Students’ Mental Models in Acid-Base Topic Based on Gender

V D Putriani 1, I W Redhana 2, and S Maryam 3

1,2,3 Universitas Pendidikan Ganesha, Indonesia, Jalan Udayana 11 Singaraja Bali 81116 Indonesia

Email: vinadputriani@yahoo.com

Abstract. This study aimed to describe differences of student’s mental models based on gender and the factors influencing the student’s mental models in understanding acid-base topic. The study was a survey research. The population consisted of 279 students of 11th-grade of Mathematics and Natural Sciences Classes of SMA Negeri 1 Singaraja in Buleleng Bali at an academic year of 2018/2019. In this study, all members of the population became members of the sample. The data needed in this study were the student's mental model scores and factor that influence student’s mental model. Data were collected using a diagnostic test and questionnaire. Data were analysing descriptively by grouping student’s mental model based on gender and factors that influence student’s mental model. The results showed that there was no significant difference in student’s mental model based on gender. In addition, most of the factors that influence student’s mental model were the internal and external factors.

Keywords: acid-base, diagnostic test, gender, mental model

1. Introduction

Chemistry is a branch of natural science that studies the nature of matter, the structure of matter, changes in matter, and the energy that accompanies changes in matter. Chemistry plays a role in advancing the power of human thought because through chemistry, the little things of life can be explained logically. Studying chemistry is not enough with the achievement of theory alone, but there needs to be an understanding of the three levels of representation that are interrelated to one another, namely macroscopic, submicroscopic and symbolic [1]. To build a complete understanding of chemistry, students must be able to connect the three levels of representation in explaining a phenomenon.

Students' ability to relate the three levels of chemical representation will reflect their mental models [2]. Mental models are intrinsic representations of objects, ideas, or processes that arise during cognitive processes to give reasons, describe, explain, or predict a phenomenon [3]. In chemistry learning, students’ mental models can be identified by the way students represent the three levels of chemistry and their interconnections. Each student has a different perspective and understanding of chemical concepts so that each student's mental model is different [4]. The difference in mental models of these students can be influenced by internal factors and external factors. In addition to internal factors and external factors also affect by gender.

Gender is anything that is associated with a person's sex, including the roles, behavior, preferences, and other attributes that describe men and women. Gender differences are related to the
ability to think and the achievement of student learning outcomes. Elliot [5] which stated that boys often experience problems in terms of language, so girls are declared superior in terms of verbal ability. This gender difference also seems to affect the amount of student motivation for achievement. This is due to the notion that boys are superior in science and mathematics, while girls will be superior in more feminine tasks such as art and music. This research is in line with Bang and Baker [6] which states that, (1) girls consider science a difficult subject, (2) girls are not confident in their scientific process abilities, and (3) girls show poor performance in science and mathematics. This shows that boys have higher scientific learning achievement than girls. Based on these data, male students have higher science scores than female students. Male student have higher critical thinking skills so the scientific mental models are formed. Female students have higher verbal abilities, but the critical thinking skills is low, so the mental models formed tend to be initial and synthetic mental models.

Mental models are classified into three types, namely scientific, synthetic, and initial mental models [7]. Scientific mental models can be built if students have the ability to develop critical thinking skills and are supported by good chemistry learning. In fact, students are less able to develop critical thinking skills and solve problems so students have difficulty building scientific mental models. Several studies of mental models have found that many students have very simple mental models about chemical phenomena, for example atomic and molecular models that are described as discrete and concrete structures, but do not have the skills to build more complex mental models [8].

There are several ways that are used to find out students' mental models, one of them with a mental model diagnostic test. Through this diagnostic test, the teacher can find out the reasons for student answers and students' understanding of chemical structures. Information about student understanding can be used by teachers in planning teaching and learning strategies that are appropriate to improve student learning outcomes.

One topic of chemistry that requires an understanding of the three levels of chemical representation is acid base. The topic of acid-base is a prerequisite topic to be able to understand the next topic, such as hydrolysis, buffer solutions and acid-base titration. Conceptually, the topic of acid and base tends to be abstract, making it difficult for students to connect the three levels of chemical representation. The existence of submicroscopic level which tends to be abstract causes the concepts on the topic of acid-base to be considered difficult by some students. The results showed that students had difficulty in describing the microscopic aspects of an acid or base solution [9]. The difficulty is caused by the inability of students to think at the submicroscopic level using chemical symbolic language.

Given the importance of knowing students' mental models, this study investigated students' mental models on the topic of acid and base. The results of this study can be used by chemistry teachers to choose the right learning strategies so that they can overcome students' problems related to mental models.

2. Method

This research is a survey research. The topic of chemistry studied is acid-base. The study population was all students of class XI MIPA SMA Negeri 1 Singaraja in the 2018/2019 school year consisting of 279 students. All members of the population were sampled. In this study, the sample consisted of 120 male and 159 female. Data of students’ mental models were collected by test. The instrument used in this study was a diagnostic test of mental models in the form of essay with an open reason. This diagnostic test has two levels of answers, the first level is in the form of essay questions with answers along with students' reasons and the second level is in the form of a description of particulate arrangements. Data from diagnostic test results were analyzed descriptively by grouping students' mental models based on gender. There are three types of mental models of students, namely mental, scientific, synthetic, and initial mental models [7]. The data analysis technique of students' mental models based on gender is done by testing the proportion of two samples with a significance level of 5%. Data of factor that influence student’s mental model were collected using a questionnaire. The questionnaire consist of source of students' answers in test, such as book, internet, teacher, and the
others source. These factors are investigated through the responses of the students in the questionnaire given.

3. **Results and Discussion**

Profiles of students' mental models based on gender are shown in Figure 1.

![Figure 1. Chart of Mental Model Profile Based on Gender](image)

Based on the data in Figure 1, male students have a percentage of scientific mental models of 3.75% and female students have a percentage of scientific mental models of 3.46%. The percentage of scientific mental models of male students was 0.29% greater than female students. In testing the proportion of students' scientific mental models based on gender, the calculated Z value is 0.45, while the Z table is 1.96. The value of Z count < Z table, so the null hypothesis is accepted meaning that there is no significant difference in the scientific mental models of male and female students.

In testing the hypothesis of the proportion of students' synthetic mental models based on gender, the calculated Z value is 0.61, while the Z table is 1.96. The value of Z count < Z table, so the null hypothesis is accepted meaning that there is no significant difference in the synthetic mental models of male and female students.

In testing the hypothesis of students' initial mental models proportion based on gender, the calculated Z value is -0.79, while the Z table is 1.96. The value of Z count < Z table, so the null hypothesis is accepted meaning that there is no significant difference in the initial mental models of male and female students.

Initial mental models are perceptions that are incompatible with scientific knowledge or experience misconceptions. Students who are classified as mental models have wrong or illogical answers. In problem number one about the nature of the methylamine compound (CH$_3$NH$_2$), male students who have the initial mental model answer CH$_3$NH$_2$ are acidic because they have the element H as shown in Figure 2, while female students answer CH$_3$NH$_2$ are acidic because they have an H$^+$ ion as shown in Figure 3.
Students think that this is in accordance with Arrhenius's theory that compounds which, when dissolved in water, release H\(^+\) ions have acidic properties. Based on this, it is known that students only use Arrhenius's theory in determining the nature of acid base. Students are less able to apply Lewis's theory in determining the nature of acid base. These results are consistent with Amry et al. [10] study which found students assume that all compounds containing H atoms are acids and those containing OH groups are bases. Male and female students who have this initial mental model experience the same misconception, so that gender does not affect the level of student misconceptions. This is in line with the findings of Utami et al. [11] who found that gender had no effect on student misconceptions.

In general, there was no significant difference in mental models between male and female students. These results are consistent with Ajayi's [12] study which found that there were no significant differences in the academic achievement scores between male and female students. In line with the findings revealed by Heong et al. [13] that gender, academic achievement, and socioeconomic status do not affect students' thinking abilities. So, gender does not significantly influence students' mental models.

Factors that influence students' mental models are obtained based on the source or origin of students' answers on each diagnostic test item. Factors affecting students' mental models on the topic of acid-base according to the results of this study are shown in Figure 4.
Student mental models can be caused by two factors, namely internal factors and external factors. Internal factors are factors that originate from within students such as intuition and intellectual intelligence, while external factors are factors that originate from outside the student's-self such as books, internet and teachers. The high percentage of books is because students consider books to be the most appropriate source of learning. Books used by students become a factor that influences students' mental models. The book that used by students are Chemistry Student Worksheet and textbook. The low percentage of teachers in influencing students' mental models due to the learning managed by teachers in the classroom emphasizes less on the submicroscopic level. This causes the low ability of students to explain phenomena at the submicroscopic level. This finding is in line with research Devetak et al. [14] shows that learning managed by teachers does not emphasize the submicroscopic level so that students have difficulty interpreting the molecular structure. Based on the diagram of the factors that influence mental models in Figure 4, the low percentage of teachers in influencing students' mental models is due to teachers giving little concepts so students tend to get concepts through other sources such as books and the internet.

4. Conclusions
Based on the results of research and discussion can be concluded as follows. There is no significant difference in students' mental models based on gender. Factors that influence students' mental models are internal factors (intuition and intellectual intelligence) and external factors (books, internet and teachers).

Based on the results of this study it can be suggested that teachers need to apply appropriate learning methods and strategies to the topic of acid-base covering three levels of chemistry and their interconnections. It aims to remediate student understanding to become a scientific mental model

5. Acknowledgments
We would like to express our highest gratitude to the head of SMA Negeri 1 Singaraja for permission so that this study could be carried out properly. We also expressed our gratitude to the teachers who helped us in collecting data on this study.

References
[1] Stieff M 2005 J. Chem. Educ. 82 3 489-493
[2] Chittleborough G 2004 The Role of Teaching Models and Chemical Representations in Developing Student’s Mental Model of Chemical Phenomena Doctoral dissertation (Perth: Curtin University of Technology)
[3] Wang C Y 2007 The Role of Mental-Modeling Ability, Content Knowledge, and Mental Models in General Chemistry Students’ Understanding about Molecular Polarity. Doctoral dissertation. (Colombia: The Faculty of the Graduate School University of Missouri)
[4] Laliyo L A R 2011 J. Penelitian dan Pendidikan, 8 1 1-10
[5] Elliot S N, Kratochwill T R, Cook J L and Travers J F 2000 Educational Psycology: Effective Teaching, Effective Learning, Third Edition. United States of America: Mc.
[6] Bang E and Baker D R 2013 Meylana Int. J. Educ. 3 2 27–42
[7] Kurnaz M A and Eksi C 2015 Educ. Sci.: Theor. Pract. 15 3 787-795
[8] Chittleborough G and Treagust D F 2007 Chem. Educ. Res. Pract. 8 3 274–292
[9] Amalia F R, Ibnu S, Widarti H R and Wuni H 2018 J. Pendidikan IPA Indonesia 7 2 187-192
[10] Amry U W, Rahayu S and Yahmin 2017 J. Pendidikan: Teori, Penelitian, dan Pengembangan 2 3 385-391
[11] Utami R D, Agung S and Bahriah E S Proc. Int. Conf. FKIP UNTIRTA. ISBN 978-602-19411-2-6
[12] Ajayi O V and Ogbeba J 2017 American J. Educ. Res. 5 8 839-842
[13] Heong Y M, Othman W D, Md Yunos J, Kiong T T , Hassan R, and Mohamad M M 2011 Int. J. Soc. Sci. Hum. 1 2 121-125
[14] Devetak I, Vogrinc J, and Glazar S A 2009 Res. Sci. Educ. 39 2 157-179