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STUDENTS' MENTAL MODELS OF ACID AND BASE CONCEPTS TAUGHT USING THE COGNITIVE APPRENTICESHIP LEARNING MODEL

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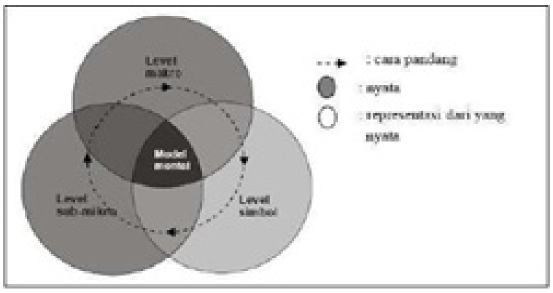
ABSTRACT

A mental model is a student's perception or description of a concept. Chemistry learning requires deep understanding which includes three levels of representation; macroscopic, sub-microscopic, and symbolic. These three levels of representation are interconnected to form a meaningful understanding and students' mental models. The purpose of this study was to look at the mental models of students on acid and base topic that was taught using the cognitive apprenticeship learning model. This research employed explanatory sequential mix method with 65 research subjects. The research instrument was in the form of a description and an interview guide. The results showed that the students' mental models were divided into three types; scientific, synthetic, and initial.

Keywords: mental model, cognitive apprenticeship, acid and base

INTRODUCTION

Chemistry learning requires understanding at three levels of representation, namely macroscopic, submicroscopic, and symbolic (Chandrasegaran et al., 2008; Davidowitz et al., 2010; Juriševi□ et al., 2008). In order to understand the chemistry concepts correctly, students must be able to understand the three representations. Chemistry learning should start from the macroscopic and symbolic and proceed to the submicroscopic aspect since such aspects are the most difficult to comprehend aspects (Cheng, 2009). A student's understanding on the macroscopic and symbolic aspects is directly idenfiable, but the understanding at the sub-microscopy level is observable if the student's mental model is recognized. Devetak, et al. (2009) revealed the relationship between mental models and the three levels of representation. The relationship between students' mental models and the three levels of representation appears in Figure 1.



Source: Devetak, et al. (2009)

Figure 1. The Relationship of Mental Models and the Three Levels of Chemistry Representation.

Johnson-Laird in Johnson-Laird (2013) stated that a mental model is a description of what the student thinks of a particular situation that can be seen in his/her way of delivering

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reasons and explanation. Gentner & Stevens (2014) also revealed that the mental model is a person's representation in understanding and explaining a phenomenon. The mental model is also used to support a person's understanding and logic explanation of a certain condition and formed spontaneously when dealing with a particular situation, but the mental model can also be stored as long-term memory (Gentner & Stevens, 2014). Students' mental models are formed when they learn new concepts and make connections between information received, either in the form of texts or images (Wang & Barrow, 2011). The same thing was expressed by Stains & Sevian (2015) that mental models can be formed when a person is facing a particular problem. (Gentner & Stevens, 2014). revealed that mental models are shaped due to a certain process and repeated certain conditions. This suggests that the mental model may vary according to students' experiences and understanding.

Students' mental models are important to be identified by teachers since it could help them know how the students understand a concept, whether or not there is a mistake in their understanding. This is in accordance with Tumay's statement (2014), by knowing the students' mental models, a misconception is diagnosed. Mental models can be identified through interviews or written tests and expressed through writing, verbal explanations, and drawings (Stains & Sevian, 2015). Several studies on mental models on learning chemistry have been done before (Strickland et al., 2010; McClary & Talanquer, 2011; Wang & Barrow, 2011; Hegarty et al. , 2013). Wang & Barrow (2011) found three levels of students' mental models namely high, medium, and low. The low mental model is influenced by a lack of understanding at the submicroscopic level. Referring to Gentner & Stevens, (2014), mental models can be shaped through explanation and understanding of submicroscopic level. This is related to the learning process experienced by students.

The learning process is influenced by several factors like teachers, learning resources, and learning models. The low mental model is due to the traditional learning model which less emphasizes on the submicroscopic level (Sevian & Talanquer, 2014). In line with this, Talanquer (2011) said that traditional learning refers much to the macroscopic and symbolic levels. Yet to form a proper mental model, it requires a thorough understanding of the three levels of representation. Therefore, a learning model that emphasizes the three levels of representation (Hilton & Nichols, 2011; Yakmaci-Guzel & Adadan, 2013) is necessary. The syntax in cognitive apprenticeship consists of modeling, coaching, scaffolding, articulation, reflection, and exploration. Through the syntaxes, Chemistry materials covering understanding at three levels of representation will be easier for students to accept.

One of the Chemistry topics at High School that requires an understanding of the three levels of representation is the acid and base. Many previous studies have been done and found that there are still many misconceptions occurred in acid and base concepts particularly about the concept of pH and pOH (Kala, et al., 2013). McClary & Talanquer (2011) have also undertaken a study of the acid and base mental models related to the causes of misconceptions. This study identified the students' mental models on acid and base materials taught using cognitive apprenticeship learning model.

METHODS

The samples used in this study were 65 students of grade XI IPA who were studying at MAN 1 Malang. The samples were picked using the cluster random sampling. There were ten questions validated by three validators. After that, 60 students were directed to work on the instruments as the results were analyzed in SPSS 25 for Windows. The results showed that there were two questions that must be elimination. The researchers discussed the instruments with the chemistry teacher and finally obtained four questions covering all the acid and base concepts to identify the students' mental models. The interview guidelines were employed in this study to get more information from the students. Here are the examples of the problems used as the research instruments: (1) Which of the followings have bigger acid rate; the same concentration of HCl and H2SO4? Explain and describe its microscopic state if both acids are dissolved in water; and (2) A strong base is diluted by adding a number of aquades. Which one is the stronger base, before or after dilution?

The students were taught the acid and base topic using the cognitive apprenticeship learning model by the researchers. The learning design and worksheets adopted have been validated by the experts, hence, it was appropriately applied in the learning process. During the learning process, some researchers conducted a question and answer randomly to some students related to the concepts studied. The final exam was performed by assigning a description test. The students' answers on the test were analyzed and categorized based on each concept. The last stage was the interview, conducted with several students who included in the mental models' category of scientific, synthetic, and initial (Kurnaz & Eksi, 2015).

Table 1. The Evaluation Rubric for Descriptive Responses

Level of Understanding (LU)	Score	Criteria
Seemingly Understand (SU)	4	The responses contain all components of the scientifically accepted response
Partially Understand (PU)	3	The responses include some components of the scientifically accepted response
Partially Understand with Alternative Conception (PU-AC)	2	The responses show understood concept yet cover alternative conceptions
Alternative Conception (AC)	1	Scientifically incorrect responses containing illogical or incorrect information
No Understanding (NU)	0	Blank, irrelevant, or unclear responses

Table 2. The Evaluation Rubric for Visual Responses

Level of Understanding (LU)	Score	Criteria
Correct Depiction (CD)	4	The drawings reflectall components of the scientific depiction
Partially Correct Depiction (PCD)	3	The drawings reflect some components of the scientific depiction
Correct Drawings yet reflects Nonscientific Depiction (CD-ND)	2	The drawings reflectscientific or partial scientific yet nonscientific depiction
Incorrect Depiction(ID)	1	The drawings reflect wholly nonscientific depiction
No Depiction(ND)	0	Blank

Table 3. The Evaluation Rubric of Mental Models

Model of Understanding	Content	Level of Understanding
Scientific	The perceptions coincide with scientific knowledge: the answers are at level 3 (PU or PCD) or 4 (SU or CD)	$\begin{bmatrix} 3 & 3 & 3 \\ 3 & 3 & 3 \end{bmatrix}$
Synthetic	The perceptions partially coincide or do not coincide with scientific knowledge.	[All Other Possibilities]
Initial	The perceptions do not coincide with scientific knowledge: the answers are at level 0 (NU or ND), 1 (AC or ID) or 2 (PU-AC or CD-ND)	$\begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 2 & 2 & 2 \end{bmatrix}$

RESULTS AND DISCUSSION

The obtained results were in the form of students' answers on the test questions and interview results. Next, the researchers chose 12 students to interview with. The results showed that the students had three categories of mental models. These categories adopted from Kurnaz & Eksi (2015).

The questions assigned to the students contained four concepts. There were acid and base ionization in water, pH of acid and base, neutralization, and dilution reaction. There were three mental models for each conceot. In the acid and base ionization concept, the highest mental model category was scientific (85.3%). In this concept, the students could understand that acid and base is ionize in water, also, they could draw the visual aspect of the ionization. However, only 14.7% of the students achieved the synthetic mental models and there was no student reached the initial mental models.

The next concept was the pH of acid and base. The results indicated that only 55.4% of themacquired scientific mental models. 39.4% of the students reached the synthetic mental models and 5.2% of the students arrived at the initial mental models. For the other concepts, there were only a small percentage of scientific mental models. This indicated that concept requiring complex understanding made the students difficult to elucidate it using scientific explanation. As a result, they spent much effort to draw the sub-microscopic aspect.

The following is an example of the students' answers to one of the questions and interviews, having three students for each category.

Example:

A student measures the pH of two acid solutions, namely hydrochloric acid and sulfuric acid. Both have the same concentration that is 0.01 M. Which solution has greater acid rate? Explain and describe its microscopic state if both acids are dissolved in water

Student A

Sulfuric acid has a greater acid rate than hydrochloric acid because its number of H + ions is bigger than hydrochloric acid's.

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$

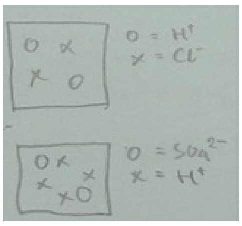

Figure 2. The Student A's Answer

Researchers: What do you mean by having a higher number of H + ions on H2SO4 (compared to HCl) when the concentration is the same?

Student A: The number of H + ions can be seen by multiplying the concentration with the H + ion coefficient based on the ionisation reaction.

Researchers: Why a stronger acid is an acid having more H +?

Student A: The more H + means the higher the H + concentration and the OH-ion concentration decrease. That means the pH is getting smaller. For the acid, the smaller the pH, the greater the strength.

Researcher: It is dissolved in water, isn't it? Does it all turn into ions? Are there the water molecules?

Student A: yes, HCl and H_2SO_4 are strong acid. So it's all ion. There is water, but it's not drawn.

Researcher: In the drawing of H_2SO_4, it's SO_4^{2-}, depicted by 1 symbol. What does SO_4^{2-} look like, actually?

Student A: That's just a picture, there's actually an S atom binding to the O.

The student A belonged to scientific mental models because s/he explained why H_2SO_4 is stronger than HCl. Student A also understood that the larger the H^+ ion, the acid gets stronger and the pH becomes smaller. The number of H^+ in H_2SO_4 is also larger and accurately described, though symbolically, instead of real H^+ and SO_4^{2-} images.

Student B

Sulphuric acid is stronger. The coefficient of H^+ is 2, whereas HCl is only 1. Based on the prior experiment, the pH of HCl is higher than H_2SO_4

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

$H_2SO_4\,(aq) \longrightarrow 2H^+ + SO_4^{2-}(aq)$

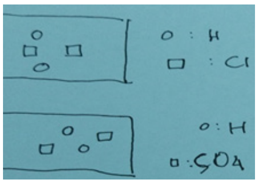

Figure 3. The Student B's Answer

Researchers: The coefficient of H^+ is higher on sulfuric acid. Why do you describe it as high as HCl's?

Student B: That's just a picture. The number is the same as the SO_4, and is not compared to HCl.

Researchers: Do you mean H and Cl, or H^+ and Cl^- ion?

Student B: There are $^+$ and $^-$ charge.

Researchers: Are you saying that the comparison between H^+ and SO_4^{2-} ions is the same?

Student B: Yes, it is the same.

Researchers: You drew it as boxes, does the SO_4^{2-} atom look like that?

Student B: Yes, it does.

Researchers: Are you sure that sulfuric acid is stronger than HCl?

Student B: I am. It has higher H^+. Its pH was also smaller.

The student B was classified to the synthetic mental models since the s/he was able to write the ionization reaction appropriately and understood if the larger H + leads to greater acid rate. However, s/he has not been able to present a microscopic picture of the ionization result of sulphuric acid. S/he thought that the ratio of $^+$ and $^-$ ions is always the same without considering the coefficients.

Student C

HCl is a stronger acid than H2SO4 because of its higher pH.

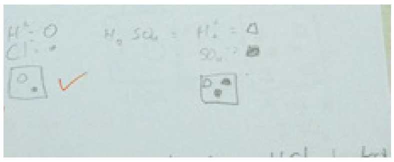

Figure 4. The Student C's Answer

Research: How do you come up with that picture?

Student C: Because they are ionized and turns H_2^+ and SO_4^{2-} .1 to H and 2 SO_4

Researcher: Is there any water in it?

Student C: No, it's all acid.

Researchers: Why is sulphuric acid stronger?

Student C: Its pH is smaller than HCl.

Researcher: If the pH is smaller, is the H^+ higher?

Student C: No, it's smaller.

Student C included in the initial mental models since s/he did not describe the ionization reaction and assumed that the H_2SO_4 ionization results were H_2^+ and SO_4^{2-}. S/he also assumed that at the terion, the number corresponds to the charge. Thus, H's charge was +1, the sum was 1, whereas SO_4^{2-}'s charge was -2, so the ionizing number was 2. Student C was also less understood if there was water in the acid, but it was not described. The phase (aq) should have indicated that there was aquades in the reaction.

Based on the result of interview, it concluded that the students with a high score on test obtained a good understanding in three levels representation. Thus, the students having good mental models were be better on concept understanding. It is similar with last study which stated that mental models have relation with concept understanding (Devetak, 2009).

CONCLUSION

Based on the results, it concluded that most of students achieved scientific mental models in acid and base ionization, and about 50% of them had scientific mental models in other concepts. Cognitive apprenticeship learning model could be considered appropriate in a learning that requires understanding at three levels of representation, since it has syntax modelings in which the teachers could strengthen students' understanding at sub-microscopic level. In addition to the last syntax, there was the exploration stage, resulting in the students' better understanding in new and more complex problems.

Future research on mental models is required since identifying students' mental model is essential for teachers to know the students' level of understanding, difficulty, and misconception. The cognitive apprenticeship learning model on Chemistry concepts also needs further investigation, inasmuch as there are not many prior research investigating such learning model. Further research is expected to award beneficial contribution to the education world.

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