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# Development of Student Worksheets based Process Oriented Guided Inquiry Learning to Remediate Student's Misconceptions on Acid and Base

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**Abstract**

This study aims to describe the feasibility of POGIL-based student worksheets to remediate misconceptions in terms of validity, practicality, and effectiveness, with the object of research of 11th grade students of Al-Islam Krian High School. Validity was measured from the content and construct validation sheets. The responses and activities of students measure practicality. Effectiveness is measured by the percentage of misconceptions that turn toward understanding the concept. The development of this Student Worksheet refers to the development of Research and Development (R&D). The model used is the 4D model, which consists of 4 stages, namely define, design, development, and dissemination. The research that has been carried out is limited to the development stage in the trial step. The validation result data is ordinal data that can be analyzed by determining the mode of each assessment aspect. The validity of worksheet is reviewed from the validity of content and construct which obtained a mode score of 4 with a valid category. The practicality results show that the worksheet is efficient with the activity for each trial of 95.56%, 95.56%; and 97.22%. The practicality of worksheet based on the POGIL learning model in terms of student response questionnaires using a Guttman scale through positive and negative statements with the answers "Yes" or "No" with the results of positive student responses of 95.78%.The effectiveness of the worksheet in terms of the results of shifting misconceptions towards understanding concepts was 81.06% in the theory of acids and bases, 70.09% in the strength of acids and bases, and 69.86% in acid and base indicators, with a significance value of 0.000 in the Wilcoxon test. The results showed that the POGIL-based worksheet developed was feasible to be able to remediate students' misconceptions on acid and base materials.

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## INTRODUCTION

Education aims to increase intellectual intelligence and academic genius through educational disciplines. Curriculum development can help achieve these educational goals (Izza et al., 2021). One of the curricula used in Indonesia is the 2013 curriculum which aims to improve students' critical thinking skills using a scientific-based scientific method that includes observation activities, formulating problems and developing hypotheses, collecting and analyzing data, and drawing conclusions (Nisa & Fitriza, 2021).

Chemistry has many complex, abstract concepts that must be gradually and thoroughly understood to be mastered. In chemistry, interrelated notions frequently arise that call for profound conceptions to achieve precise and straightforward understanding (Nasrudin & Azizah, 2018). Therefore, students understand chemistry concepts with their interpretations to solve problems related to their learning difficulties. If the interpretation made by students is wrong and they already believe it, then there is a misconception (Asnawi et al., 2017). If there is a misconception in one concept, they will have difficulty in learning the next concept (Izza et al., 2021). Students' concept understanding can be changed. This concept change can cause the knowledge of previously wrong concepts to become correct or correct to become incorrect (Titari & Nasrudin, 2017). In this study, it is expected that the wrong concept or misconception can be changed to be correct.

The existence of chemistry subjects in schools aims to develop a scientific mindset that includes a critical attitude toward chemical concepts and their applications and a skeptical attitude toward scientific claims (Titari & Nasrudin, 2017). There are three representative levels in chemistry: macroscopic, submicroscopic, and symbolic (Rares et al., 2020). Macroscopic is defined as a chemical representation that is obtained through actual observation of a phenomenon that can be seen and perceived by the five senses. A description of chemistry called a sub-microscopic representation explains the structure and motion of the observable macroscopic phenomena at the particle level. Symbolic representation is a qualitative and quantitative representation of chemistry, namely chemical formulas, diagrams, pictures, reaction equations, and other chemical representations, chemical formulas, diagrams, pictures, reaction equations, and mathematical calculations (Rahayu & Nasrudin, 2014).

Understanding submicroscopic concepts has the highest difficulty level because it can't be observed directly and requires a strong imagination (Izza et al., 2021). The characteristics of chemistry subject matter at the sub-microscopic level that connects the constituent molecules of a material with macroscopic and symbolic observations require extra attention from students causing students to often experience misconceptions in understanding chemical concepts (Khomaria & Nasrudin, 2016). One example in strong acid and strong base material, students cannot distinguish the concept submicroscopically, although symbolically students can distinguish it using arrows (Sunyono, 2015). It can therefore lead to misunderstanding and result in students making their interpretation of the submicroscopic picture (Safitri et al., 2020). One of them is found in the theory of acids and bases, according to Arrhenius, about the ionization of $H^+$ and $OH^-$ ions. Next, the concept according to Bronsted-Lowry about the process of proton transfer between acids and bases and the sharing (Wicaksono, 2016).

In research conducted by Wahyuningtyas (2020), students experienced the highest percentage of misconceptions about acid-base strength at 61.26%. Research by Mubarokah et al.,(2018) on 72 Thai and 64 Indonesian students showed that 26.67% and 30.25% of Thai students needed clarification about the theory and strength of acids and bases. Meanwhile, Indonesian students have misconceptions of 23.75% and 42.53% on both concepts. This research is supported by the results of pre-research in one of the high schools in Sidoarjo, Indonesia which showed that there were misconceptions in the acid and base theory sub-material by 53% and misconceptions in the acid and base strength sub-material by 59%. In their research on 25 students grade 11, (Anitasari et al., 2019) stated that 58% of students experienced misconceptions in the theory of acids and bases, 54.67% of students considered the strength of acidic substances based on hydrogen atoms, and 78.00% of students think that in a strong acid or strong base solution produces only a few $H^+$ or $OH^-$ ions which cause a bright light. bright lamp flame.

Students' misconceptions are caused by external and internal factors. External factors can come from textbooks, learning processes, media, and language. Conversely, internal factors that cause student misconceptions can come from students' daily experiences, which are students' initial conceptions (Nasrudin & Azizah, 2020). Misconceptions that come from students can occur due to preconceptions, incomplete or incorrect reasoning, or even intuition incomplete or incorrect reasoning, or even wrong intuition or even wrong intuition (Sari & Nasrudin, 2015). Based on an interview with a chemistry teacher at Al-Islam Krian High School, the learning media used were limited to textbooks and YouTube videos. One way to overcome the problem of misconceptions in students is to develop worksheets based on learning models that follow the characteristics of acidic and basic materials. The appropriate learning model for developing worksheets in remediating misconceptions is the POGIL learning model (Lintong et al., 2018).

Based on research by Puteri et al (2021), POGIL learning steps used in learning activities on reaction rate material can improve students' concept understanding by involving chemical representation levels (macroscopic, submicroscopic, and symbolic). The POGIL learning model has specific and consistent steps and learning strategies that lead to the expected goal of students using skills for the learning process. The skills used by students are able to change their knowledge construction and form new concepts that are in accordance with scientific concepts (Rizqiyah et al., 2020). The skills used by students are able to change their knowledge construction and form new concepts that are in accordance with scientific concepts so that this learning model can be used to reduce students' misconceptions (Suparno, 2013).

There are 3 phases in POGIL: exploration, concept formation, and application (Straumanis, 2010). The exploration and concept formation phases can remediate misconceptions because, through this phase, students are directed to understand the material with the right concepts by finding relationships in the data collected through group discussions (Straumanis, 2010). The POGIL learning model is a constructivist learning model for discovering information and knowledge and helps learners develop an understanding based on cycles in guided inquiry (Syafaati & Nasrudin, 2018). In the concept formation phase, the cognitive conflict will encourage students to reconstruct a wrong understanding of the acids and bases concept (Lintong et al., 2018). The POGIL strategy was chosen to reduce misconceptions because the steps of the POGIL strategy can make students more active and responsible for their roles in the group.responsible for their role in the group. Through teamwork to solve problems and problems from the teacher, students can better master the learning material (Erna et al., 2021).

Arpiana & Nurhadi (2020) stated through his research that the percentage of students' misconceptions about chemistry decreased by 57.83% after implementing the POGIL learning model. In the POGIL learning model, students will be the recorder, presenter, manager, and reflector in each group. The division of roles among group members aims to ensure that each group member works together so that students are responsible for their respective tasks (Erna et al., 2021). Therefore, the development of POGIL-based worksheets on acid and base materials is expected to be an alternative learning media that can help teachers in remediating students' misconceptions.

The aims of this study are: (1) to define the validity of worksheet through content and constructs, (2) to define the practicality of worksheet through response questionnaires and observation of student activities, and (3) to describe the effectiveness of worksheet through the percentage shift from misconceptions to understanding concepts.

## METHOD

This research refers to the Research and Development (R&D) development method using the 4D model proposed by Thiagarajan et al., which consists of 3 stages: define, design, develop, and disseminate (Arkadiantika et al., 2020). This study was only carried out until the trial at the development stage. At the define stage, a pre-survey was carried out to analyze and identify problems that existed during the learning process through (1) initial analysis, (2) student analysis, (3) concept analysis, (4) task analysis, and (5) destination specifications. The worksheet development process with the 4D development model can be seen in Figure 1.

The design phase is carried out to design POGIL-based worksheets. This development activity includes preparing the writing format of the worksheets that have been designed. This plan aims to produce worksheets according to the needs of students, both in terms of appearance, content, systematic format, and according to a predetermined format. At the development stage, it produces POGIL-based worksheets, which have been revised based on the suggestions submitted by the validator. Furthermore, product trials will be carried out using the developed worksheets. There are three worksheets developed in this study. Worksheet 1: Theory of Acids and Bases. Worksheet 2: Strength of Acids and Bases, and Worksheet 3: Indicators of Acids and Bases.

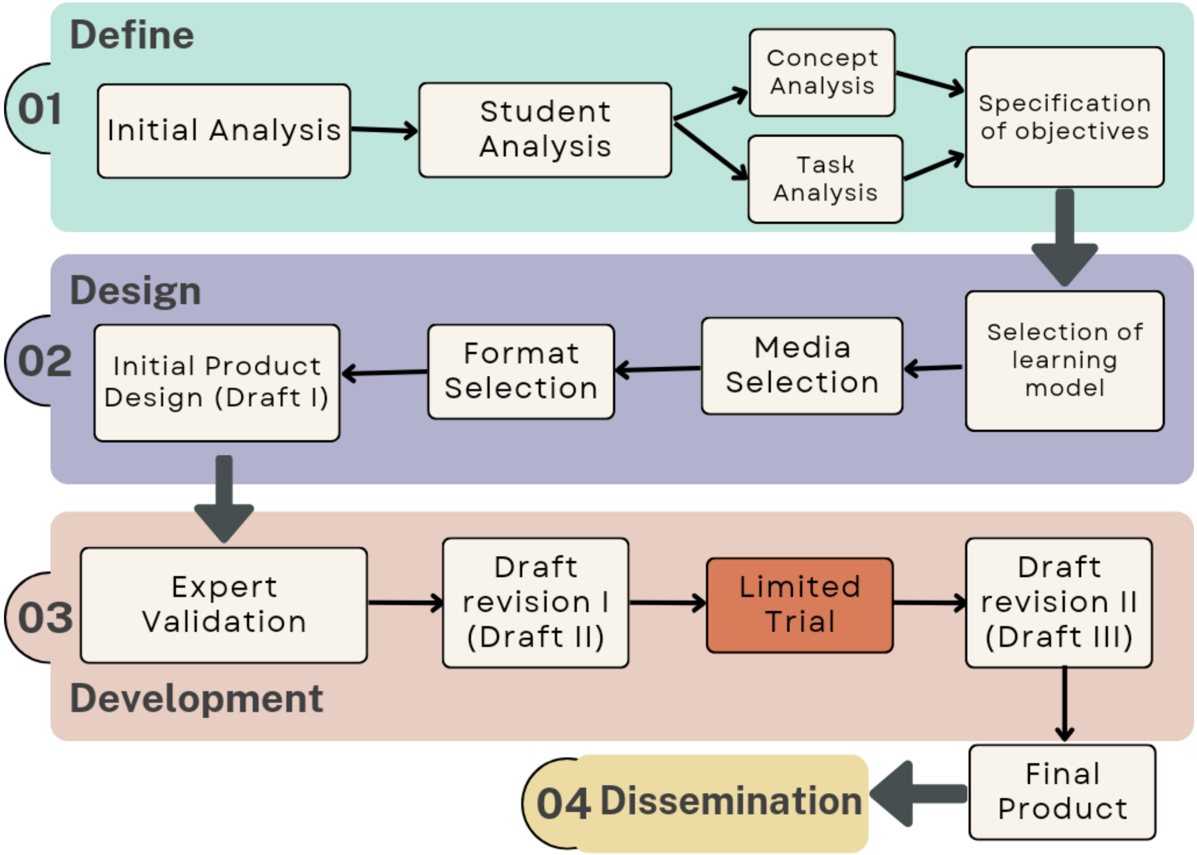


Figure 1. Flow of Development Process with 4D model

The data collection technique used is the observation method, the questionnaire method, and the test method. The observation method was carried out for pre-research activities through interviews with school teachers that would be the data collection target. In addition, the observation method was carried out at the worksheets limited trial stage, in which observers in each group were carried out to observe student activities every 3 minutes during learning activities. Student activities are considered reasonable and support the effectiveness of POGIL-based worksheet if the percentage of relevant student activities is more significant than irrelevant student activities (Riduwan, 2015).

This questionnaire method is used to obtain data on student responses regarding the practicality of the POGIL learning model-based worksheet using a Guttman scale through positive and negative statements with the answers "Yes" or "No". Positive responses for positive statements are obtained from the number of students who answer "Yes", while positive responses for negative statements are obtained from the number of students who answer "No". The criteria for the results of students' answers can be seen in table 1 below.

Table 1. Guttman Scale Criteria

| **Answer** | **Skor** | |
|---|---|---|
| | **Positive statement** | **Negative statement** |
| Yes | 1 | 0 |
| No | 0 | 1 |

(Riduwan, 2015)

This method is also used to obtain worksheet validation with three validators using a Likert scale with a score range of 1-5. The validation result data is ordinal data that can be analyzed by determining the mode of each aspect of the assessment with the following conditions: (a) If the assessed aspect has a mode score ≥ 3, then the aspect is declared valid. (b) If the assessed aspect has a mode score < 3, then the aspect is declared invalid, so it needs to be revised and validated again (Lutfi, 2021).

The test method is used for the effectiveness of the developed worksheet in remediating students' misconceptions through the pretest and post-test. The type of test used is a three-level diagnostic test to assess the effectiveness of worksheets. The classification of concept understanding level categories can be seen in the table 2 below.

Table 2. Criteria for The Level of Understanding of The Concept in Students

| **Answers** | | | **Category** | **Abbreviation** |
|---|---|---|---|---|
| **1st Tier** | **2nd Tier** | **3rd Tier** | | |
| Correct | Correct | Sure | Scientific Knowledge | SK |
| Correct | Incorrect | Sure | False positive | M1 |
| Incorrect | Correct | Sure | False negative | M2 |
| Incorrect | Incorrect | Sure | High Misconception | M3 |
| Correct | Correct | Not sure | Lack of Knowledge | LoK |
| Correct | Incorrect | Not sure | Lack of Knowledge | LoK |
| Incorrect | Correct | Not sure | Lack of Knowledge | LoK |
| Incorrect | Incorrect | Not sure | Lack of Knowledge | LoK |

Description: SK = Scientific Knowledge (understanding concept), M1 = misconception False positive, M2 = misconception False negative, M3= High Misconception, LoK = Lack of Knowledge (Didn't understand concept).

The percentage of practicality can be calculated using the following formula.

$$P = \frac{\sum score\ obtained}{\sum total\ score} x\ 100\%$$

(Hardani et al., 2020).

Table 3. Practicality Criteria of the Worksheet by User Response

| **Percentage** | **Criteria** |
|---|---|
| 0% - 20% | Very less practical |
| 21% - 40% | Less practical |
| 41% - 60% | Pretty practical |
| 61% - 80% | Practical |
| 81% - 100% | Highly practical |

(Hardani, et al., 2020)

## RESULTS AND DISCUSSION

### Define Stage

This stage was carried out pre-survey, which aims to analyze and identify problems that existed during the learning process. First, the developer carried out the initial analysis to find out the problems at Al-Islam Krian High School by interviewing Chemistry teachers. The role of a worksheet is enormous in the learning process because it can increase student activeness in learning, and its use in learning can help teachers direct students to find concepts through their activities (Wulandari, 2013). However, the results of the interviews obtained were that the teaching materials used were in the form of chemistry textbooks provided by the government and the use of worksheets from certain publishing institutions. The worksheets contains information or material so students cannot build concepts. According to Piaget, conceptual reconstruction occurs when a notion is altered to broaden understanding and align attitudes with the most recent facts. Additionally, the constructivist approach asserts that when students learn science, they interpret new information in the context of their preexisting ideas and beliefs, which they might later change or alter (Nasrudin & Azizah, 2020). However, based on student analysis of academic abilities shows that there are still many students who need clarification about acids and bases.

Based on the results of this observation, the researcher developed media that is POGIL-based student worksheets. The POGIL learning model was chosen because it can be used in material that is conceptual so that it can remediate misconceptions. POGIL is an instructional approach that combines guided inquiry with cooperative learning, where students are involved in the learning process (Putri & Gazali, 2021).

### Design Stage

The design stage is to design media developed as Student Worksheets accompanied by learning tools and other instruments. Learning tools and instruments developed together with the worksheet include a syllabus, lesson plan, and a three-tier diagnostic test consist of15 questions. The preparation of worksheets must consider the presentation and language and the selection of colors and designs to attract interest in learning and motivate students. The developed worksheets consist of 3 worksheets, titles with the A4 paper size, and the number of pages for each worksheets is approximately 15 pages.


Figure 2. Cover Design of Worksheets

The initial design of the worksheets was done by making a cover on Canva, which was then distributed in Microsoft Word. There are three worksheets developed with different designs and colors. The color difference in the cover design aims to make it easier for students to distinguish the worksheet titles. The first worksheet in red contains the theory of acids and bases, the second in orange contains the strength of acids and bases and the third in blue contains indicators of acids and bases. In addition to compiling the cover, at this stage, it also determines that the features included in the worksheets are phenomena, exploration, concept formation, applications, chemical facts, and conclusions.

## Development Stage

### *Validity*

The validity of a study relates to the extent to which a researcher measures what should be measured In this case, worksheet is intended to remediate students' misconceptions about acids and bases. If the worksheet is not valid, the validity of the test results or application obtained from the worksheet is doubtful. The validity assessed in the development of worksheet is content validity and construct validity (Budiastuti & Bandur, 2018). Content validity relates to whether the items comprise a media or device developed to cover all the material to be measured (Ulum, 2016). Three aspects are used as validity indicators in content validity: the suitability of the material with basic competence, the suitability of the worksheets needed to remediate misconceptions, and the truth of the substance of the learning material with three validators.

Table 4. Validity Assessment Results

| No. | Aspect of Validity | assessment score | | | Mode Score | Category |
|---|---|---|---|---|---|---|
| | | V1 | V2 | V3 | | |
| 1. | conten | 4 | 5 | 4 | 4 | Valid |
| 2. | language | 4 | 5 | 4 | 4 | Valid |
| 3. | appearance | 4 | 5 | 5 | 5 | Highly valid |
| 4. | presentation | 4 | 5 | 4 | 4 | Valid |

Description: V1 = Validator 1, V2 = Validator 2, V3 = Validator 3

Based on the diagram in table 4 shows that the mode score of each aspect of the content validity of the worksheet meets the valid category with a mode score is 5. Based on Luthfi (2021), if the assessed aspect has a mode value $\geq 3$, then the aspect is declared valid so that it can be continued at the limited trial stage. Furthermore, the assessment of construct validity includes language, appearance, and presentation. Construct validity relates to whether the tool developed has been compiled based on an appropriate and relevant theoretical framework (Ulum, 2016). Construct validity is the worksheet format comprising text, colors, images, tables, and concept coherence. All of these aspects are expected to attract students' interest in learning the concept of acids and bases so that they can remediate misconceptions.

The worksheets developed are expected to be applied according to the developer's goals from the results of valid. The developer hopes to help remediate misconceptions about acids and bases through these worksheets. In addition, the existence of worksheets is expected to facilitate and motivate students in learning chemical concepts in acid and base materials.

### *Trials of Worksheets*

The limited trial of this research was carried out in one of the 11th-grade students at SMA Al-Islam Krian in the even semester of the 2022/2023 academic year on 16-20 May 2023. The limited trial phase was carried out to define the feasibility of POGIL-based student worksheets to remediate misconceptions on acid-base material regarding the practicality and effectiveness of worksheets. Practicality refers to the condition that the media developed is easy for students to use as media users so that learning activities become more meaningful, interesting, fun, and useful for students (Milala et al., 2022). Practicality can be seen from observing student activities and student response questionnaires. Student learning activities are activities that students do during learning. Learning is carried out for 90 minutes with three meetings. Student learning activities are observed for 3 minutes once. Student learning activities include activities carried out based on worksheet's activities.

Table 5. Percentage of Student Learning Activity

| **No.** | **Observed aspect** | **Persentage each trials** | | |
|---|---|---|---|---|
| | | **1** | **2** | **3** |
| 1. | Observing phenomena on worksheets | 4% | 7% | 8% |
| 2. | Collect data in the "Exploration" section | 24% | 22% | 21% |
| 3. | Analyzing the concept of the "Concept formation" section | 21% | 21% | 16% |
| 4. | Working on the "Applications" section | 12% | 16% | 13% |
| 5. | Express the results of discussions or give opinions | 14% | 4% | 15% |
| 6. | Responding to teacher's questions/explanations | 13% | 16% | 16% |
| 7. | Writing/delivering conclusions | 8% | 10% | 8% |
| 8. | Doing irrelevant activities (other than activities 1 – 10) | 4% | 4% | 3% |
| | **Total** | **100%** | **100%** | **100%** |

Based on Table 4, student activities that are relevant to the worksheet's activities are greater than those that are irrelevant in each worksheet trial. In the first and second trials, students carried out relevant activities as much as 96%, while in the third trial, the relevant activities were 97%. The most extended activity carried out by students was during exploration and concept formation. Therefore, worksheets are categorized as very practical based on student activity. There are other activities that support the activeness of students in the learning process, namely responding to teacher explanations and questions and expressing opinions or presenting the results of their work. The activeness of students during the learning process can maximize the potential that exists in students so that learning objectives are easier to achieve (Fitriana, 2023).

Practicality can also be reviewed through student response questionnaires after learning activities using the worksheets and post-test are completed. Student responses can be known by giving a questionnaire distributed to students. In general, the questionnaire asked about students' interest in the worksheets, the ease of using the worksheets, and making it easier for students to develop concepts consisting of 11 questions. The average percentage of student questionnaire results is 95.78%, with a highly practical category (81-100%), according to Riduwan (2015).

Table 6. Criteria for The Level of Understanding of The Concept in Students

| **Answers** | | | **Category** | **Abbreviation** |
|---|---|---|---|---|
| **1st Tier** | **2nd Tier** | **3rd Tier** | | |
| Correct | Correct | Sure | Scientific Knowledge | SK |
| Correct | Incorrect | Sure | False positive | M1 |
| Incorrect | Correct | Sure | False negative | M2 |
| Incorrect | Incorrect | Sure | High Misconception | M3 |
| Correct | Correct | Not sure | Lack of Knowledge | LoK |
| Correct | Incorrect | Not sure | Lack of Knowledge | LoK |
| Incorrect | Correct | Not sure | Lack of Knowledge | LoK |
| Incorrect | Incorrect | Not sure | Lack of Knowledge | LoK |

Description: SK = Scientific Knowledge (understanding concept), M1 = misconception False positive, M2 = misconception False negative, M3= High Misconception, LoK = Lack of Knowledge (Didn't understand concept).

The final goal of this study is to define effectiveness through shifting misconceptions. These results were obtained from the pre-test and post-test values using a three-tier diagnostic test.

Through the test results, students will be grouped into several levels of conceptual understanding. The level of understanding of the concept is divided into 5, namely understanding the concept, not understanding the concept, false positives, false negatives, and misconceptions (Arslan, 2012).

Through the categories in Table 6, the number of students who have misconceptions on the pretest and posttest can be calculated. After knowing the test results, the percentage of misconceptions shifting to Scientific Knowledge can be calculated.

Table 7. Percentage of Students' Comprehension Level at Pretest

| No. | Concept | No. Question | ***Percentage of students' comprehension level*** | | | | | Percentage of Misconception |
|---|---|---|---|---|---|---|---|---|
| | | | **SK** | **M1** | **M2** | **M3** | **LoK** | |
| 1. | **Theory of acids and bases** | **1** | 0,00 | 0,00 | 37,93 | 58,62 | 3,45 | 96,55 |
| | | **2** | 3,45 | 41,38 | 20,69 | 34,48 | 0,00 | 96,55 |
| | | **3** | 10,34 | 13,79 | 24,14 | 51,72 | 0,00 | 89,66 |
| | | **4** | 13,79 | 6,90 | 13,79 | 58,62 | 6,90 | 79,31 |
| | | **5** | 3,45 | 24,14 | 31,03 | 41,38 | 0,00 | 96,55 |
| | | **6** | 3,45 | 17,24 | 31,03 | 48,28 | 0,00 | 96,55 |
| | | **14** | 6,90 | 24,14 | 10,34 | 48,28 | 10,34 | 82,76 |
| | **Mean(%)** | | **5,91** | **18,23** | **24,14** | **48,77** | **2,96** | **91,13** |
| 2. | **Strength of acids and bases** | **7** | 3,45 | 17,24 | 31,03 | 44,83 | 3,45 | 93,10 |
| | | **8** | 10,34 | 24,14 | 20,69 | 41,38 | 3,45 | 86,21 |
| | | **9** | 10,34 | 31,03 | 20,69 | 34,48 | 3,45 | 86,21 |
| | | **10** | 41,38 | 10,34 | 6,90 | 37,93 | 3,45 | 55,17 |
| | | **15** | 13,79 | 31,03 | 17,24 | 34,48 | 3,45 | 82,76 |
| | **Mean(%)** | | **15,86** | **22,76** | **19,31** | **38,62** | **3,45** | **80,69** |
| 3. | **Acids and bases indicator** | **11** | 10,34 | 31,03 | 10,34 | 44,83 | 3,45 | 86,21 |
| | | **12** | 6,90 | 13,79 | 6,90 | 65,52 | 6,90 | 86,21 |
| | | **13** | 17,24 | 10,34 | 10,34 | 58,62 | 3,45 | 79,31 |
| | **Mean(%)** | | **11,49** | **18,39** | **9,20** | **56,32** | **4,60** | **83,91** |

Description: SK = Scientific Knowledge (understanding concept), M1 = misconception False positive, M2 = misconception False negative, M3= High Misconception, LoK = Lack of Knowledge (Didn't understand concept).

Table 7 shows that the highest misconceptions of students are in the theory of acids and bases at 91.13%, followed by indicators and strengths of acids and bases with percentages of 83.91% and 80.69%. In the theory of acids and bases, students assume that CH3COOH is an Arrhenius base because it contains 'OH'. This data follows research conducted by Mubarokah et al.,(2018) that students chose CH3COOH as a base solution because it contains OH- ions. This means that some students had some misconceptions of the concept of acid and base. Students consider the compound with H to be an acidic solution, while the compound with OH is alkaline. The next acid and base theory is the Bronsted-Lowry theory contained in question items number 3 and 4. In question item number 3, learners are asked to determine the correct reaction if $HClO_4$ is basic based on the Bronsted-Lowry theory. In item number 4, learners are asked to determine the conjugate acid-base pair from a chemical reaction equation. In question number 3, students should choose answer option d where in the right segment of the reaction equation, HClO4 becomes $H_2ClO_4^+$ because it gets protons from $N_2H_5^+$. In accordance with the Bronsted-Lowry base concept, namely a species that receives protons ($H^+$) from other species (Haryono, 2019). Many students cannot answer correctly because they are less careful about the problem and do not understand the concept of species that accept protons in Bronsted-Lowry's theory.

The same thing also happened in question number 4 where students could not choose the conjugate acid-base pair due to the wrong concept in determining the conjugate acid-base species and conjugate bases so they could not answer correctly with the reasons. In previous research, the results of students' misconceptions of the Bronsted-Lowry acid-base concept were also quite high reaching 70% (Ekawisudawati et al., 2021)

In the concept of acid and base strength, most students needed to be corrected in connecting the concept of pH and degree of ionization with the sequence of acid and base strengths. The correct concept is that the greater the Ka and Kb values, the stronger the acid and base. However, in acids, the smaller the pH, the stronger the acid. While in bases, the stronger the base, the greater the pH (Haryono, 2019) This concept is still misunderstood by students. In addition, students are also fooled by the power values of Ka and Kb. The powers on Ka and Kb are usually negative, where the larger the number, the smaller the value. This confuses students in determining the order of strength of acids and bases. Student’s misconceptions on this concept amounted to 80.69%. After knowing the percentage of misconceptions in 29 students, the shift pattern can be calculated with the following data.

Table 8. Percentage of students' misconception shifting patterns

| Concept | The shift of misconception | Total | Total Misconception | % the shift of misconception |
|---|---|---|---|---|
| **Theory of acids and bases** | M - SK | 150 | 185 | 81,08 |
| | M – LoK | 0 | | 0,00 |
| | M - M | 35 | | 18,92 |
| **Strength of acids and bases** | M - SK | 82 | 117 | 70,09 |
| | M – LoK | 0 | | 0,00 |
| | M - M | 35 | | 29,91 |
| **Acids and bases indicator** | M - SK | 51 | 73 | 69,86 |
| | M – LoK | 0 | | 0,00 |
| | M - M | 22 | | 30,14 |
| **Mean of M being SK** | | | | **73,68** |

Description: M – SK (Misconception being Scientific Knowledge), M – LoK (Misconception being Lack of Knowledge), M – M (still misconception).

Overall, most students who experience misconceptions shift towards understanding the concept. Table 7 shows that students' misconceptions change to understand concepts by 73.68%. This can indicate the achievement of worksheet development to remediate students' misconceptions about acid-base material. The results of the shift in misconceptions show that the worksheet developed is said to reduce misconceptions in students effectively. Based on Erna's research (2018), using the POGIL learning model can reduce misconceptions by 47.05% in chemistry about chemical equilibrium. The misconception shift is high if the percentage shift is ≥ 50% (Zukhruf, Khaldun, & Ilyas, 2018). After the trial, it was expected that all students' misconceptions could be remediated. However, in reality there are students who still maintain their misconceptions. This happens because the understanding of the concept that students receive is incomplete. According to Ekawisudawati et al., (2021), misconceptions are resistant or difficult to change and tend to persist

Statistical test results support the results of this study. First, a normality test was conducted using the Shapiro-Wilk test using SPSS with decision-making if the significance value was > 0.05. The data were normally distributed, and if the significance value <0.05, the data were not normally distributed (Payadnya & Jayantika, 2018). The significance value of the Shapiro-Wilk test shows a value of 0.001 in the pretest and 0.000 in the posttest. Therefore, the normality test shows that the data distribution is abnormal, so further analysis is carried out using the Wilcoxon test using non-parametric statistics. The Wilcoxon signed test was used to determine the difference in the pretest and posttest averages which had non-normal data distribution.

Table 9. Wilcoxon signed rank test results

| | Test Statistics[a] |
|---|---|
| | Posttest PK - Pretest PK |
| Z | -4.714[b] |
| Asymp. Sig. (2-tailed) | .000 |

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

From the Wilcoxon signed test results, the Z value is -4.714, and the Asymp value. Sig. (2-tailed) is 0.000. A value of 0.000 <0.05 indicates that Ho is rejected, so there is a difference in the average pretest and posttest scores after implementing the POGIL-based worksheet trials.

The advantage of the worksheet developed in this study is that it can help teachers in remediating students' misconceptions on acid and base materials by more than 50%. This worksheet is also flexible because it was developed through POGIL syntax which can help improve students' concept understanding. In addition, the worksheet developed can reduce misconceptions by improving students' analytical skills through activities in the worksheet. Based on research conducted by Ardhana (2020), the impact of learning with the POGIL approach can improve metacognitive knowledge on acid and base materials. This research is supported by the results of research conducted by Rizqiyah et al (2020), which showed that the profile of students' conceptions after learning by using the POGIL learning model, most of the students' conceptions experienced positive changes with the translation of students who were initially misconceptions, did not know the concept turned into knowing the concept. The change in misconceptions that occurred was from 26.09% to 7.97% of 19 students on chemical equilibrium materials.

## CONCLUSION

The conclusion of this study is that the developed worksheet meets the criteria of validity, practicality, and effectiveness. Validity by three validators shows the results of content validity and construct validity get a mode score of 4 with a valid category. On the practicality criterion, the student questionnaire showed that 95.78% of students agreed that the worksheet developed could make it easier for students to develop concepts and make learning fun. This is supported by student activities that are relevant to learning by 96.11%. The result of shifting misconceptions into understanding concepts is also very high 73.68%, with a significance value on the Wilcoxon test of 0.000, which means there is a difference in the average pretest and posttest scores after implementing the POGIL-based worksheet trials. The results showed that the POGIL-based worksheet developed was feasible to be able to remediate students' misconceptions on acid and base materials.

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