model).

Profiles of students' mental models of acid, base, and salt solutions, between before and after learning in the experimental group and the control group are shown in Table 4.

Table 4. Profile of Students' Mental Models

Types of Mental Models	Experiment Group		Control Group	
	Pretest (%)	Posttest (%)	Pretest (%)	Posttest (%)
Scientifically Correct	7.72	50.74	1.84	26.10
Partially Correct	71.69	47.06	82.72	67.65
Specific Misconceptions	15.07	0.74	9.91	4.78
No Response	5.51	1.47	4.78	2.94

The data in Table 4 shows that most students' mental models of chemistry before learning are classified as correct mental models, partly contributed by their understanding of the macroscopic level of chemistry. The proportion of specific misconceptions about mental models before learning in the experimental and control groups is higher than in the conceptual models. Visually, students' mental models of acid, base, and salt solutions in the experimental and control groups are shown in Figure 2.

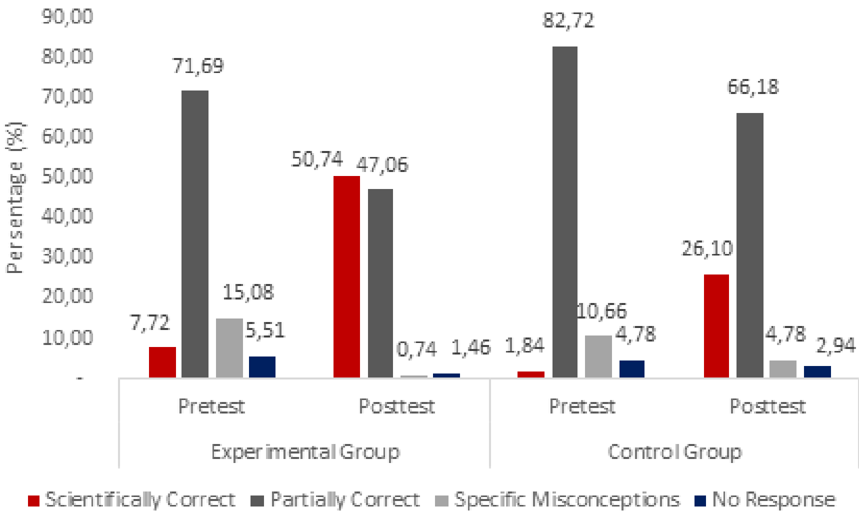

Figure 2. Comparison of Chemical Mental Model Profiles

The data in Figure 2 above shows a very large increase in the proportion of conceptual models and a sharper decrease in the proportion of specific misconception mental models in the experimental group compared to the control group. The data shows that the *TripleChem* learning model containing Balinese local wisdom is more effective to be applied in chemistry learning than the Discovery Learning model for building students' mental models about acid-base solutions.

The results of this study include the pretest and posttest values of visual literacy and mental models in the experimental and control groups, as shown in Table 5.

Table 5. Descriptive Analysis Results of Data in Experimental and Control Groups

Descriptive Statistics	Experimental Group		Control Group	
	Visual Literacy	Mental Model	Visual Literacy	Mental Model
A. Pretest				
N	34	34	34	34
Mean	37.91	31.25	40.26	35.15
Max. score	50	52.50	64	57.50
Min. score	26	7.50	27	12.50
SD	5.69	9.03	6.91	8.94
B. Posttest				
N	34	34	34	34
Mean	68.35	68.60	58.38	50.22
Max. score	86	92.50	76	72.50
Min. score	45	37.50	34	25.00
SD	9.19	11.94	8.97	14.60

The data in Table 5 shows that the average value of visual literacy and mental models of students in the experimental and control groups is less than 60, where the minimum completeness criteria (MCC) for science in the school is 60. After learning, the average value of visual literacy and mental models in the experimental group is over 60 each, whereas in the control group, less than 60. The data shows that the *TripleChem* learning model is better to be applied to improve students' visual literacy and mental chemistry than the Discovery Learning model.

The results of the prerequisite test analysis show the following data. First, the normality test results with Kolmogorov-Smirnov show that the visual literacy data and mental models of students in the experimental and control groups each show sig. (0.200) > 0.05. Thus, all data is normally distributed. Second, the homogeneity of variance test with Levene's test on data on the results of the visual literacy pretest, visual literacy posttest, and mental model posttest for the experimental and control groups, respectively, shows sig (0.466; 0.988; and 0.540) > 0.05. The data shows that all data to be analyzed is classified as homogeneous. The mental model pretest results are used as a covariate variable in this case. Third, the homogeneity test of the variance-covariance matrix with Box's equality test of covariance matrices shows a sig. (0.091) > 0.05. This value indicates the observed covariance matrices of the dependent variables are equal across groups. Fourth, the results of the Pearson correlation test show the correlation coefficient values of the visual literacy pretest and posttest (r = 0.079), visual literacy pretest and mental model posttest (r = 0.524), and visual literacy posttest and mental model posttest (r = 0.426) <0, 80. It can be concluded that there is no significant correlation between visual literacy and mental models.

The results of the MANCOVA tes analysis show a significance value of 0.000 (Sig <0.05) for Pillai's Trace, Wiks' Lambda, Hotelling's Trace, and Roy's Largest Root. This value indicates a simultaneous difference in visual literacy and mental model between students who use the *TripleChem* Learning Model with Balinese local wisdom and Discovery Learning Model. The analysis results of the multivariate test are presented in Table 6.

Table 6. Analysis Results of Multivariate Test[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pilla's Trace	0.861	129.865[b]	3.000	63.000	0.000
	Wilks' Lambda	0.139	129.865[b]	3.000	63.000	0.000
	Hotelling's Trace	6.184	129.865[b]	3.000	63.000	0.000
	Roy's Largest Root	6.184	129.865[b]	3.000	63.000	0.000
Pretest Mental Model	Pilla's Trace	0.930	277.580[b]	3.000	63.000	0.000
	Wilks' Lambda	0.070	277.580[b]	3.000	63.000	0.000
	Hotelling's Trace	13.218	277.580[b]	3.000	63.000	0.000
	Roy's Largest Root	13.218	277.580[b]	3.000	63.000	0.000
Teaching Learning Model	Pilla's Trace	0.937	312.163[b]	3.000	63.000	0.000
	Wilks' Lambda	0.063	312.163[b]	3.000	63.000	0.000
	Hotelling's Trace	14.865	312.163[b]	3.000	63.000	0.000
	Roy's Largest Root	14.865	312.163[b]	3.000	63.000	0.000

a. Design: Intercept + Pretest Mental Model + Teaching and Learning Model
b. Exact statistic

The effect of each learning model on students' visual literacy and chemical mental models about acid-base solutions is tested with the Test of Between-Subjects Effects. The analysis results show a sig 0.000 (Sig < 0.05) for visual literacy and mental model variables separately. Thus, it can be concluded: (1) there is a significant difference in effect between the *TripleChem* learning model containing Balinese local wisdom and the Discovery Learning model on visual literacy scores, and (2) there is a significant difference in effect between the *TripleChem* learning model containing Balinese local wisdom and the Discovery Learning model on the value of students' mental models.

The results of this study show that the *TripleChem* model is more effective to be applied to build conceptual models (scientifically correct) and reduce misconceptions about acid-based solution materials than the Discovery Learning model. In learning with the discovery model, the submicroscopic level is not emphasized. As a result, students tend only to remember the macroscopic and symbolic levels of chemistry, which leads them to form alternative mental models (partially correct or misconceptions). The formation of correct mental models is partly contributed by students' lack of understanding of the submicroscopic level of chemistry. In addition, the stages of *TripleChem* learning are sequentially and systematically directed to build students' mental models starting from getting to know the macroscopic level at the observing stage, understanding the submicroscopic level at the reasoning stage, visualizing the structure and chemical formulas of compounds at the modeling stage, and building a complete chemical mental model at the explaining stage.

Studying chemical concepts, including acid-base solutions, should be done in stages, level by level (Tasker & Dalton, 2006; Suja, 2018a). Learning chemistry without emphasizing the submicroscopic level (including ions, molecules, atoms, and sub-elementary particles measuring $10^{-9} – 10^{-10}$m) has not entered learning chemistry's core. Students who have not been conditioned to investigate the sorts and structures of matter particles tend to memorize chemical formulas but have no idea what they imply and use them to give scientific explanations for the chemical processes they are investigating. These conditions gave alternative mental models in the minds of students (Redhana et al., 2020; Putri & Wiyarsi, 2022). This condition does not only occur in high schools but also tertiary institutions (Suja, 2015; Lathifa et al., 2020; Suja et al., 2021). These data show that alternative mental models can be formed in chemistry learning if learning does not involve exposure to the three chemical levels, especially the submicroscopic level.

The findings of this study indicate that students who experience misconceptions need to understand the process of ionization and dissociation in solution as a determinant of the solution's acidic, basic, and neutral properties. Students only guess the solution's nature based on the dissolved compound's molecular formula. The hydrogen formic compound (HCOOH) is predicted to be basic because it contains –OH groups, while ammonia (NH_3) is stated to be acidic because it contains a hydrogen atom (H). This study's findings align with the results of other studies showing that students who do not understand changes in molecular structure in the dissolving process of compounds tend to guess the properties of compounds based on the presence of H atoms or OH groups in these compounds. The same findings are conveyed by Kelly and Akaygun (2016), Putri and Wiyarsi (2022), and Suja (2018b), who report that students tend to "guess" the nature of compounds from their molecular formulas. Any compound that contains the -OH group is considered basic, while those containing H atoms are considered acidic.

The advantage of the *TripleChem* learning model is to improve students' visual literacy and mental models of chemical concepts because the learning syntax is by the steps to gradually build students' visual literacy and mental models of chemistry. Previous researchers state that the chemical mental model of interconnection between chemical levels is built gradually because students' working memory often could not handle all three chemical levels simultaneously (Levy & Wilensky, 2009; Kelly, 2016). The suitability of the syntax of the *TripleChem* model with visual literacy and chemistry mental models about acid-base solutions can be described as follows. First, the observing stage forms students' mental models about the macroscopic level of acid-base solutions, such as changes in the color of litmus paper, the color of natural indicator solutions, and the taste of the identified ingredients. The observing stage also plays a role in differentiating visual stimuli from acidic, basic, and neutral solutions. Second, the reasoning stage aims to form students' mental models about the submicroscopic level of chemistry, namely the types of particles that make up an acid, base, and salt solution as a determinant of the properties of the solution. At the reasoning stage, students build molecular arguments about the macroscopic properties of chemistry and build visual associations. Third, the modeling stage aims to understand the symbolic level of chemistry by visualizing the particle structure of solutions of acids, bases, and salts in the form of ions or polar molecules. Considering that understanding the particle structure of matter, complete with its ionization and dissociation reactions, is used as the basis for explaining and predicting the properties of solutions, the modeling stage is the core of learning acid-base solutions (Drechsler & Van Driel, 2008; Kelly, 2014). The modeling stage is also a vehicle for training students to think visually, involving skills in using symbols and chemical formulas and communicating data with graphs, tables, and chemical symbols (Kaberman & Dori, 2009; Avargil et al., 2012). The modeling stage also helps students understand abstract concepts and makes storing information in their long-term memory easier. Fourth, the explaining stage aims to build students' mental models of chemistry by involving the interconnection of three chemistry levels. At the explaining stage, students also practice reconstructing the meaning of visual messages that enter into long-term memory to complete the mental model that is already in the students' minds.

The findings of this study indicate that the understanding of the submicroscopic level is the lowest compared to the other two chemical levels, which will contribute to the formation of alternative mental models. The application of the *TripleChem* learning model, in its learning syntax, is supported by visualization models of substance particles in solution. This treatment makes abstract chemical material easier to understand. Students must be taught the skill of visualizing material particles because this ability is not innate but must be learned. Visualizing the submicroscopic level in learning with the *TripleChem* model in this study is proven to increase visual literacy and assist students in building their mental models as a whole and scientifically correct. The findings of this study conform to the findings of other studies, which suggest that learning using Macromedia Flash to visualize chemical levels has an effect on the creation of 70% intact mental models (conceptual models) in the experimental group and 37% in the control group (Siregar & Kurniawati, 2022). Previous research has demonstrated that using Macromedia Flash and molecular representation can assist students comprehend an abstract concept in chemistry (Kelly et al., 2017; Farheen & Lewis, 2021; Kurniawati et al., 2021; Putri et al., 2022; Siregar & Kurniawati, 2022). These findings are reinforced by the results of other studies, which find that spatial abilities are needed to build a complete mental model of chemistry, especially to visualize the submicroscopic level of abstract chemistry. The results of other studies show that mastery of mental models and spatial abilities contribute positively to students' chemistry learning outcomes (Wildan et al., 2023).

The content of local wisdom in implementing the *TripleChem* model makes learning contextual. Integrating Balinese local wisdom into teaching acid-base solutions makes learning more interesting and meaningful because of its contribution to the macroscopic level of chemistry and its benefits to people's lives. These findings are in line with the results of previous studies, which conclude that the integration of culture and local wisdom into learning chemistry concepts could make learning more meaningful, improve critical and creative thinking skills, increase scientific literacy, and improve students' scientific attitudes (Atmojo et al., 2018; Dewi et al., 2019; Parmin & Fibriana, 2019; Rahmawati et al., 2019; Nuralita, 2020; Sumarni & Kadarwati, 2020; Widayanti, 2020; Hikmawati et al., 2021; Suciyati et al., 2021).

CONCLUSION

The profile of students' mental models about acid-base solutions taught with the *TripleChem* learning model containing local wisdom is better than the Discovery Learning model. The increase in the percentage of conceptual models (scientifically correct) and the decrease in specific misconceptions as a result of applying the *TripleChem* learning model is stronger than Discovery Learning. On the other hand, students' visual literacy and mental models after learning with the *TripleChem* model are better than Discovery Learning. Thus, the *TripleChem* learning model is more effective to be applied to improve students' visual literacy and mental models than Discovery Learning. To support the application of the *TripleChem* learning model, it is necessary to provide chemical laboratory facilities (tools and materials) to display chemical macroscopic phenomena and animated media to explain these phenomena at the level of matter particles (submicroscopic level). Understanding the submicroscopic level will contribute positively to the formation of scientifically correct chemical mental models (conceptual models). Further research should compare the effect of the *TripleChem* learning model with other general learning models suggested for learning science (chemistry), such as the problem-based learning model and the project-based learning model.

REFERENCES

Atmojo, S. E., Kurniawati, W., & Muhtarom, T. (2019). Science Learning Integrated Ethnoscience to increase Scientific Literacy and Scientific Character. In *Journal of Physics: Conference Series* (Vol. 1254, No. 1, p. 012033). IOP Publishing.

Avargil, S., Herscovitz, O., & Dori, Y. J. (2012). Teaching thinking skills in context-based learning: Teachers' challenges and assessment knowledge. *Journal of science education and technology*, *21*, 207-225.

Azhara, F., Dahlan, D., & Tewa, Y. (2020). Efektivitas model pembelajaran discovery learning untuk meningkatkan hasil belajar kimia siswa pada materi pokok asam basa kelas XI IPA di SMA Negeri 1 Loghia. *Jurnal Pendidikan Kimia FKIP UHO*, *5*(3), 117–126.

Coman, C., Țîru, L. G., Meseșan-Schmitz, L., Stanciu, C., & Bularca, M. C. (2020). Online teaching and learning in higher education during the coronavirus pandemic: Students' perspective. *Sustainability*, *12*(24), 10367.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, Quantitative, and mixed Methods Approaches*. Sage publications.

Cunha, S.G.D., Dias, D.D.V, & Streit, L. (2023). The electronic structure of the atom: (Mis)interpretations of quantum concepts by Brazilian university chemistry students. *Journal of Chemical Education, 100*(2), 627-637.

Dewi, C. A., Khery, Y., & Erna, M. (2019). An ethnoscience study in chemistry learning to develop scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *8*(2), 279-287.

Dewi, I. G. A. K. K., Suja, I. W., & Sudiatmika, A. R. (2021). Modul kimia berbasis *TripleChem* untuk meningkatkan model mental peserta didik. *Jurnal Pendidikan Kimia Undiksha*, *5*(2), 60–66.

Drechsler, M., & Van Driel, J. (2008). Experienced teachers' pedagogical content knowledge of teaching acid–base chemistry. *Research in science education*, *38*, 611-631.

Farheen, A., & Lewis, S. E. (2021). The impact of representations of chemical bonding on students' predictions of chemical properties. *Chemistry Education Research and Practice*, *22*(4), 1035-1053.

Fraenkel, J. R. & Wallen, N. (2006). *How to Design and Evaluate Research in Education*. (6th Ed.). New York: McGraw-Hill Companies, Inc

Franco-Mariscal, A. J., Oliva-Martínez, J. M., & Almoraima Gil, M. L. (2015). Students' perceptions about the use of educational games as a tool for teaching the periodic table of elements at the high school level. *Journal of Chemical Education*, *92*(2), 278-285.

Hikmawati, H., Suastra, I. W., & Pujani, N. M. (2021). Ethnoscience-based science learning model to develop critical thinking ability and local cultural concern for junior high school students in Lombok. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 60–66.

Kaberman, Z., & Dori, Y. J. (2009). Question posing, inquiry, and modeling skills of chemistry students in the case-based computerized laboratory environment. *International Journal of Science and Mathematics Education*, *7*, 597–625.

Kelly, R.M. (2014). Using variation theory with metacognitive monitoring to develop insights into how students learn from molecular visualizations. *Journal of Chemical Education, 91*(8), 1152-1161.

Kelly, R. M. (2016). Exploring the instructional use of contrasting molecular animations of a redox reaction. In *Technology and Assessment Strategies for Improving Student Learning in Chemistry* (pp. 117-136). American Chemical Society.

Kelly, R. M., & Akaygun, S. (2016). Insights into how students learn the difference between a weak acid and a strong acid from cartoon tutorials employing visualizations. *Journal of Chemical Education*, *93*(6), 1010-1019.

Kelly, R. M., Akaygun, S., Hansen, S. J., & Villalta-Cerdas, A. (2017). The effect that comparing molecular animations of varying accuracy has on students' submicroscopic explanations. *Chemistry Education Research and Practice*, *18*(4), 582-600.

Kurniawati, Y., Wigati, M. R., & Hasri, S. (2021). Information and communications technology (ICT) based of chemistry instructional learning design for students with multiple intelligence. In *Journal of Physics: Conference Series* (Vol. 1779, No. 1, p. 012062). IOP Publishing.

Lathifa, U., Ajiati, D., & Udaibah, W. (2020). Investigasi model mental pada materi alkohol menggunakan tes diagnostik interview about event. *Jurnal Inovasi Pendidikan Kimia*, *14*(1), 2479–2489.

Levy, S. T., & Wilensky, U. (2009). Crossing levels and representations: The connected chemistry (CC1) curriculum. *Journal of Science Education and Technology*, *18*, 224–242.

MacVaugh, J., & Norton, M. (2012). Introducing sustainability into business education contexts using active learning. *International Journal of Sustainability in Higher Education*, *13*(1), 72–87.

Mahdian, M., Patimah, S., & Kusasi, M. (2022). Efektivitas Model Discovery Learning Dalam Pembelajaran Daring Berbantuan Video Conference Terhadap Kemampuan Berpikir Kreatif Dan Self Regulation Peserta Didik Pada Materi Larutan Elektrolit Dan Non-Elektrolit. *Quantum: Jurnal Inovasi Pendidikann Sains*, *13*(1), 20–35.

Mayer, R. (2020). *Multimedia Learning* (3rd Ed.). Cambridge: Cambridge University Press.

Mudjid, R. M., Supahar, S., Putranta, H., & Hetmina, D. S. (2022). Development of Android Physics Learning Tools Based on Local Wisdom Traditional Game Bola Boy as a Learning Source. *International Journal of Interactive Mobile Technologies*, *16*(6), 92-112.

Nagel, M. L., & Lindsey, B. A. (2021). Implementation of reasoning chain construction tasks to support student explanations in general chemistry. *Journal of Chemical Education*, *99*(2), 839-850.

Nuralita, A. (2020). Analisis penerapan model pembelajaran berbasis etnosains dalam pembelajaran tematik SD. *Mimbar PGSD Undiksha*, *8*(1), 1–8.

Nuralita, A., Reffiane, F., & Mudzanatun, M. (2020). Keefektifan model PBL berbasis etnosains terhadap hasil belajar. *Mimbar PGSD Undiksha*, *8*(3), 457–467.

Parmin, P., & Fibriana, F. (2019). Prospective teachers' scientific literacy through ethnoscience learning integrated with the indigenous knowledge of people in the frontier, outermost, and least developed regions. *Jurnal Penelitian dan Pembelajaran IPA*, *5*(2), 142–154.

Parmiti, D. P., Rediani, N. N., Antara, I. G. W. S., & Jayadiningrat, M. G. (2021). The effectiveness of local culture-integrated science learning through project-based assessment on scientific attitudes and science process skills of elementary school students. *Jurnal Pendidikan IPA Indonesia*, *10*(3), 439–446.

Permatasari, D., & Laksono, E. W. (2019, June). Exploring guided discovery learning: The effect on students' integrated ability and self-regulated in Chemistry. In *Journal of Physics: Conference Series* (Vol. 1233, No. 1, p. 012023). IOP Publishing.

Pujawan, I. G. N., Rediani, N. N., Antara, I. G. W. S., Putri, N. N. C. A., & Bayu, G. W. (2022). Revised Bloom Taxonomy-Oriented Learning Activities to Develop Scientific Literacy and Creative Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 47-60.

Putri, S., Abdurahman, A., Andrian, D., Angraini, L., & Effendi, L. (2022). Development of interactive multimedia-based mathematics learning media macromedia flash 8. *International Journal of Trends in Mathematics Education Research*, *5*(2), 206–213.

Putri, D. N., & Wiyarsi, A. (2022). Identification of mental models of high school students on acid-base theory. In *AIP Conference Proceedings* (Vol. 2468, No. 1, p. 040009). AIP Publishing LLC.

Rahmawati, Y., Baeti, H. R., Ridwan, A., Suhartono, S., & Rafiuddin, R. (2019). A culturally responsive teaching approach and ethnochemistry integration of Tegal culture for developing chemistry students' critical thinking skills in acid-based learning. *Journal of Physics: Conference Series*, *1402*(5), 055050.

Rahmawati, Y., Mardiah, A., Taylor, E., Taylor, P. C., & Ridwan, A. (2023). Chemistry Learning through Culturally Responsive Transformative Teaching (CRTT): Educating Indonesian High School Students for Cultural Sustainability. *Sustainability*, *15*(8), 6925.

Redhana, I. W., Sudria, I. B., Suardana, I. N., Suja, I. W., & Putriani, V. D. (2020). Students' mental models in acid-base topic. In *Journal of Physics: Conference Series* (Vol. 1521, No. 4, p. 042092). IOP Publishing.

Rizaldi, D. R., Andayani, Y., Doyan, A., Makhrus, M., Fatimah, Z., & Nurhayati, E. (2021). The use of Betel leaf in Nyirih tradition: Analyzing an ethnoscience-based learning material. *International Journal on Education Insight*, *2*(1), 29-36.

Sartika, R. P., & Hadi, L. (2015). Pengembangan Perangkat Pembelajaran Model Siklus Belajar 5E Pada Materi Hukum Dasar Kimia Dalam Meningkatkan Hasil Belajar Mahasiswa. *Jurnal Pendidikan Matematika dan IPA*, *6*(1), 74–81.

Sendur, G., Toprak, M., & Pekmez, E. S. (2010, November). Analyzing of students' misconceptions about chemical equilibrium. In *international conference on new trends in education and their implications* (pp. 1-7).

Siregar, E. A., & Kurniawati, Y. (2022). The Analysis of Students' Mental Models Using Macromedia Flash-Based Learning Media on Molecular Shapes Lesson. *Jurnal Inovasi Pendidikan Kimia*, *16*(1), 47-52.

Stiawan, E., Basuki, R., Liliasari, L., & Rohman, I. (2022). Enhancement of Indonesian High School Student Conceptual Mastery on VSEPR Topic Using Virtual Simulation of Molecule Shapes: A Case Study of Quasi-Experimental Evidence. *Jurnal Pendidikan IPA Indonesia*, *11*(4), 511-518.

Suciyati, A., Suryadarma, I. G. P., & Paidi, P. (2021). Integration of ethnoscience in problem-based learning to improve contextuality and meaning of biology learning. *Biosfer: Jurnal Pendidikan Biologi*, *14*(2), 201-215.

Suja, I. W. (2015). Model mental mahasiswa calon guru kimia dalam memahami bahan kajian stereokimia. *JPI (Jurnal Pendidikan Indonesia)*, *4*(2).

Suja, I. W. (2017). Integrasi Kearifan Lokal Ke Dalam Kurikulum Ilmu Alamiah Dasar. *Wahana Matematika Dan Sains: Jurnal Matematika, Sains, Dan Pembelajarannya*, *11*(1), 77-93.

Suja, I. W. (2018a). *Model pembelajaran TripleChem untuk mengembangkan kompetensi mahasiswa calon guru kimia.* [Doctoral dissertation, Unpublished]. Universitas Negeri Surabaya Indonesia.

Suja, I. W. (2018b). Profil model mental siswa SMA kelas XII tentang struktur dan sifat senyawa organik. *Wahana Matematika dan Sains: Jurnal Matematika, Sains, dan Pembelajarannya*, *12*(2), 58–64.

Suja, I. W., Sudiana, I. K., Redhana, I. W., & Sudria, I. B. N. (2021, March). Mental model of prospective chemistry teachers on electrolyte and nonelectrolyte solutions. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1115, No. 1, p. 012064). IOP Publishing.

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia*, *9*(1), 11–21.

Meristin, A., Meristin, A., & Rosita, I. (2023). The Chemical Learning Effectiveness Based on Pelangiran Ethnoscience in Improving Students' Scientific Process Skills Through Electrolyte and Non-electrolyte Material Solution. In *3rd Universitas Lampung International Conference on Social Sciences (ULICoSS 2022)* (pp. 118-128). Atlantis Press.

Supriadi, S., Wildan, W., Hakim, A., Savalas, L. T., & Haris, M. (2021). Model mental dan kemampuan spasial mahasiswa tahun pertama dan ketiga pendidikan kimia di Universitas Mataram. *Jurnal Pijar Mipa*, *16*(3), 282–287.

Suradika, A., Dewi, H. I., & Nasution, M. I. (2023). Project-based learning and problem-based learning models in critical and creative students. *Jurnal Pendidikan IPA Indonesia, 12*(1), 153-167.

Tasker, R., & Dalton, R. (2006). Research into practice: visualisation of the molecular world using animations. *Chemistry Education Research and Practice*, *7*(2), 141-159.

Tsaparlis, G., & Finlayson, O. E. (2014). Physical chemistry education: its multiple facets and aspects. *Chemistry Education Research and Practice, 15*(3), 257-265.

Widayanti, E. (2020). Potensi pembelajaran saintifik bernuansa etnosains untuk memberdayakan kemampuan berpikir kritis siswa. *Wahana Didaktika: Jurnal Ilmu Kependidikan*, *18*(1), 82–94.

Wildan, W., Hakim, A., Supriadi, S., Hadisaputra, S., & Savalas, L. R. T. (2023, April). Correlation of the mental models, spatial abilities, and student learning outcomes in environmental chemistry courses. In *AIP Conference Proceedings* (Vol. 2619, No. 1). AIP Publishing.

Yerimadesi, Y., Warlinda, Y. A., Rosanna, D. L., Sakinah, M., Putri, E. J., Guspatni, G., & Andromeda, A. (2023). Guided Discovery Learning-Based Chemistry e-Module and ITS Effect on Students' Higher-Order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*, *12*(1), 168-177.

Yulianti, Y., Pursitasari, I. D., & Permana, I. (2022). Spatial ability and digital literacy profiles: Preceding survey on the need of augmented reality media in chemistry instruction. *Indonesian Journal of Educational Research and Review*, *5*(2).

Yulianto, F., Winarno, W., & Indriayu, M. (2023). Audiovisual Learning Media Based on Local Wisdom Values of the Baduy Tribe Community to Grow Student Character. *International Journal of Elementary Education*, *7*(1), 43-53.