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Original Article

Development of Concept Change-Oriented Acid-Base Worksheet to Eliminate Acid-Base Misconceptions in Senior High School Students

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Abstract

Facts in the field showed that students encountered misconception towards several basic concepts of acid-base. The misconception occurred is resistant and hard to be changed. To change the misconception occurred, the students must experience cognitive conflict that may lead them to do concept changing. Concept-change oriented learning is effective in preventing students from misconception. By the use of worksheet that oriented to concept-change will help reducing misconception encountered by the students. The aim of this study is to determine the process of developing acid-base worksheet which oriented to concept-change, to know the feasibility of the developed worksheet and to determine the effectiveness of the developed worksheet in reducing misconception that students face. The study used Borg and Gall theory. The result of the study showed that the developed worksheet is feasible to be used with validation value of 90,11%, and the developed worksheet is also effective in eliminating misconception encountered by the students, with pre-test value of 67.6% and post-test value of 2%.

Keywords: Acid-Base Chemistry, Concept Change, Misconception Remediation, Senior High School, Worksheet Development.

1. Introduction

One of the concepts that must be taught to high school students is Acid-Base (Irawati & Sofianto, 2019). Acid-base has important topics because it is related to other chemistry materials such as the nature of matter, stoichiometry, chemical reactions, chemical equilibrium, buffer solutions, salt hydrolysis, and acid-base titration (Sesen & Tarhan, 2011). Johnstone (2006) previously also revealed that to understand acid-base concepts, all levels of concept translation ability are needed including macroscopic, microscopic, and symbolic levels. Several studies reveal that students experience misconceptions on several basic acid-base concepts (Amry et al., 2017; Ekawisudawati et al., 2021). Misconceptions are situations when concepts believed by students differ from actual concepts (Barke et al., 2008). Misconceptions that occur are difficult to eliminate (Chandrasegaran et al., 2007) because they are persistent and difficult to change (Yürük, 2007). Students who experience misconceptions will have difficulty connecting new knowledge with their prior knowledge.

The seriousness of misconception impacts makes misconception prevention efforts important and reasonable to implement (Chandrasegaran et al., 2007). Based on this, experts develop conceptual change theory based on three perspectives: epistemological, ontological, and motivational. Ezema et al. (2022) in his journal reveals that conceptual change in students will occur when students are able to abandon beliefs they hold toward scientifically accepted concepts. Students will not experience conceptual change simply by being told that their believed concepts are inaccurate (Addido et al., 2022), but students should feel dissatisfied with their current knowledge and understanding, and they must be more open to new knowledge they believe has the potential to be logical (plausibility), meaningful (intelligible), and useful in solving other problems (fruitfulness) (Posner et al., 1982).

Based on the above description, it can be concluded that conceptual change will occur if it involves cognitive conflict within students (Iskandar, 2022). Cognitive conflict will likely emerge when there are differences in understanding between concepts already possessed by students and newly learned concepts (Panjaitan et al., 2022). This difference will encourage students to compare their initial concepts with new, correct, and scientific concepts (Ezema et al., 2022). Research by Amry et al. (2017) mentions that conceptual change-oriented learning is more effective in preventing misconceptions than using conventional learning.

Irawati & Sofianto (2019) identified one of the main reasons for low understanding of students' acid-base concepts is the limited worksheets oriented toward conceptual change. Trianto (2010) mentions that worksheets can be an appropriate alternative teaching material for students. Until now, worksheets used in schools have not been able to overcome conceptual understanding problems because they are limited to problem-solving exercises based on material, their content is less interesting, and they cannot help students develop their own conceptual construction (Fannie & Rohati, 2022; Lisa et al., 2017). Based on the above description, the author considers it important to develop Acid-Base Worksheets oriented toward conceptual change to eliminate acid-base misconceptions in high school students. The objectives of this acid-base worksheet development research are to determine: (1) the process of developing acid-base worksheet products oriented toward conceptual change to eliminate acid-base misconceptions in high school students; (2) the feasibility of acid-base worksheet products oriented toward conceptual change to eliminate acid-base misconceptions in high school students; and (3) the effectiveness of acid-base worksheet products oriented toward conceptual change to eliminate acid-base misconceptions in high school students.

2. Methods

This study uses a product development model by adapting Borg and Gall's theory in Irawati & Sofianto (2019) and uses a pre-experimental design with a one-group pretest-posttest design, namely providing a pretest then deliberately and systematically providing treatment to a group in the form of learning treatment using concept change-based worksheets and finally providing a posttest. This study only uses one class as an experimental class without a control class.

The pretest was conducted to obtain data on acid-base misconceptions experienced by students before being taught with concept change-oriented acid-base worksheets. After providing treatment using concept change-oriented acid-base worksheets, the sample was given a posttest to see the effectiveness of concept change-oriented acid-base worksheets in eliminating acid-base misconceptions experienced by students.

2.1. Population and Sample

This research was conducted at Madrasah Aliyah Yayasan Darussalam Al Kubro (Yadaro) Moyot. Population is a group of individuals who have the same special characteristics (Creswell, 2015). The population of this study is Class XI MA Yadaro Moyot. Sample is a subgroup of the target population planned to be studied to generalize the target population (Creswell, 2015). Sampling was done with cluster random sampling, so one class was selected as a sample.

2.2. Research Variables

Variables used in this study are independent variables, dependent variables, and control variables. The independent variable in this study is the Concept Change-Oriented Acid-Base Worksheet, the dependent variable is acid-base misconceptions, and the control variables in this study are the teaching teacher, experiment implementation time, pretest and posttest.

2.3. Research Instruments

There are two things that affect the quality of research results: instrument quality and data collection quality. Instruments used in this study consist of two types: treatment instruments and measurement instruments. The treatment instrument in this study is the Concept Change-Oriented Acid-Base Worksheet. This worksheet is used to carry out the learning process and is not measured statistically.

The next instrument used in this study is the Measurement Instrument. This instrument is in the form of acid-base diagnostic tests consisting of 20 items that measure acid-base misconceptions. The acid-base diagnostic test used is a two-tier diagnostic test, which is a test that provides answer choices accompanied by reasons. Diagnostic test questions are used in pretest and posttest activities. Diagnostic questions in pretest activities are used to determine acid-base misconceptions experienced by students, while in posttest activities they are used to determine whether there is an effect of using concept change-oriented acid-base worksheets in eliminating misconceptions experienced by students.

2.4. Data Collection

Data collection in this study was conducted through classroom experiment activities. One class was selected as the experimental class to receive treatment. The stages of data collection are the product development stage and the product implementation stage. In the product development stage, there are several stages carried out such as preliminary study and information gathering, worksheet creation planning, worksheet development, product expert testing, product revision, limited testing, product revision, and final product.

The next stage is the research implementation stage. At this stage, products that have been developed will then be applied to predetermined samples. At the beginning of the research, students will be asked to work on two-tier questions to identify misconceptions experienced. After that, it continues with learning using concept change-oriented acid-base worksheets that have been developed. Then in the final stage, students are given two-tier diagnostic tests again to identify misconceptions experienced. Misconception change data from diagnostic test I and diagnostic test II will be analyzed descriptively to determine conceptual changes in students.

2.5. Data Analysis

Data analysis aims to give meaning to the data produced. Data collected are feasibility data from concept change-oriented acid-base worksheets developed, student misconception data before treatment, and student misconception data after treatment. Media feasibility data is obtained from material expert validation results. Acid-base misconception data obtained is then analyzed with descriptive analysis. Before test score data from research results is converted to test value data, the steps taken are: (1) correcting student answers based on answer keys, (2) applying the same score for all test items, (3) score 1 for correct answers and score 0 for wrong answers, (4) calculating total score sums, and (4) converting scores obtained by each student to values with a range of 1-100.

This study only uses inferential analysis in the form of prerequisite tests and descriptive analysis. Prerequisite tests consist of normality tests and homogeneity tests. Normality tests aim to determine whether data has normal distribution. Normality calculations are done through SPSS 26.0 for Windows using the Kolmogorov-Smirnov test with significance value α = 0.05, and homogeneity tests are done through SPSS 26.0 for Windows using the Levene test. Meanwhile, descriptive analysis is done through data grouping, misconception percentage calculations, and data interpretation. Student misconception percentage calculations are done using the formula $P = \frac{s}{js} \times 100\%$ where P is the percentage of students experiencing misconceptions, S is the number of students experiencing misconceptions, and JS is the total number of test students.

3. Results and Discussion

3.1. Development of Concept Change-Oriented Acid-Base Worksheets

Based on the results of the preliminary study and information gathering stage, it can be concluded that acid-base material often experiences misconceptions after classroom learning as previously reported in earlier research. This data is then used as a foundation for developing concept change-oriented acid-base worksheets. After that, an acid-base concept map is compiled aimed at facilitating researchers in creating concept/material descriptions to be presented in the developed worksheets. Based on the concept map created, the worksheet consists of seven chapters: acid-base characteristics, development of acid-base theory (Arrhenius theory, Brønsted-Lowry theory, and Lewis theory), acid-base strength, acid-base solutions as electrolyte solutions, acid-base calculations, and neutralization reactions. From the existing concept descriptions, indicators and learning objectives will be compiled.

After material compilation is complete, the next stage is product compilation. Worksheets are compiled as attractively as possible while paying attention to the learning sequence oriented toward conceptual change. After that, validation is conducted. Average validation data by experts is presented in the table below.

Table 1. Average worksheet validation results

No	Assessed Aspect	Average (%)	Criteria
1	Learning Achievement Indicators	100	Valid, No Revision Needed
2	Material Accuracy Aspect	93.75	Valid, No Revision Needed
3	Worksheet Ease of Use Aspect	79.17	Valid, No Revision Needed
4	Display Aspect	87.50	Valid, No Revision Needed
	Average Feasibility	90.11	Valid, No Revision Needed

Based on the average worksheet validation assessment results, it can be concluded that display aspects, attractiveness, ease, accuracy, fulfillment of learning indicators in worksheets, and suitability of material presentation with conceptual change stages of the developed concept change-oriented acid-base worksheets have met valid criteria and do not need revision, and these concept change-oriented acid-base worksheets are suitable for use as student learning support to eliminate acid-base misconceptions. This also means that materials or content contained in the developed acid-base worksheets are appropriate for material topics, learning indicators, and expected achievement target indicators.

3.2. Development Results

Learning steps in concept change-oriented acid-base worksheets consist of providing apperception, prediction stage, reasoning stage, dissonance confrontation stage, mental set construction stage, and challenge question stage. The apperception stage will help students remember previously learned material or relate to daily life. This will be able to increase student learning motivation, so learning will be more enjoyable and effective. Next is the prediction stage, at this stage there are questions that directly lead to possible misconceptions experienced by students. Given predictions will show knowledge possessed by students. In this reasoning stage, students will use and show their prior knowledge more clearly and in detail. Therefore, this stage can be said to be a stage capable of confirming initial concepts possessed. If at the prediction stage students experience misconceptions then strengthened by providing explanations at the reasoning stage, then students can be confirmed to experience misconceptions. After providing predictions and reasons for given phenomena, then their truth is challenged through the confrontation stage. This will make students who have inappropriate prior knowledge revise their knowledge.

Prediksikanlah jawaban dari pertanyaan di bawah ini sesuai dengan pemahaman Anda!

1. Tentukanlah urutan kekuatan asam dari larutan yang terdapat pada Tabel di bawah ini !

Tabel harga pH pada suhu 25°C

Larutan	pH	pOH	K_a
HCl 0,0001 M	4	10,00	-
CH_3COOH 0,1M	2,89	11,11	$1,8 \times 10^{-5}$
HNO_2 0,001M	3,34	10,66	$4,6 \times 10^{-4}$

2. Tentukanlah urutan kekuatan basa dari larutan yang terdapat pada Tabel di bawah ini !

Tabel harga pH pada suhu 25°C

Larutan	pH	pOH	K_b
NaOH 0,0001 M	10,00	4	-
NH_3 0,1 M	11,03	2,97	$1,8 \times 10^{-5}$
$(CH_3)_2NH$ 0,01M	11,37	2,63	$5,4 \times 10^{-4}$

Figure 1. Prediction stage: acid-base strength

In the mental set confrontation stage, students are given facts about concepts learned through microscopic descriptions, animation videos, practical activities, and demonstrations. Activities provided will stimulate students to think more seriously so as to cause cognitive conflict in their cognitive structure. Questions presented at the confrontation stage will lead students to feel dissatisfied with old knowledge possessed so they will replace their old knowledge (misconceptions) with correct knowledge they consider logical (plausibility) and meaningful (intelligible) (Posner et al., 1982).

Observasi

KONFRONTASI

Pada tahap ini anda akan mengetahui kekuatan asam basa dari berbagai perspektif. Perhatikanlah secara seksama dan tuliskanlah pemahaman anda.

1. Menurut animasi yang telah anda lihat, bandingkan jumlah partikel/molekul asam lemah yang terionisasi dengan jumlah molekul asam kuat yang terionisasi!
2. Menurut animasi yang telah anda lihat, bandingkan jumlah partikel/molekul basa lemah yang terionisasi dengan jumlah molekul basa kuat yang terionisasi!
3. Menurut gambaran mikroskopik, jelaskan kemampuan ionisasi asam kuat basa kuat dan asam lemah basa lemah dalam air !

Figure 2. Confrontation stage: acid-base strength

Practical activities are part of confrontation stage activities in worksheet activities. In addition to using practical activities at the confrontation stage, students are also given animation videos that can facilitate students' understanding of taught concepts.

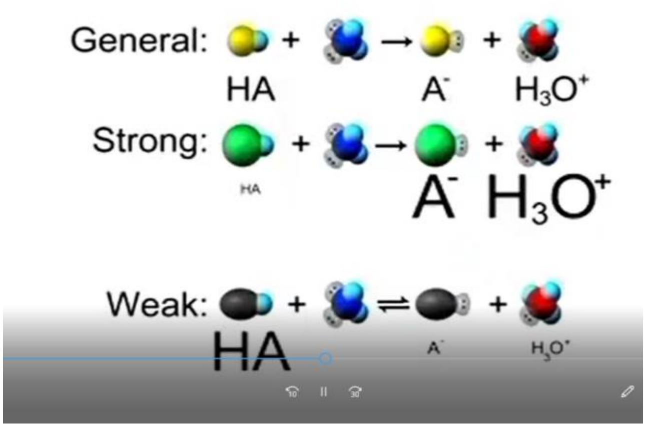

Figure 3. Animation video used at confrontation stage: acid-base strength characteristics

In this mental set construction stage, students are given a series of questions leading to discovering correct concepts, namely scientifically accepted concepts. At this stage, students will replace old concepts they believed with new concepts accepted scientifically.

KONSTRUKSI MENTAL SET

Setelah mengkaji beberapa representasi sebelumnya jawablah pertanyaan-pertanyaan di bawah ini!

1. Tuliskan reaksi ionisasai HCl, CH_3COOH, NaOH dan NH_3 dalam air!

2. Jelaskan definisi kekuatan asam dan kekuatan basa?

3. Jelaskanlah hubungan harga Ka/Kb dengan kemampuan terionisasinya?

Figure 4. Mental set construction stage: acid-base strength

5. **Kekuatan asam basa**

Zat	pH	Zat	pH
Jus apel Batu	3	Larutan soda kue	9
Minuman kopi	5	Pasta gigi	9
Larutan gula	7	Asam cuka	3
Susu	6	Abu gosok	12

(Efendy, 2008)

PREDIKSI

Berdasarkan data pada tabel di atas, dapatkah zat-zat tersebut diurutkan tingkat kekuatan asam maupun kekuatan basanya?

EXPLAIN

Berikanlah alasan atas jawaban Anda!

Figure 5. Challenge stage: acid-base strength

The challenge stage is the final stage in concept change-oriented acid-base worksheets. At this stage, students are given opportunities to test new knowledge they possess so they will feel confident that new knowledge they possess is useful in solving other problems (fruitfulness) (Posner et al., 1982). Types of questions given at this stage are more focused on concept application to daily problems.

3.3. Effectiveness of Using Concept Change-Oriented Acid-Base Worksheets to Eliminate Acid-Base Misconceptions in High School Students

3.3.1. Prerequisite Test Data

Normality and homogeneity tests were conducted on both data sets: pretest data and post-test data. Normality and homogeneity test results for pretest data show that data distribution is normally distributed and has the same or homogeneous variance. Normality and homogeneity test results for post-test data show that data distribution is normally distributed but has different or non-homogeneous variance.

3.3.2. Acid-Base Learning Using Concept Change-Oriented Acid-Base Worksheets

In learning activities after students are given apperception, then students will be directed to provide temporary answers or predictions related to material being studied. In the conducted research, this activity is effective in analyzing initial concepts possessed by students. This is caused by several things: first, because this stage presents material that experiences many misconceptions based on literature studied by researchers, so if students experience misconceptions, they will be easier to identify. Second, the sequence of questions asked uses straightforward and easy-to-understand language so it does not cause interpretations outside the context. Third, phenomena raised are core acid-base concepts being studied. Below is shown one example of student answers at the prediction stage.

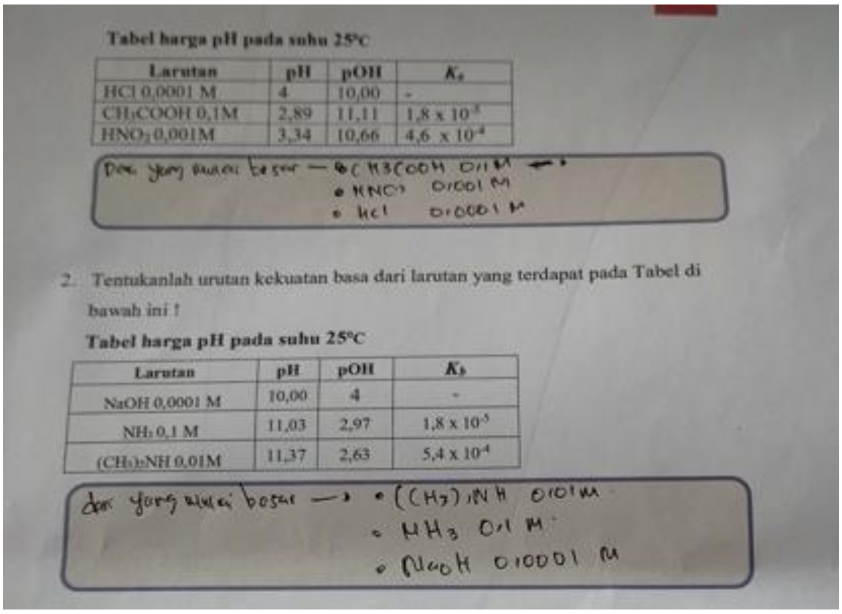

Figure 6. Student prediction answers

In the above figure, students are given two tables containing lists of solutions with pH, pOH, and Kb values. Students are then asked to rank acid strength and base strength in each table. Based on predictions given by students, it was found that 97% of students predicted acid-base strength based on pH of acid or base solutions, and 3% of students predicted acid-base strength based on solution concentration levels.

Students' prior knowledge that lower pH will show stronger acid strength is similar to misconceptions previously reported in earlier research by Demircioğlu et al. (2009), Kala et al. (2012), and Sheppard (2006). Students' prior knowledge stating that increasing pH values mean increasing base strength is similar to misconceptions previously reported by Metin (2011). Therefore, it can be assumed that students possibly experience similar misconceptions as reported in literature. This possibility is further strengthened by reasons explained by students at the reasoning stage in worksheets. The following is an example of student answers at the reasoning stage.

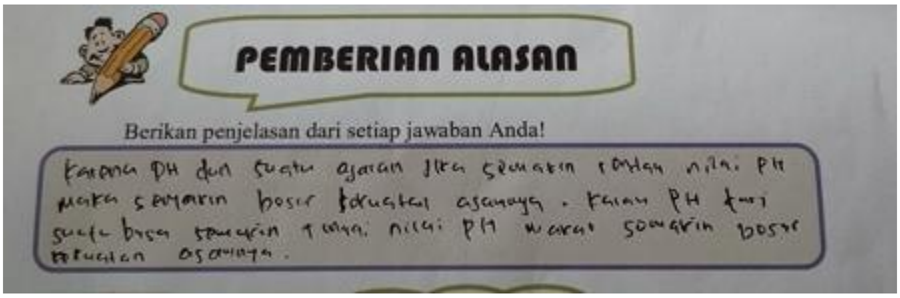

Figure 7. Student reasoning answers

At the prediction stage, students can convey their prior knowledge, questions displayed at the prediction stage are core concepts of discussed material. Therefore, students' prior knowledge will be very visible. In every learning activity using acid-base worksheets, misconceptions experienced by students are always considered, making students more active and causing cognitive conflict in students' cognitive structure. This triggers conceptual change so learning becomes more meaningful and interesting.

Next, at the dissonance confrontation stage, students find facts or actual concepts through provided learning media (videos, practical, reaction equations, microscopic descriptions). Providing this learning media can make students think more seriously so as to cause cognitive conflict in their cognitive structure. The existence of this cognitive conflict will make students feel dissatisfied with their knowledge. This situation will force students to change their cognitive structure to match received new information (Hitipeuw, 2009). After cognitive conflict occurs within students, then worksheets provide a mental set formation stage. At this stage, students are directed to construct their own understanding through questions that lead students to discover correct acid-base concepts comprehensively.

After students compile new mental sets (correct new knowledge), then students are given challenges in the form of Challenge Situated Learning Events (CSLE). As an example in discussing acid-base strength concepts, students are given tables that only include substance types and pH values, then students are asked to predict their acid-base strength. The following is an example of challenge questions at the CSLE stage.

CSLE will provide opportunities for students to apply new mental sets (new knowledge) they possess. CSLE will convince that students have made conceptual changes. Based on student answers in CSLE, it is known that most students have made conceptual changes. This is shown by answer patterns given by students. The answers given by students are as follows:
"*Cannot. Because acid-base strength cannot be determined by pH. Acid-base strength is determined by the compound's ability to ionize in water.*"

Although many have made conceptual changes, it turns out there are still students who have not changed their prior knowledge. This is shown by answer patterns given.
"*Yes, it can, because we can rank based on pH, if an acid has a smaller pH then the acid is stronger, and if a base has a larger pH then the base will be stronger.*"

This is what becomes the advantage of learning using concept change-oriented acid-base worksheets. Providing CSLE will help educators evaluate given learning. If misconceptions are still found in CSLE, then educators will be faster to identify and evaluate so they can immediately provide actions in the form of remedial or additional classes to improve student concepts. Therefore, conducted learning is more effective and impacts improved student conceptual understanding.

These research results strengthen previous research reporting that using teaching materials is effective in reducing misconceptions (Safrida et al., 2017). Furthermore, this research also shows the same results that using teaching materials and animation media can effectively reduce misconceptions. The novelty of research conducted by researchers is (1) using worksheets oriented toward conceptual change; (2) developed worksheets discuss acid-base material; (3) using more than one type of learning media in dissonance confrontation stages such as animation media, practical activities, reaction equations, table lists, etc.; (4) developed worksheets are based on literature review of acid-base misconceptions possibly experienced by students; (5) diagnostic tests used are two-tier acid-base diagnostic tests.

3.3.3. Misconception Data Before and After Learning Activities

Analysis results of misconceptions before and after learning using concept change-oriented acid-base worksheets are presented in Table 2 below.

Table 2. Student misconceptions before and after learning using acid-base worksheets

No.	Misconception	Average (%)	
		Pre	Post
1	**Acid-base theory**		
	a. The compound contains H atoms so it is acidic because it will be able to produce H+ ions when dissolved in water solvent	97,00	0,00
	b. One acid-base theory can explain all acid-base reactions	5,00	0,00
2	**Neutralization reaction**		
	Reactions between strong acids and strong bases will always produce neutral solutions even though the amounts of acid or base are not equivalent	45,00	0,00
3	**Acid strength**		
	a. The lower the pH value, the more acidic because pH affects acid strength	97,00	3,00
	b. The lower the pH value, the stronger the acid because pH shows H^+ ion concentration in solution	90,00	0,00
4	**Base strength**		
	Base strength is directly proportional to pH value. The larger the pH value, the more basic the solution	97,00	0,00
5	**Acid and base solution characteristics**		
	Only acids are dangerous because they contain H^+ which is destructive, while bases are not dangerous	73,00	0,00
	Acids contain H atoms and can release H^+ ions which are destructive	65,00	0,00
6	**Acid and base solutions as electrolyte solutions**		
	Strong bases conduct electric current because they have stronger covalent bond strength than weak bases	96,00	14,00
Average		**67,6**	**2,00**

Note: Pre = Before Learning, Post = After Learning

Based on the above average, it has been proven that using concept change-oriented acid-base worksheets effectively reduces student misconceptions (Pre-test 67.6% and Post-test 2%). Misconceptions are still found after post-test on acid strength concepts, namely 3%. This misconception is possibly caused because students do not yet understand that pH shows the amount of H+ ions in solution (Effendy, 2011). In the concept group of acid and base solutions as electrolyte solutions also shows that misconceptions still exist after learning, namely 14%. This data shows students still have not experienced conceptual change after treatment. Student misconceptions are possibly caused by weak student understanding of prerequisite learning materials for acid-base, namely chemical bonding material and electrolyte solution material.

4. Conclusion

Based on data analysis results, findings, and discussions conducted, it can be concluded that concept change-based acid-base worksheets developed are valid and suitable for use in learning activities and effective in reducing acid-base misconceptions experienced by students. Suggestions that can be given based on research results such as misconceptions still found after learning, then remedial learning needs to be conducted to eliminate misconceptions experienced by students, and to reduce misconception quantities on chemistry concepts, worksheet development on materials other than acid-base needs to be conducted.

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