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MENTAL MODEL AND SCIENTIFIC REASONING ABILITY OF CHEMISTRY EDUCATION STUDENTS DURING COVID-19 PANDEMIC ONLINE LEARNING

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Abstract: This study aims to find: (1) the development of students' scientific reasoning abilities; (2) mental models developed by students in understanding the concept of dissolving weak acids and weak bases; and (3) the relationship between scientific reasoning abilities and mental models. The research approach is a descriptive study. The research subjects were 38 first-year students of the Chemical Education Study Program, Faculty of Teacher Training and Education, The University of Mataram. The research data collected were scientific reasoning ability data and student mental model data on the concept of dissolving weak acids and weak bases. Students' scientific reasoning ability was measured using the revised Classroom Test of Scientific Reasoning (CTSR) instrument in 2000, developed by Lawson and translated into Indonesian. The translation test has a reliability coefficient, calculated by the KR-20 formula, of 0.74. Identification of mental models using written tests and interviews. The content validity of the mental model test instruments is 94.2%. The data obtained were analyzed descriptively. The identification of mental models is made by using a constant comparative technique. The results showed a delay in developing students' scientific reasoning abilities compared to the criteria set by Lawson. Most of the students developed initial mental models in understanding dissolving weak acids and bases. In addition, the higher the student's scientific reasoning ability, the mental model developed tends to approach the scientific mental model.

Keywords: *Mental Model, Scientific Reasoning Ability, Online Learning*

INTRODUCTION

The current pandemic has forced Mataram University students to carry out online learning. Online learning at the University of Mataram is carried out through several media, namely, through SPADA, Zoom meetings, or Google meet, and many even use the Whatsapp application. Based on the author's observations during online learning, teachers have difficulty controlling students because they do not activate videos, so the quality of learning becomes less. It can lead to a lack of student understanding of what is being studied.

The implementation of online chemistry learning at the University of Mataram needs to be evaluated through students' perceptions and learning outcomes. One type of student learning outcome that is important to evaluate is mental models. A mental model is the ability to represent three chemical representations. In studying chemistry, students are required to have the ability to have three chemical representations, namely macroscopic, submicroscopic, and symbolic, because complete chemical material must be studied through these three levels of representation. A mental model represents ideas in a person's mind that are used to explain a phenomenon [1]. Every chemical phenomenon that occurs in life can be explained in detail using three levels of representation [2,3].

Identification of students' mental models is very important in developing learning designs, overcoming student misunderstandings to meet learning objectives, and conceptual development and conceptual change of students. Understanding mental models is also a central issue for cognitive science because mental models are important in reasoning about complex physical systems, making and articulating predictions about the world, and finding causal explanations for what happens around us. Mental models in learning and teaching have become an important topic for researchers and instructional designers worldwide [4].

Besides mental models, students' scientific reasoning abilities are also important to identify because these abilities affect mental models. Mental models are also influenced by scientific reasoning abilities [5]. Scientific reasoning skills are needed in developing students' mental models [6]. Scientific reasoning abilities support mental models developed by individuals in interpreting external representations of chemical phenomena. In explaining a phenomenon, a person does reasoning and will form a mental model to explain or describe the phenomenon.

Scientific reasoning is the cognitive ability needed to understand and evaluate scientific information-theoretically, statistically, and causal hypotheses [7]. Students use scientific reasoning skills in doing tasks that require abstract thinking [8]. According to Piaget's theory of intellectual development, its ability is theoretically achieved when the individual is at the formal operational stage. According to Piaget, at the formal operational stage, a person can think not only

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limited to concrete objects but also abstract. Only at this stage can a person control and associate variables or look for relationships such as proportions [9]. The characteristics of learners' abilities at the formal operational stage are isolating and controlling variables, combinational thinking, correlational thinking, probability thinking, and correlational thinking. The abilities at the formal operational stage are also the constituents of scientific reasoning abilities [7]. One who has reached the formal operational stage generally has good scientific reasoning abilities [9].

Scientific reasoning skills are needed to understand scientific material and construct chemical concepts, such as concepts on the topic of acid-base solutions [9-11]. Empirical studies both conducted at home and abroad show a delay in developing students' thinking [12-15]. Oloyede revealed that 50-70% of students cannot yet reason scientifically [16]. According to Lawson [8], 18-year-old learners have achieved scientific reasoning skills at the post-formal level. The delay in developing students' scientific reasoning abilities can cause students to tend to have difficulty understanding abstract concepts such as concepts on the topic of acid-base solutions. It aligns with Asnawi's research that 18-year-old students have not yet achieved scientific reasoning abilities at the post-formal level [17]. Therefore, even though students (students) are between 18-22 years old, there is a possibility that most of the students have not reached the level of scientific reasoning (formal or post-formal) that they should be able to achieve by age.

Students with concrete reasoning are included in the level of concrete thinking and fail to solve problems because they do not have logical reasoning. Therefore, it can be estimated that students with concrete reasoning will develop initial mental models. Mental models are not following scientific knowledge. In contrast to students who have formal and post-formal reasoning abilities that are included in the level of formal thinking, they are successful in solving problems because their mental models guide the logical reasoning involved in problems have been developed and have been able to reason hypothetically-deductively [13]. It is possible that students with formal and post-formal reasoning can develop synthetic mental models and even go to scientific mental models. So, the higher a person's reasoning ability, the mental model developed is increasingly towards a scientific mental model, namely a mental model that follows scientific knowledge.

This research is expected to find mental models developed by students in explaining the concept of dissolving weak acids and weak bases and students' scientific reasoning abilities, and the relationship between mental models and students' scientific reasoning abilities. By knowing the learner's mental model, the difficulty and success of students in understanding the concept of a weak acid and weak base solutions at the macroscopic, submicroscopic, and symbolic levels will be known [1]. In addition, by analyzing mental models, their conception of the concepts of weak acids and weak bases given in the lesson will be revealed, including the possibility of finding misconceptions.

RESEARCH METHOD

This research is a descriptive approach. Descriptive research is intended to describe students' scientific reasoning abilities, identify mental models and the factors that influence the formation of students' mental models in understanding the concept of acid-base solutions, and analyze the relationship between mental models and students' scientific reasoning abilities. The subjects of this study were the second-semester students of the Chemistry Education Study Program, Mataram State University, totaling 38 students. Sampling using a purposive sampling technique. Sampling is based on new students entering college in the chemical education study program.

Table 1. Student Mental Model Rubric

Types of mental models	Content
Initial model	The perception that is not following scientific knowledge: non-scientific and not submicroscopic depictions
Synthetic model	The perception that is partly or partially incompatible with scientific knowledge: drawing apart from the scientific picture to the submicroscopic level
Scientific model	Perception according to scientific knowledge: drawing all components from scientific representation to submicroscopic level.

[19]

In this study, two types of research data are collected: data on students' mental models and data on students' scientific reasoning abilities. Students' mental models were collected by using mental model tests and interviews. The student's mental model identification test consisted of 2 essay questions about a weak acid solution and a weak base solution. This question is used to see students' mental models by examining the analysis and predictions of the student's answers. The mental models' identification is made using the constant comparative technique, which is applied to the respondents' answers [18].

The types of mental models will be grouped into initial mental models, synthetic

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mental models, and scientific mental models. The classification of mental models is carried out according to the rubric in Table 1. The percentage of students who achieve each level of mental models is calculated.

The measurement of students' scientific reasoning ability uses the revised 2000 edition of The Classroom Test of Scientific Reasoning (CTSR) instrument developed by Lawson, which has been translated into Indonesian. The CTSR consists of 24 multiple choice items, including questions about conversion, identification, and control of variables, correlational reasoning, proportional reasoning, probability reasoning, and hypothetico-deductive reasoning. The CTSR instrument is an instrument that is commonly used to measure students' reasoning ability and has been tested for validity and reliability [9]. The level of students' scientific reasoning ability is based on the scientific reasoning ability test scores obtained by students. Students' scientific reasoning abilities are classified into four levels based on the criteria set by Lawson, which are shown in Table 2. Then the percentage of students who reach a certain reasoning ability level is calculated.

Table 2. Criteria for Students' Scientific Reasoning Ability Level Based on CTSR Score

No	CTSR Score	Level of Scientific Reasoning Ability
1	0-9	Concrete
2	10-14	Low formal
3	15-19	Upper formal
4	20-24	Post-formal

[10]

RESULTS AND DISCUSSION
Student Mental Model

. A mental model is a student's ability to relate three levels of chemical representation. The three levels of representation are macroscopic, symbolic, and submicroscopic. There are three categories of student mental models: initial, synthetic, and scientific. The initial category has the lowest level, while scientific is the highest level.

Based on the analysis results of students' explanations and descriptions of the dissolution of weak acids and weak bases, the categories of students' mental models are given in Table 3.

Table 3 depicts some of the student's developed initial mental models. The mental model developed by students still contains alternative concepts. The alternative concept is that weak electrolyte compounds such as acetic acid and ammonium hydroxide dissolve completely in water to form ions, and some think that they do not form ions in water, even though these compounds are partially soluble. An example of a mental model containing alternative concepts is given in Figure 1.

Table 3. Categories of Student Mental Models

Mental Model Category	Number of students	Percentage (%)
Initials	31.0	81.6
synthetic	7.0	18.4
scientific	0.0	0.0

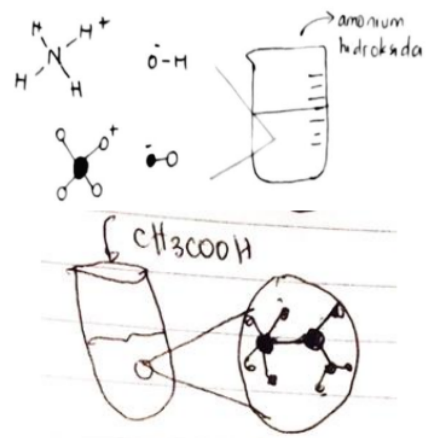

Figure 1 . Students' mental model of dissolving weak acid and weak base compounds in water

The examples of mental models developed by students can be seen in Figure 2.

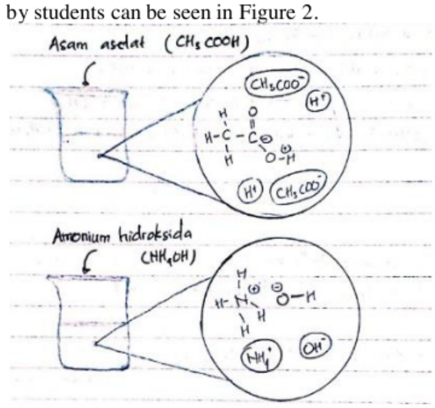

Figure 2. Description of the synthetic mental model developed by students

New students (second semester) aged around 18-19 years who are included in the adult age should have developed a scientific mental model. Table 3 shows that only 7% of students developed a synthetic mental model, and no student developed a scientific mental model to explain the process of dissolving weak acids and weak bases. It

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shows that there is a delay in students developing their mental models.

A person's mental model develops and occurs continuously throughout the development of a person's life. Many factors affect the mental model. One of the dominant factors is individuals' learning experience when formal learning at school. The accumulation of learning experienced by new students of the chemistry education study program at the University of Mataram at the elementary, junior high, and high school levels is still ineffective in developing their mental models. So far, the learning process they get at the elementary, junior high, and high school levels are learning with a verification approach, where learning is dominated by the provision of material by the teacher. They do practical work to prove the concepts they get. The evaluation of learning that they have received at the elementary, junior high, and high school levels is only a matter of cognitive and conceptual, and algorithmic in nature. The learning process and evaluation obtained have not been able to guide them in solving problems related to everyday life. It is one of the reasons for the delay in the development of their mental models.

Several factors influence the development of a person's mental model. The factors that determine students' ability to interpret external representations of chemical phenomena include students' reasoning abilities, students' understanding of the relevance of concepts to the phenomena described, and student's ability to engage their reasoning and understanding in interpreting chemical phenomena [20]. In addition, students' mental models are also influenced by intellectual stimulation and students' ability to connect the three levels of representation, namely macroscopic, submicroscopic and symbolic representations [21]. One of the dominant factors is intellectual stimulation. Long suggested that intellectual development depends on the quality and frequency of intellectual stimulation individuals receive from adults or their environment. Much intellectual stimulation arises from the learning process in the classroom. Learning chemistry at the Department of Chemistry Education at FKIP University of Mataram has been using a verification approach. Learning is more verbal, and learning methods that do not support the elaboration of submicroscopic representation strategies. In addition, the learning process in the classroom is not prepared or does not support the optimization of learning experiences that help students understand phenomena properly and correctly. Students must be able to create or form an understanding construction that can represent their mental models at the macroscopic, microscopic, and symbolic levels and make connections between these three levels with each other. The lack of intellectual stimulation received by students during the learning process is one of the causes of the delay in developing their mental models [22,23].

Students' Scientific Reasoning Ability

Based on the criteria set by Lawson, the scientific reasoning ability of chemistry education students at the University of Mataram is given in Table 4.

Table 4. Level of Scientific Reasoning Ability of Chemistry Education Students

Score	Number of students	%	Level of scientific reasoning ability
0 – 9	27.0	71.0	Concrete
10 – 14	9.0	23.7	Low formal
15 – 19	2.0	5.3	Upper formal
20 – 24	0.0	0.0	Post formal

Students with a minimum age of 19 years should have reached the post-formal operation level. The data in Table 4. shows that there are no students who have reached the level of post-formal operations. So, these students experience delays in developing scientific reasoning abilities [24].

According to Piaget's theory of intellectual development, the ability to reason scientifically belongs to individuals who are already at the formal operational stage. The development of scientific reasoning skills depends on many factors. According to Piaget, these factors include maturity (maturation), social interaction, scientific experience, logical-mathematical experience, and intellectual stimulation. One of the dominant factors is intellectual stimulation.

Learning chemistry at the Department of Chemistry Education at the University of Mataram has used a verification approach. Learning is done by first explaining the subject matter, especially concepts and principles, to students, followed by laboratory activities. In the usual laboratory activities, everything related to the experiments to be carried out has been explained to students before they work. Students are given detailed experimental procedures and explanations on how to analyze the data obtained from the experimental results. Thus the purpose of laboratory activities tends only to provide opportunities for students to be skilled in working in the laboratory. Verification learning is less able to lead to the development of students' formal thinking [25]. So, the learning process used in teaching chemistry material in the chemistry education department at FKIP University of Mataram tends to be less effective in improving students' scientific reasoning abilities. Likewise, the chemistry learning process they get in high school is mostly still using a verification approach, even though they have used the 2013 curriculum,

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which has a scientific approach. The lack of intellectual stimulation received by students during the learning process is one of the causes of the delay in developing their scientific reasoning abilities.

Relationship between Mental Models and Students' Scientific Reasoning Ability

The distribution of students' mental models regarding the concept of dissolving weak acids and weak bases in terms of scientific reasoning abilities is given in Figure 3.

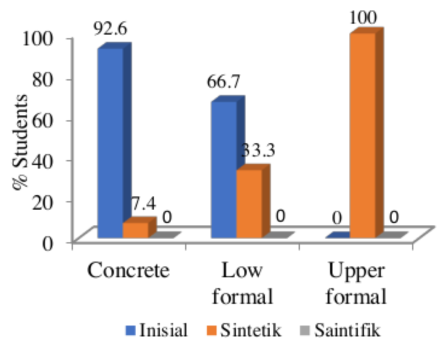

Figure 3. Student Mental Model Distribution in terms of Scientific Reasoning Ability

Figure 3 shows a decrease in the percentage of students who have initial mental models from concrete to upper formal scientific reasoning abilities. In contrast, for synthetic mental models, on the contrary, there is an increase in the percentage of students with concrete to upper formal scientific reasoning abilities. It shows that the higher the level of scientific reasoning ability, the mental model developed tends to approach the scientific mental model.

The data in Figure 3 shows that although students' scientific reasoning abilities are at the formal upper level, it does not guarantee that the mental model they develop is a scientific mental model or a scientific mental model. It shows that the development of an individual's mental model is not only influenced by his scientific reasoning ability. According to Laird, the development of mental models that occur in each individual is influenced by several factors, including the reasoning process of each individual, due to the learning process and daily experiences [26,27]. The learning process experienced by students of the chemistry education program at the University of Mataram at the elementary, junior high, high school, and college levels does not seem to be effective in developing their mental models. So far, the learning process they get tends to be learning with a verification approach, where learning is dominated by giving material from the teacher, and then they do practical work to prove the concepts they get. The learning evaluations they have received so far are only cognitive questions that are conceptual and algorithmic. The learning process and the evaluation obtained do not seem to have been able to optimize the development of their mental model.

In addition to students' reasoning abilities, mental models are also influenced by students' understanding of the relevant concepts to the phenomena described and students' ability to involve reasoning and understanding in interpreting chemical phenomena [20]. Students' mental models are also influenced by students' ability to relate the three levels of representation, namely macroscopic, submicroscopic and symbolic representations [21]. The learning process obtained by students at the high school and college-level tends to present chemistry material at the level of macroscopic and symbolic representation. Only a few teachers or lecturers present chemistry material using models or modelings such as mollymood and animation. However, some students have difficulty understanding chemistry at the submicroscopic level of representation. They have difficulty connecting the three chemical representations, which causes students' understanding of chemistry to be incomplete and causes learning difficulties. Students tend not to be given learning to the most basic level, namely the submicroscopic level. Before students were given learning at the submicroscopic level, students were not able to describe the process of chemical phenomena. However, after being given learning at the submicroscopic level, students had an overview of the process of chemical phenomena. Therefore, scientific reasoning ability is not the only thing that affects students' mental models [28].

Based on interviews with several students, it was found that the learning they received did not emphasize submicroscopic representations. Suppose the applied learning provides students with experience in visualization at the submicroscopic representation level. In that case, students will likely be able to visualize (model) chemical phenomena at the submicroscopic representation level [29].

CONCLUSION

Based on the results of research and discussion, it can be concluded that there is a delay in the development of students' scientific reasoning abilities compared to the criteria set by Lawson. Most students develop initial mental models in explaining the concept of weak acids and weak bases. The higher students' scientific reasoning abilities, the mental models developed tend to approach the scientific mental model.

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