TÜRK FEN EĞİTİMİ DERGİSİ
Yıl 15, Özel Sayı, Aralık 2018

Journal of
TURKISH SCIENCE EDUCATION
Volume 15, Special Issue, December 2018

http://www.tused.org

Identifying Students' Misconceptions of Acid-Base Concepts Using a Three-Tier Diagnostic Test: A Case of Indonesia and Thailand

Febriati Dian MUBAROKAH[1], Sri MULYANI[1], Nurma Yunita INDRIYANTI[1]

[1] Depertment of Chemistry Education, Universitas Sebelas Maret, Indonesia

Received: 20.06.2018 **Revised:** 20.09.18 **Accepted:** 15.12.2018

The original language of article is English (v.15, n. Special Issue, December 2018, pp. 51-58, doi: 10.12973/tused.10256a)

ABSTRACT

Through a descriptive exploratory research design, the current study purposed to diagnose students' misconceptions of acid-base concepts. A Three-Tier Diagnostic Test (TTDT) with 20 items was administered to 72 Thai and 64 Indonesian grade 12 students in the science program. The semi-structured interview was used to probe their responses to the interview questions. Then, their misconceptions were classified under four categories. The result indicated that the Thai and Indonesian students' misconceptions were similar to each other. Most of the students had misconceptions of such concepts as acid-base theories, the strength of acids and bases, pH concept in electrolyte and non-electrolyte characteristics of acids and bases. The results shed more light on students' conceptual understanding. Students should be encouraged to overcome their misconceptions and change them scientific conceptions.

Keywords: acids and bases, chemistry education, misconceptions, three-tier diagnostic test

INTRODUCTION

National educational researches recommend to establish new insights for further learning. Variation in the variables will be more various in the multiple countries. Involving a cross-cultural research within two countries appears some biases, i.e, a researcher's educational background [1]. In addition, understanding another country's science education improves researchers' insights into their national science education [2].

Some researchers have compared their countries' science education programmes with one another and improved their own ones. For example; a study investigated how to teach mole concept at sub-microscopic level in Indonesia and German [3]. This study indicated both countries had different understanding level in the mole concept. Then, a research found the similarities and differences of the English and Turkish students' understanding of genetics concepts [4]. Students' insights from various educational contexts in both countries can be beneficial and significant to identify their pitfalls and learning qualities [5].

© ISSN:1304-6020

Several of the ASEAN countries have a 12-year formal education, i.e., Indonesia and Thailand. Indonesian government started this rule in 1970 to promote an educational equity, while Thailand begun it in 1940. The 12-year formal education is divided into primary, lower secondary and upper secondary levels. The secondary school subjects (i.e., science) in these countries are rather similar [6]. Trend in International Mathematics and Science Study (TIMSS) in 2011 showed that Indonesia's and Thailand's science scores ranked the 40th and 27th out of 45 countries respectively. Examining these countries' achievement levels will be interesting to know more about the Thai and Indonesian students' understanding of some science concepts.

Students sometimes bring their pre-existing knowledge to the class. These pre-conceptions are not consistent with scientific ones. After studying in the class, such factors as inappropriate teaching methods and materials may cause misconceptions, called school-made misconceptions [7]. After investigating the Thai and Indonesian students' misconceptions, the current study will highlight the students' school-made misconceptions.

Students' incomplete knowledge explicitly occur misconceptions [13], which have become a central issue in science education since the past three decades [7–12]. Students' misconceptions of acids and bases are very well documented in such countries as Queensland [14], Turkey [15–18], Malaysia [19], New York [20], Thailand [21] and Indonesia [22–24]. This study will focus on the Thai and Indonesian students' misconceptions of acid-base concepts.

All researchers have used different assessment types to identify students' misconceptions of acids and bases. In this study, the authors used a Three-Tier Diagnostic Test (TTDT of Acids and Bases) consisting of multiple-choice questions. The first tier is a usual multiple-choice test, while the second tier asks for its reason. The third tier inquiries their confidence levels for their answers in the first and second tiers [12].

Because students' misconceptions are often similar to each other despite of different culture, religion, and language [25]. Hence, the present study is unique to focus on two different countries (e.g., Indonesia and Thailand) with different cultures, religions, and languages. Hence, the objective of this study was to diagnose the Thai and Indonesian grade 12 students' misconceptions of acids and bases by using the TTDT of Acids and Bases and to clarify their reasons through a semi-structured interview protocol.

METHODOLOGY

Through a descriptive exploratory research design, the sample of the current study comprised of 136 grade 12 students purposefully selected from two schools in Indonesia and Thailand. The researchers used the TTDT of Acids and Bases to identify their misconceptions. This instrument was developed from previous studies by Amry, Sri, and Yahmin [26], Bayrak [18] and Cetin-Dindar and Geban [17]. To check its content validity, two chemistry lecturers, three chemistry teachers (two from Thailand and one from Indonesia) went over the instrument. Its revised version of the TTDT of Acids and Bases (with 20 items) was administered to 136 grade 12 students (72 Thai students and 64 Indonesian students). They responded the TTDT of Acids and Bases within 45 minutes. The TTDT of Acids and Bases contained 4 fundamental concepts, i.e., acid-base theories, the strength of acids and bases, pH concept in electrolyte and non-electrolyte characteristics of acids and bases. To triangulate the results from the TTDT of Acids and Bases, semi-structured interview protocols were conducted to clarify their responses and reasons students' misconceptions of the acid-base concepts.

a) Data Collection

The participants were informed one week before the test. In Thailand, the researchers employed a Thai version of the TTDT of Acids and Bases validated by two Thai chemistry teachers and one Thai chemistry lecturer. Later, its Indonesian version of the TTDT of Acids and Bases was used. All students responded it about 45 minutes. Then, their responses to the TTDT of Acids and Bases were analyzed. Afterwards, their misconceptions and percentages were identified and calculated. In addition, nine Thai students and three Indonesian students were interviewed to clarify their responses and to investigate their reasons of Acid-Base misconceptions. Interviewees were selected based on their responses to the TTDT. Each interview session took about 5-10 minutes. All interviews were tape recorded and transcribed for analysis.

b) Data Analysis

Each item was analyzed via four categories provided by Kaltakci and Didi: scientific knowledge, lack of knowledge, error and misconception [27]. The criteria were figured out at Table 1.

Table 1. *Categories in the TTDT of Acids and Bases adapted from Kaltakci et al. (2007)*

Categories	Response Types	Code
Scientific Knowledge	correct response + scientific explanation + sure	SK
Lack of Knowledge	correct response + scientific explanation + not sure incorrect response + scientific explanation + not sure correct response + unscientific explanation + not sure incorrect response + unscientific explanation + not sure	LoK
Error	incorrect response + scientific explanation + sure	E
Misconception	correct response + unscientific explanation + sure incorrect response + unscientific explanation + sure	M

RESULTS AND DISCUSSION

Data were tabulated and grouped for each tier. As seen in Figure 1, the percentages of the students, who answered correctly to the TTDT of Acids and Bases from all items, they performed better in their first tiers. In the second and third tiers, the percentages of the correct answers decreased. The same pattern appeared for the Indonesian and Thai students.

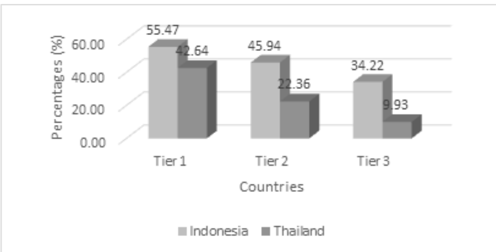

Figure 1. Percentages of the students

These results are consistent with earlier researches using two-tier diagnostic instruments [30]. Almost all of the students had better results in the first tier than other tiers. It also means that a three tier diagnostic test is the most effective assessment to diagnose students' misconception of acids and bases as compared with conventional multiple choice and two tier diagnostic tests. The three tier diagnostic test accurately detected the students' misconceptions with a lack of knowledge or confidence level [12].

As observed in Table 2, the percentages of the Indonesia and Thailand students' misconceptions were similar to one another. These misconceptions may stem from the students' different cultures, religions, and languages [25].

Table 2. *Percentages of the Indonesia and Thai Students' Misconceptions of the TTDT of Acids and Bases*

Item Number	Concepts	Items	Percentages (%) Misconceptions (M)	
			Thai	Indonesian
1	Acid-Base Theories	1	31.94	37.50
		2	34.72	15.63
		3	29.17	31.25
		4	19.44	10.94
		5	18.06	23.44
	Mean		**26.67**	**23.75**
2	The Strength of Acids and Bases	6	15.28	26.56
		7	44.44	60.94
		8	37.50	57.81
		9	26.39	56.25
		10	23.61	57.81
		11	20.83	17.19
		12	37.50	25.00
		13	43.06	25.00
		14	23.61	56.25
	Mean		**30.25**	**42.53**
3	pH Concept in the Environment	15	31.94	10.94
		16	18.06	15.63
		17	9.72	15.63
	Mean		**19.91**	**14.06**
4	Electrolyte and Non-electrolyte Characteristics of Acids and Bases	18	41.67	43.75
		19	26.39	40.63
		20	23.61	43.75
	Mean		**30.56**	**42.71**
	Overall mean value		**26.84**	**30.76**

As seen in Table 2, the Thai and Indonesian students possessed some similar misconceptions. For example; both of them understood the concepts regardless of the contextual factors. But, conceptualizations took place as an influence of different educational contexts [4].

Given the four concepts in this diagnostic test, the highest percentage was belonging to 'Electrolyte and Non-electrolyte Characteristics of Acids and Bases Concept'. Almost all of the students viewed KOH as the only solution that can conduct electricity, since only strong base with a stronger covalent bond can conduct an electric current. A quotation is presented as follows (R: Researcher and S: Student):

R: How about number 18, do you know the answer?
S: That's absolutely A.
R: You're really sure with your answer, why do you choose it?
S: because KOH is the strongest one, so it will conduct the electric current.

As can be clearly seen from the dialogue, the students thought that electricity conductivity was dependent on the strength of the acid-base solution(s). This means that they did take the dissociation value of the solution into account.

Scientifically, the dissociation of a solution determines its electrolyte or non-electrolyte type. Since the solution dissociate in aqueous, it produces ions too. These ions are free to move in solution, therefore the solution conducts electricity. Whatever acids and bases are strong or weak, they have ions that are free to move in an electrolyte solution. The only difference between them is the strength of the electricity produced by the solution.

The percentages of the Thai and Indonesian students' misconceptions of the strength of acids and bases concept were 30.25 and 42.53 respectively. They considered that knowing pH of the solution was enough to identify a strong or weak acid because an increase in pH value decreases its acid strength. An excerpt is in the following:

S: Hm, really? When I read this answer, I just see the pH that will determine the characteristic of the solution, so I absolutely chose it.
R: So, when you read this question, you thought that pH value was the only one determining acidity or basicity of the solution?
S: Yeah, I think so.

As seen from the excerpt, the teacher's explanation of this concept affected their understanding. Most of them saw pH value as the only one to determine the characteristic of the solution. Scientifically, the dissociation of the solution determines a strong or weak acidity of a solution. If the acids are strong, the number of the dissociation is higher than that of the weak one. Even, strong acids or bases completely dissociate in aqueous solution to produce ions. This result is in a parallel with the study by Artdej et al [21] in Thailand. So it proves that misconceptions are resistant to change, persistent, and difficult to relieve in the usual class [31].

The percentages of the Thai and Indonesian students' misconceptions of the acid-base theory were 26.67 and 23.75 respectively. These students chose CH3COOH as a base solution because it contains OH- ion. This means that some students had some misconceptions of the concept of acid and base. In view of Demircioglu [15], students consider that the compound with H is an acidic solution while the compound with OH is alkaline. This is in line with the case in Item 2. A sample excerpt is as follows:

S: … This compound contains OH, so I choose it as a base
R: Hm, do you still remember about acid-base theory that explain about this?
S: Brownsted-Lowry, Arrhenius and lewis?
R: Yes that's right, could you connect it to this question?
S: Sorry, but I am still confused how to differentiate the theory in the question
R: I see…..

As can be seen from that dialogue, grade 12th students were confused with the acid-bases theory that would affect their understanding. Scientifically, CH_3COOH is a vinegar solution that we often meet in our daily life. That appears why students should understand the characteristic(s) of the vinegar. However, many students still had misconception about it. Therefore, context-based learning should be used to enhance their understanding levels. Hence, they may have an opportunity to make abstract concepts more understandable.

The lowest percentages of the Thai and Indonesian students' misconceptions was pertaining to the pH concept in the environment. Their answers were equally distributed. They answered correctly to the first tier, but wrong for the reason tier. The fact that all reason options were equally chosen by the students may result from inability to relate the pH change of a solution with the relevant factors.

Some findings of the current study were practically similar to some previous studies in varied countries, e.g., Turkey [17]. The results emphasized that the TTDT of acids and bases was an effective way to diagnose their misconceptions by differentiating their understanding levels from each other. Students sometimes know the answers but they cannot give their reasons to the answers. By using the TTDT of acids and bases teacher will get insight into their understanding and make some plans to solve any difficulty. Even though students have different languages, cultures, and religions, misconceptions are frequently similar for students at different countries. For example, the results of the present study is similar to such different countries as Queensland [14], Turkey [16], Malaysia [19], and New York [20]. They found similar misconceptions despite of the use of different assessment tools. The TTDT of acids and bases can help teachers effectively elicit their understanding levels because it is time-efficient, easily applicable and effective for accessing many students.

CONCLUSION and IMPLICATION

The Thai and Indonesian students, who had different cultures, religions, and even languages, possessed the same problems in studying the chemistry concepts, especially acid-base concepts. Some misconceptions are in the following:

- 30.56 % of the Thai students and 42.71 % of the Indonesian students thought that only strong acid or base solutions could conduct electricity,
- 30.25 % of the Thai students and 42.53 % of the Indonesian students considered that pH value was the only one to determine the characteristic(s) of the solution,
- 26.67 % of the Thai students and 23.75 % of the Indonesian students viewed CH_3COOH as a base solution because it contains OH^- ion,
- Most of the students was confused with differentiating the acid-base theory from each other,
- 19.91 % of the Thai students and 14.06 % of the Indonesian students were unable to relate the pH change of a solution with the relevant factors.

Therefore, teachers should pay more attention to this problem. The TTDT of Acids and Bases can be used to investigate students' misconceptions. Afterwards, teacher will decide what students need to know the concept(s) scientifically. Hence, they may encourage students to confront their misconceptions and to change their understanding towards a scientific concept.

The results of this study can be a reference for teachers to deliver the subject so that students eliminate their misconceptions and understand the concept(s) correctly. Thus, teachers may know and synchronize students' pre-conceptions before teaching a new concept. Then, teachers are able to prepare appropriate method(s) to instruct acid-base concepts by refraining from new misconception(s).

AKNOWLEDGMENT

The research was supported by the SEA-Teacher Program and the Faculty of Teacher Training and Education, Universitas Sebelas Maret in 2017.

REFERENCES

Amry, U.W., Sri, R. & Yahmin,. (2016). Pengembangan Instrumen Tes Diagnostik Two-Tier pada Materi Asam Basa. *Pros. Semnas Pend. IOA Pascasarjana UM, 1*, 715–722.

Artdej, R., Ratanaroutai, T., Coll, R. K., & Thongpanchang, T. (2010). Thai Grade 11 students' alternative conceptions for acid–base chemistry. *Research in Science & Technological Education*, *28*(2), 167-183.

Barke, H.D., Hazari, A., & Yitbarek, S. (2009). Acid – Base Reactions, *Misconceptions in Chemistry*, 173–206.

Cetin-Dindar, A., & Geban, O. (2011). Development of a three-tier test to assess high school students' understanding of acids and bases. *Procedia-Social and Behavioral Sciences*, *15*, 600-604,

Damanhuri, M. I. M., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). High School Students' Understanding of Acid-Base Concepts: An Ongoing Challenge for Teachers. *International Journal of Environmental and Science Education*, *11*(1), 9-27.

Demircioglu, G., Ayas, A., & Demircioglu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice*, *6*(1), 36-51.

Fraser, B. J., Aldridge, J. M., & Adolphe, F. G. (2010). A cross-national study of secondary science classroom environments in Australia and Indonesia. *Research in Science Education*, *40*(4), 551-571.

Gurel, D. K., Eryılmaz, A., & McDermott, L. C. (2015). A Review and Comparison of Diagnostic Instruments to Identify Students' Misconceptions in Science. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(5).

Hand, B. M., & Treagust, D. F. (1988). Application of a conceptual conflict teaching strategy to enhance student learning of acids and bases. *Research in science education*, *18*(1), 53-63.

Haslam, F., & Treagust, D. F. (1987). Diagnosing secondary students' misconceptions of photosynthesis and respiration in plants using a two-tier multiple choice instrument. *Journal of biological education*, *21*(3), 203-211.

Indriyanti, N. Y., & Barke, H. D. (2017, August). Teaching the mole concept with sub-micro level: Do the students perform better?. In *AIP Conference Proceedings* (Vol. 1868, No. 1, p. 030002). AIP Publishing.

Kaltakçi, D., & Didiş, N. (2007, April). Identification of Pre-Service Physics Teachers' Misconceptions on Gravity Concept: A Study with a 3-Tier Misconception Test. In *AIP Conference Proceedings*, *899*(1), 499-500, AIP.

Kılıç, D., Taber, K. S., & Winterbottom, M. (2016). A Cross-National Study of Students' Understanding of Genetics Concepts: Implications from Similarities and Differences in England and Turkey. *Education Research International*, *2016*.

Lemmer, M., Kriek, J., & Erasmus, B. (2018). Analysis of students' conceptions of basic magnetism from a complex systems perspective. *Research in Science Education*, 1-18.

Muchtar, Z. (2012). Analyzing of students' misconceptions on acid-base chemistry at senior high schools in Medan. *Journal of Education and Practice*, *3*(15), 65-74.

Mulford, D. R., & Robinson, W. R. (2002). An inventory for alternate conceptions among

first-semester general chemistry students. *Journal of chemical education*, *79*(6), 739.
OECD (2009). PISA 2006 Programme for International Student Assessment.
Othman, J., Treagust, D. F., & Chandrasegaran, A. L. (2008). An investigation into the relationship between students' conceptions of the particulate nature of matter and their understanding of chemical bonding. *International Journal of Science Education*, *30*(11), 1531-1550.
Peterson, R. F., & Treagust, D. F. (1989). Grade-12 students' misconceptions of covalent bonding and structure. *Journal of chemical education*, *66*(6), 459.
Peterson, R., Treagust, D., & Garnett, P. (1986). Identification of secondary students' misconceptions of covalent bonding and structure concepts using a diagnostic instrument. *Research in Science Education*, *16*(1), 40-48.
Pinarbasi, T. (2007). Turkish undergraduate students' misconceptions on acids and bases. *Journal of Baltic Science Education*, *6*(1), 23-24.
Ross, P. (1994). The relevance of the term 'misconception'. *Research in Science Education*, *24*(1), 376-377.
Sadhu, S., Tima, M. T., Cahyani, V. P., Laka, A. F., Annisa, D., & Fahriyah, A. R. (2017, August). Analysis of acid-base misconceptions using modified certainty of response index (CRI) and diagnostic interview for different student levels cognitive. In *International Journal of Science and Applied Science: Conference Series*, *1*(2), 91-100).
Sheppard, K. (2006). High school students' understanding of titrations and related acid-base phenomena. *Chemistry Education Research and Practice*, *7*(1), 32-45.
Taber, K. (2002). *Chemical misconceptions: prevention, diagnosis and cure* (Vol. 1). Royal Society of Chemistry.
Taber, K. S. (2012). Vive la différence? Comparing "like with like" in studies of learners' ideas in diverse educational contexts. *Education Research International*, *2012*.
Treagust, D. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science education*, *16*(1), 199-207.
Turgut, Ü., Gürbüz, F., & Turgut, G. (2011). An investigation 10th grade students' misconceptions about electric current. *Procedia-Social and Behavioral Sciences*, *15*, 1965-1971.
UNESCO, Education Systems in ASEAN + 6 Countries : A Comparative Analysis Selected Educational Issues. 2014.
Widarti, H. R., Permanasari, A., & Mulyani, S. (2017). Undergraduate students' misconception on acid-base and argentometric titrations: a challenge to implement multiple representation learning model with cognitive dissonance strategy. *International Journal of Education*, *9*(2), 105-112.