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Misconception of High School Students on Acid-Base Topics and Effectiveness of Argument-Driven Inquiry Learning Model as an Effort to Improve Misconception

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Abstract: The objectives of this study were: 1) calculate the average percent of students in each subtopic on the pretest, posttest, and delay test, 2) identify students' misconceptions in acid-base topic, 3) test the effectiveness of the ADI learning model in correcting students' misconceptions in acid-base topic, and 4) measuring retention of students conceptual understanding of acid-base topic after being given improvements by the ADI learning model. The misconceptions found were used as a basis for reference in implementing the ADI learning model. The results showed that most students did not understand the concept (55%) while the misconceptions (24%) and understood the concept (21%). After improvement using the ADI learning model, the number of students who understood the concept increased to 64%, misconceptions of students' decreased to 17%, students who did not understand the concept also declined to 19%. This shows that most students successfully construct their understanding.

Key Words: CRI technique, ADI learning model, misconception, acid-base topic

Abstrak: Penelitian ini dilakukan dengan tujuan (1) menghitung rerata siswa di setiap sub-sub topik pada pretes, postes, dan tes tunda, (2) mengidentifikasi kesalahan konsep siswa pada materi asam-basa, (3) menguji keefektifan model pembelajaran ADI (*Argument-Driven Inquiry*) dalam memperbaiki kesalahan konsep siswa pada materi asam basa, dan 4) mengukur retensi pemahaman konsep siswa pada materi asam basa setelah diberikan perbaikan dengan model pembelajaran ADI. Kesalahan konsep yang ditemukan digunakan sebagai dasar acuan dalam pelaksanaan model pembelajaran ADI. Hasil penelitian menunjukkan bahwa, sebagian besar siswa ternyata tidak paham konsep (55%) sementara yang miskonsepsi sebanyak 24% dan paham konsep sebesar 21%. Setelah dilakukan perbaikan dengan model pembelajaran ADI, jumlah siswa yang paham konsep meningkat menjadi 64%, siswa dengan miskonsepsi menurun menjadi 17%, siswa dengan ketidakpahaman konsep juga menurun menjadi 19%. Hal ini menunjukkan sebagian besar siswa berhasil mengkonstruk pemahamannya.

Kata kunci: teknik CRI, model pembelajaran ADI, miskonsepsi, materi asam-basa

INTRODUCTION

Acid-base topics are part of Chemical learning in high school. This topic is very complex and related to several other important topics, including, Chemical calculations, Equilibrium Reactions, Buffer Solutions, Hydrolysis Reactions, and Acid-base Titrations. The statement was also supported by Artdej, Ratanaroutai, Coll, & Thongpanchang, 2010, and Acar Sesen & Tarhan, 2013, as knowledge of the topic of acid-base is comprehensive including the discussion of chemical reactions, calculations, and chemical solutions. As a result, mistakes are often experienced by students in understanding the topic of acid base (Sirhan, 2007). The error then repeatedly occurs consistently, which can then be referred to as a misconception. (Effendy, 2002). As a result of the difficulty of eliminating misconception (Iskandar, 2011; Yuruk, 2006), then several attempts to resolve the misconception were made, accordingly it is important to conduct research on misconceptions.

Misconception among student is sometimes difficult to distinguish. It is difficult to observe between

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misconceptions, incomprehension of concepts, and well-comprehended concept. Thus, to obtain such data, a technique is needed in detecting the misconceptions, incomprehension of concepts, and well-comprehended concept. The CRI (Certainty of Response Index) technique published by (Hasan, Bagayoko, & Kelley, 1999) is a technique that aims to detect misconceptions experienced by students, as well as can classify students who understand, do not understand, and misconcept. When this detection takes place, students are directed to answer multiple choice questions accompanied by reasons for choosing the answers provided by choosing the level of confidence or CRI on the answer sheet provided. Measures of student confidence are measured using a scale between zero and five (Likert). This CRI technique was further developed by (Hakim, Liliasari, & Kadarohman, 2012) by comparing modified CRI techniques and multiple choice data retrieval for open reasons. This technique is more detailed and specific in identifying and differentiating between misconceptions, incomprehension of concepts, and well-comprehended concept. Table 1 presents the confidence level/CRI with a Likert scale.

Table 1. CRI Criteria

CRI	Criteria
0	Do not know
1	Unsure
2	Relatively unsure
3	Sure
4	Relatively sure
5	Strongly sure

Argument-Driven Inquiry (ADI) as a learning model is a step for researchers to improve conceptual errors experienced by students of SMA Negeri 9 Ternate. Originating from the social constructivist theory, the ADI learning model was developed, because it can improve critical thinking and be able to exploit the abilities and skills in group discussions and activities during practicuum (Chen, Wang, Lu, Lin, & Hong, 2016; Walker & Sampson, 2013). The model is able to motivate students to develop scientific creativity such as data collection, design analysis, problem identification, and describe the findings by arguing in every problem that exists in scientific activities with group friends (Sampson, Grooms, & Walker, 2010). Based on the explanation, it is expected that the ADI learning model can correct students' misconception.

The correct scientific concept is expected to last for a long time, accordingly students can understand other scientific concepts well without being obstructed by the mistakes of the previously acquired concepts. The amount of knowledge students have learned and can be recalled in a certain period of time is called retention of understanding concepts (Rose, 2007). According to (Dahar, 2011), retention is one indicator of the meaningfulness of the learning process so it needs to be measured in order to improve the quality of learning. The objectives of this study were (1) to calculate the average percent of students in each subtopic on pretest, posttest, and delayed tests, (2) identify students' misconception in acid-base topic, (3) examine the effectiveness of the ADI learning model in improving students' misconceptions in acid-base topic, and (4) measure retention of students' conceptual understanding of acid-base topic after being taught by ADI learning model.

METHOD

The study design was a descriptive and pre-experimental design. The pre-experimental design used to determine the effectiveness of the ADI learning model was one-group pretest-posttest design. Descriptive research design was carried out to describe misconceptions and retention of conceptual understanding of students in the eleventh grade of SMA Negeri 9 Ternate in acid-base topic with 30 research subjects who had acquired acid-base learning. Purposive sampling technique was a technique used to obtain research subjects. Misconceptions of students were identified using Modified CRI techniques. Table 2 contains an example of a decision-making step.

In general the decision-making criteria refer to Table 2, with the CRI criteria presented in Table 3. Based on Table 3, the researcher could identify students who understand the concept, misconception, and do not understand the concept.

Misconception found was used as a basis for reference in implementing the ADI learning model. The instruments used in this study consisted of two kinds, the learning instrument (lesson plan, worksheet) and the test instrument (blueprint). Based on the statistical program, the results of the reliability index value in the trial test were 0.736.

RESULTS AND DISCUSSION

There were three results of the research obtained, namely (1) types of misconceptions in acid-

Table 2. Decision-making Steps of Student Misconception

No	Step	Student's Answer	Expected Answer
1	**Question**	The appropriate container to store acidic solutions such as lemon juice and vinegar is a container made of ... a. Iron d. Glass b. Zinc e. Nickel c. Copper	The appropriate container to store acidic solutions such as lemon juice and vinegar is a container made of ... d. Iron d. Glass e. Zinc e. Nickel f. Copper
2	**Answer**	"D. Glass"	"D. Glass"
3	**Reason**	Acidic solutions can be exposed to sunlight, thus it can conduct electricity well	Acid solutions can react with metals, but are not reactive to glass (silicon dioxide / SiO2).
4	**CRI**	>2,5	>2,5
5	**Interview**	Sure the answer is correct	Sure the answer is correct
6	**Conclusion**	**Misconception**	**Understand**

Table 3. Criteria (a) Understand, (b) Misconception, and (c) Do not understand

(a) Understand

Answer	Reason	CRI Value
Correct	Correct	>2,5
Correct	Correct	<2,5

(b) Misconception

Answer	Reason	CRI Value
Incorrect	Correct	>2,5
Incorrect	Incorrect	>2,5
Correct	Incorrect	>2,5

(c) Do not understand

Answer	Reason	CRI Value
Incorrect	Correct	<2,5
Incorrect	Incorrect	<2,5
Correct	Incorrect	<2,5

base topic, (2) Effectiveness of ADI learning models in improving students' misconception (3) retention of students' conceptual understanding.

Types of Students' Misconception

The misconception discussed in acid-base topic are the characteristics, theories, indicators of acidity, acidity degree, and acid-base neutralization reactions. An explanation of students' misconception found in each acid-base sub concept. The following are some examples of students' misconception found during the interview process.

Acid-base Characteristics

From the data obtained, the average misconception of students in the sub-topic of acid-base characteristics was 25%. Student was then interviewed to reassure the misconception. The following excerpts are the interview dialogue with student.

G: "what is the most appropriate container to store acidic solution such as lemon juice and vinegar?"

S: "A glass container, Sir"

G: "why do you think so?"

S: "When it is stored in glass container, it will be exposed by suinlight and thus it can conduct electricity"

G: "So, acidic solution could conduct electricity if it is exposed by sunlight?"

S: "Yes, Sir"

According to the excerpts above, the misconception was: *When it is stored in glass container, it will be exposed by suinlight and thus it can conduct electricity properly*. This shows that students did not understand the nature of acid solutions that can react with metals, even students feel confident about the misconception.

Acid-base Theory

From the data obtained, the average misconception of students in the sub-topic of acid-base theory was 29%. Student was then interviewed to reassure the misconception. The following excerpts are the interview dialogue with student.

G: "Based on acid-base theory by Bronsted-Lowry, the the following particles (item no 4) are acid-base, except?"

S: "option (d)since HCO_3^- bermuatan negatif atau bersifat basa is negative or is an acid-base"

G: "negative means acid-base?"

G: "The option C is also negative! why?"

S: "It contains no H atom"

G: “then, if it is negative and contains H atom, it is acid-base?”

S: “Yes, Sir”

According to the excerpts above, the misconception was: *base according to Bronsted-Lowry is a particle that has an H atom and is negative*. This shows that students focused on an H atom, yet the ability of a particle to dispense or receive protons by reacting with water solvents should be taken into account.

$$HCO_3^- + H_2O \Leftrightarrow CO_3^- + H_2O^+$$

(a) Acidity Indicator

From the data obtained, the average misconception of students in the sub-topic of acidity indicator was 29%. Student was then interviewed to reassure the misconception. The following excerpts are the interview dialogue with student.

G: “Red litmus paper will turn into blue if it is dripped with solution (Item no 14)”

S: “option A Sir!”

G: “Why do you think so?”

S: “ since sulfuric acid is acidic so the red litmus paper turns into blue “

G: “are you sure?”

S: “yes, Sir!”

According to the excerpts above, the misconception was: *Since sulfuric acid is acidic thus the red litmus paper turn into blue*. This misconception occurs naturally if students have not done practicum yet, which results in justification of the wrong answer, it is necessary to give an understanding through practicum as included the ADI learning model.

(b) Acidity Degree

From the data obtained, the average misconception of students in the sub-topic of acidity degree was 20%. Student was then interviewed to reassure the misconception. The following excerpts are the interview dialogue with student.

G: “from the example above (no 18) which one is a weak acid and a weak base solution? “

S: “option A Sir!”

G: “why do you think so?”

S: “ since Chloride Acid and lime water in water cannot conduct electricity “

G: “any other reason?”

S: “no, I dont know Sir”

G: “Are you sure?”

S: “not really!”

According to the excerpts above, the misconception was: *Hydrochloric acid and ammonia solutions are weak acids and weak bases because in the water can not conduct electricity*. This misconception shows that students have not been able to explain the degree of acidity and still relate it to electrolyte solutions, thus student was hesitant about the answer.

c) Acid-Base Neutralization Reaction

From the data obtained, the average misconception of students in the sub-topic of acid-base neutralization reaction was 16%. Student was then interviewed to reassure the misconception. The following excerpts are the interview dialogue with student.

G: “ The most acidic solution in the following salt solutions below are (soal no 21)

S: “option A Sir!”

G: “why do you think so?”

S: “since NaCl is the most acidic solution and can conduct electric current “

G: “any other reason?”

S: “No Sir!”

G: “are you sure?”

S: “Yes Sir!”

According to the excerpts above, the misconception was: *NaCl is the most acidic solution and can conduct electric current*. This misconception shows that students are consistent with the wrong answers, and still connect with electrolyte solutions.

Based on the pretest results, the biggest misconception percentage was in the acid-base theory subtopic which obtained 29%. The low understanding acquired was possibly because students were less able to associate the concept of acid-base solutions with the surrounding life (Lathifa, Ibnu, & Budiasih, 2015). Students’ inability to understand the relationship between chemical concepts and the surrounding environment is also expressed by (Aikenhead, 2003) and (Shen, 1993) as one of the problems. Based on the results of the pretest, the average percentage in each sub-topic before giving treatment (pretest) is as Table 4.

Based on Table 4, it can be seen that, although students have acquired acid-base topic learning, the average students who have conceptual understand-

Table 4. Students' Average Percentage in Each Sub-Topic Before Giving Treatment (Pretest)

No	Sub Topic	Student Percentage (%)			Misconception Criteria
		Understand	Misconception	Do not Understand	
1	Acid-base characteristics	27%	25%	48%	Insignificant
2	Acid-base theory	17%	29%	54%	Insignificant
3	Acid-base indicator	18%	28%	54%	Insignificant
4	Acid-base degree	18%	20%	63%	Insignificant
5	Neutralization reaction	23%	16%	61%	Very Insignificant
Avg		21%	24%	55%	Insignificant

ing was 21%, students who experience misconceptions were 24% and students experience conceptual incomprehension were 55%.

The Effectiveness of ADI Learning Model in Resolving Student Misconception

The pretest results show that the percentage of misconception is 24%. After giving ADI Learning Model to resolve, misconception within student was calculated one by one. Then, it shows that misconception within student decreased. Table 5 show the percentage of misconception for each student.

In general, Table 5 indicates a decrease of 8%. Table 6 shows students misconception percentage based on each sub-topic.

After receiving the ADI learning model, the number of students who understood the concept of acid-base increased to 64%, the number of students misconception decreased to 17%, and students who did not understand the concept of acid-base decreased to 19%. These results indicate that students succeed in constructing their understanding.

Figure 1 is an example of student learning outcomes that shows a change.

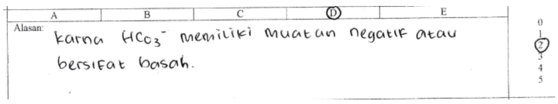
Table 5. Percentage of Misconception Before (Pretest) and After (Postes) Treatment

Student No	Misconception Percentage (%)		
	Pretest	Posttest	Changing
1	15%	5%	Decrease 10%
2	15%	15%	No Changing 0%
3	35%	15%	Decrease 20%
4	30%	25%	Decrease 5%
5	20%	10%	Decrease 10%
6	25%	20%	Decrease 5%
7	20%	5%	Decrease 15%
8	20%	25%	Increase 5%
9	30%	5%	Decrease 25%
10	20%	15%	Decrease 5%
11	25%	20%	Decrease 5%
12	20%	10%	Decrease 10%
13	40%	20%	Decrease 20%
14	15%	40%	Increase 25%
15	45%	35%	Decrease 10%
16	30%	15%	Decrease 15%
17	25%	10%	Decrease 15%
18	30%	15%	Decrease 15%
19	5%	0%	Decrease 5%
20	35%	25%	Decrease 10%
21	30%	15%	Decrease 15%
22	25%	20%	Decrease 5%
23	20%	25%	Increase 5%
24	15%	15%	No Changing 0%
25	35%	10%	Decrease 25%
26	15%	15%	No Changing 0%
27	25%	20%	Decrease 5%
28	25%	10%	Decrease 15%
29	30%	20%	Decrease 10%
30	25%	20%	Decrease 5%
$\bar{\Sigma}$	**25%**	**17%**	**Decrease 8%**

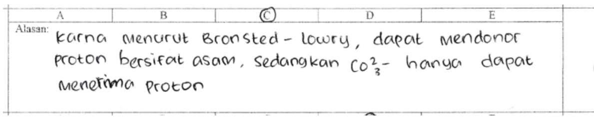
Table 6. Students' Average After Acquiring Treatment in Each Sub-topic (posttest)

No	Sub Topik	Student Percentage (%)			Misconception Criteria
		Understand	Misconception	Do not Understand	
1	Acid-base characteristics	68%	18%	14%	Very Insignificant
2	Acid-base theory	65%	14%	21%	Very Insignificant
3	Acid-base indicator	73%	12%	16%	Very Insignificant
4	Acid-base degree	56%	22%	21%	Insignificant
5	Neutralization reaction	57%	20%	23%	Very Insignificant
	Avg	64%	17%	19%	Very Insignificant

1. Based on the Bronsted-Lowry acid base concept, the following compounds are acidic, except …
   a. NH_4^+ c. CO_3^{2-} e. H_2CO_3
   b. H_2O d. HCO_3^-

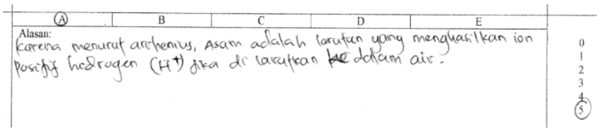


Student's Answer Before Receiving ADI

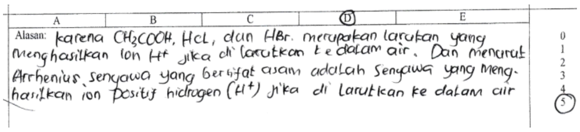


Student's Answer Before Receiving ADI

2. The following groups of compounds which belong to Arrhenius acids are ….
   a. HCl, HBr, and NH_3 d. CH_3COOH, HCl, and HBr
   b. HCl, HBr, and KOH e. CH_3COOH, KOH, and NH_3
   c. CH_3COOH, $H_2C_2O_4$, and NH_3

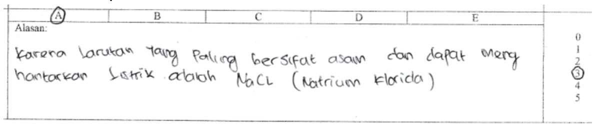


Student's Answer Before Receiving ADI

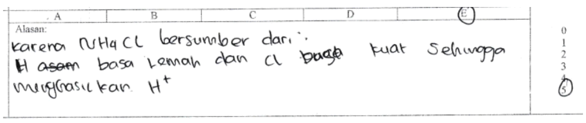


Student's Answer Before Receiving ADI

3. The following salt solutions with the most acidic are…
   a. NaCl c. CH_3COONa e. NH_4Cl
   b. $NaSO_4$ d. NaI



Student's Answer Before Receiving ADI



Student's Answer Before Receiving ADI

Figure 1. Example of Student Learning Outcomes that Shows A Change

Retention of Student Conceptual Understanding

Three weeks after the post-test, a delay test was conducted which aims to determine the resilience of students' conceptual understanding. Based on the delay test, the retention percentage of students' conceptual understanding was analyzed by comparing the percent of questions understood by students during the delay test with the percent of questions understood by students during the posttest. Table 7 is a summary of the retention percentage of conceptual understanding in each student.

Although the results of the hypothesis test show a significant difference between students' understanding after three weeks of treatment, there are still some students who actually experience an increase in misconception. This could be due to two possibilities. The first possibility, students rejects the true concept taught with the ADI learning model, thus misconceptions were not interrupted, students who maintained their misconceptions as if they did not receive improvements (Gilbert, Krull, & Malone, 1990). As the results of research by Zirbel (2004), He states that some students whose ideas contradict with new information, will ignore new information that supports students' beliefs, and even end up defending their own beliefs. The second possibility, students accept the concept but experience obscurity, thus the misconception is increasingly strengthened (Gilbert et al., 1990).

Table 7. Percentage of Retention of Students Conceptual Understanding in Each Individual

Student	Questions Understood by Student		% Retention	Category
	Posttest	Delayed Test		
1	15%	13%	87%	Very Good
2	13%	11%	85%	Very Good
3	12%	12%	100%	Very Good
4	14%	10%	71%	Good
5	11%	10%	91%	Very Good
6	12%	12%	100%	Very Good
7	16%	12%	75%	Good
8	13%	12%	92%	Very Good
9	13%	11%	85%	Very Good
10	13%	11%	85%	Very Good
11	12%	10%	83%	Very Good
12	13%	11%	85%	Very Good
13	12%	11%	92%	Very Good
14	11%	10%	91%	Very Good
15	10%	9%	90%	Very Good
16	12%	11%	92%	Very Good
17	13%	12%	92%	Very Good
18	14%	12%	86%	Very Good
19	15%	13%	87%	Very Good
20	13%	10%	77%	Good
21	13%	11%	85%	Very Good
22	12%	11%	92%	Very Good
23	10%	10%	100%	Very Good
24	14%	12%	86%	Very Good
25	13%	11%	85%	Very Good
26	13%	11%	85%	Very Good
27	12%	11%	92%	Very Good
28	12%	11%	92%	Very Good
29	13%	11%	85%	Very Good
30	13%	9%	69%	Good
Avg			**87%**	**Very Good**

On the delay test, student achievement decreased slightly. The number of students who comprehended the concept decreased to 55%, students with misconceptions became 25%, students who did not comprehend the concept also increased by 20%. Decreased student performance on the delay test was also reported by Özmen, Demircioglu, and Demircioglu (2009) who said that this was natural because in a certain time interval students forgot about the concepts they had learned. Thus, the reduction in student retention to 87% or 86%, three weeks after treatment in this study, is still common, but other efforts need to be improved to increase the understanding of retention.

CONCLUSION

Based on the results of research and discussion, it can be concluded that (1) in acid-base topic, 24% of students experience a misconception, with details: on the sub-concept of acid-base characteristics 25%, sub-concept of 29% acid-base theory, sub concept acid-base indicator 28%, sub concept of acid-base degree 20%, and sub concept of neutralization reaction is 16% of 30 students, (2) ADI learning model is effective in reducing misconceptions in acid-base topic from an average percentage of 24% to 17% per-individual, and (3) Retention of conceptual understanding in students three weeks after the ADI learning treatment was 87% or 86% of the number of students who understood the concept, with very good criteria.

ADI learning that has been applied to the acid-base lesson can further elaborate the problem of misconceptions caused by previous misconceptions. More careful calculation and analysis can ultimately prevent misconceptions and this is better than correcting the wrong understanding. ADI learning also needs to be applied to other topic in Chemistry, which requires a series of sequential concepts to understand other chemical phenomena.

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