



Development of Student Worksheet based Guided Inquiry to Train Students Critical Thinking Skills on Buffer Solution

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Abstract: Development of Student Worksheet based Guided Inquiry to Train Students Critical Thinking Skills on Buffer Solution. Based on the context of the problems found in the pre-research, this study was conducted to describe the feasibility of guided inquiry-based worksheets to train critical thinking skills on buffer solution material developed in terms of validity, practicality, and effectiveness. This research used the 4-D research method. The limited trial was tested on 36 students of class XI IPA 2 SMA Negeri 1 Driyorejo. The results showed that the worksheet produced was considered very valid in terms of content and construct validity, with a mode score of 5. Practicality obtained an average response questionnaire score of 83.88% supported by observation results with an average percentage of 86.90%, 86.90%, and 95.23% with practical categories. Effectiveness is obtained from the students' critical thinking ability test, namely the pre-test and post-test with a percentage of 79.65% in the high category, 56.89% in the medium category and 24.16% in the low category.

Keywords: Worksheet feasibility, guided inquiry, critical thinking skill, buffer solution.

Abstrak: Pengembangan LKPD Berbasis Inkuiri Terbimbing untuk Melatihkan Keterampilan Berpikir Kritis Siswa pada Materi Larutan Penyangga. Berdasarkan konteks permasalahan yang ditemukan pada pra-penelitian, penelitian ini dilakukan untuk mendeskripsikan kelayakan lembar kerja berbasis inkuiri terbimbing untuk melatih keterampilan berpikir kritis pada materi larutan penyangga yang dikembangkan ditinjau dari validitas, kepraktisan, dan keefektifan. Penelitian ini menggunakan metode penelitian 4-D. Uji coba terbatas diujicobakan kepada 36 siswa kelas XI IPA 2 SMA Negeri 1 Driyorejo. Hasil penelitian menunjukkan bahwa lembar kerja yang dihasilkan dinilai sangat valid dari segi validitas isi dan konstruk, dengan skor modus 5. Kepraktisan mendapatkan rata-rata skor angket respon sebesar 83,88% didukung dengan hasil observasi dengan rata-rata persentase sebesar 86,90%, 86,90%, dan 95,23% dengan kategori praktis. Keefektifan diperoleh dari tes kemampuan berpikir kritis siswa yaitu pre-test dan post-test dengan persentase 79,65% kategori tinggi, 56,89% kategori sedang dan 24,16% kategori rendah.

Kata kunci: Kelayakan LKPD, inkuiri terbimbing, keterampilan berpikir kritis, larutan penyangga.

• INTRODUCTION

Entering the 21st century is a century of openness or a period of globalization, which implies that compared to the preceding century, life is changing in unique ways (Mardhiyah et al., 2021). Schools as educational institutions are required to possess the capacity to problem-solve, communicate, and cooperate; and to think creatively and critically, or called the 4Cs (Septikasari & Frasandy, 2018). Therefore, the involvement of all parties, especially schools, is needed in preparing the nation's children to have many skills needed in 21st century life. Based on Permendikbudristek No. 16 of 2022, the implementation of learning is built with a learning atmosphere that provides opportunities for students to express opinions and experiment, so it is expected to be applied to chemistry subjects. Chemistry subjects contain various concepts, facts, and theories related to chemical calculations and reactions that are quite difficult for students to understand (Andini & Azizah, 2021). One of the materials that is often considered difficult to learn is buffer solution (Sariati et al., 2020). The characteristics of buffer solution material are material with factual, conceptual and procedural knowledge dimensions (Maypalita & Zainul, 2018). One of the chemical materials is buffer solution material taught in class XI which is complex and mathematical in nature (Sanjiwani et al., 2018). Buffer solution material which is often considered difficult is one of the materials that requires strengthening students' understanding through practicum activities (Sariati, et al., 2020). Students' learning difficulties in understanding buffer solution material are reinforced by research by Yunitasari et al. (2013) which states that the concept in buffer solution material is a complex concept, so students have a lot of difficulty in understanding the material.

Practical activity is a learning activity intended for students that is useful for developing the thinking, analyzing, problem-solving, proving, and drawing conclusions from the material examined (Royani et al., 2018). With practicum activities, students carry out a series of activities that can build their understanding and thinking skills based on the ability to investigate to evaluate and students are requires critical thinking abilities (Cahyani & Azizah, 2019).

Critical thinking skills are defined as one of the higher-level thinking processes, pressing a logical and rational basis of belief and being able to provide a series of procedures to activate the skills of interpreting, analyzing, identifying statements, evaluating evidence/ideas, and making conclusions (Dewi & Azizah, 2019). People with critical thinking abilities may solve problems and reach choices using their cognitive processes (Facione, 2016). This study uses critical thinking components from Facione using four indicators namely interpretation, inference, analysis, and explanation.

Using the right learning model, efforts that may be made to teach critical thinking abilities can receive training while studying. The guided inquiry learning paradigm may be utilized to develop students' critical thinking abilities. Learning will be more meaningful using the inquiry learning paradigm since students will investigate their level of knowledge. and actively engaged in using instructor assistance to conclude observed occurrences. Learning carried out using the guided inquiry learning model involves an inquiry process that can help students discover new knowledge by training students to improve their critical thinking skills (Rahmadani & Novita, 2018). Research by Fadiawati et al. (2022) explains that inquiry learning is effective in improving students' critical thinking skills seen from the average score of students' critical thinking skills in the experimental class greater than the control class. In this research using guided inquiry based on Joyce (2015) and the stages of guided inquiry learning must be implicated in the teaching materials used, among which is the student worksheet.

Student worksheets are student activities in learning activities to apply the knowledge gained and are very important to determine student success in mastering knowledge (Simatupang & Santika, 2021). Student worksheets can facilitate learning by helping students comprehend the subject and train their learning independence because they are rich in tasks to practice. It is vital to create more interesting student worksheets since instructional materials in the form of student worksheets have not been implemented successfully because they employ less communicative language, which makes it difficult for students to comprehend what is being intended and demotivates them.

After conducting pre-research, a total of 36 students from SMA Negeri 1's Driyorejo class XII IPA were involved it was claimed that chemistry is a difficult subject to understand as much as 81.3% and 71.9% of students have difficulty learning buffer solution material. 43.8% of students said that the teaching technique was the learning method used by teachers was the lecture method or direct learning and 84.4% of students stated that they preferred learning that involved experimenting, analyzing, and finding concepts. Learning carried out at school also uses student worksheets, but 37.5% stated that the worksheets used only contained a summary of the material and practice questions. Low student critical thinking abilities are caused by monotonous learning as described above. It is possible to create a student worksheet-based guided inquiry to teach students critical thinking skills about buffer solutions based on the literature that has been provided and the facts in the field as shown by the answers to the questionnaire.

• **METHOD**

This study falls under the heading of development research using the 4-D research method was used to carry out this development research according to (Thiagarajan, 1974), and this research was conducted until the development stage (Develop). Data sources for this study's data will come from 2 chemistry expert lecturers, 1 chemistry teacher, and 36 students from SMA Negeri 1's Driyorejo class XI IPA 2 towards the developed student worksheets. The supervising expert lecturer will provide input or suggestions by filling out the review sheet given to the worksheet. Furthermore, validation was carried out using a scale of 1 to 5, two chemistry lecturers and one teacher of chemistry serve as the three validators. used to assess the worksheets developed consisting of content validity and construct validity. The validation sheet assessment uses a Likert Scale in Table 1 below.

Table 1. Student Worksheet Validation Assessment Criteria

Scale	Criteria
1	Not Good
2	Less
3	Enough
4	Good
5	Verry Good

(Riduwan, 2016)

Based on the rating scale criteria, if the content validity and construct validity aspects of content and construct validity obtain a mode value ≥ 3 , then the worksheet developed is declared valid (Lutfi, 2021)

The next step is the worksheet that has been validated and carried out in a limited trial to 36 students of class XI IPA 2 SMA Negeri 1 Driyorejo. The trial phase aims to ascertain the effectiveness and practicality of the worksheets developed. Info from the survey of student opinions and observations of students' activities throughout the brief trial were used to

practically determine how useful the worksheet was. By calculating the Guttman scale scores when applying the calculation below, the percentage results of student answer surveys and student activity observations may be determined:

$$P = \frac{F}{N} \times 100$$

The percentage among the findings from the student response survey is interpreted into the categories in Table 2 below.

Table 2. Score Interpretation Category

Percentage (%)	Category
0 – 20	Very impractical
21 – 40	Not impractical
41 – 60	Enough practical
61 – 80	Practical
81 – 100	Verry Practical

(Riduwan, 2016)

Based on the score interpretation category, the worksheet developed can be said to be practical if it gets a percentage of $\geq 61\%$ (Riduwan, 2016). For student activity observations, it is declared practical if the percentage of relevant activities is greater than irrelevant activities.

The results of the student critical thinking skills test are used to determine the effectiveness of the worksheet, which can then be quantified using the N-gain score formula. The following equation can be used to calculate the N-gain score value:

$$N - gain\ score = \frac{Posttest\ score - Pretest\ score}{Maximum\ score\ (100) - Pretest\ score}$$

(Hake, 1999)

The worksheet is considered effective if students meet the N-gain score requirement by achieving an *n-gain score* of $g \geq 0.3$ with a medium category to high category.

After calculating the *N-gain* pretest and posttest scores, the next step is to do a normality test using the Kolmogorov Smirnov Test on SPSS, if the data is not normally distributed, the Wilcoxon Signed Rank Test is carried out on SPSS.

• RESULT AND DISCUSSION

This development aims to develop student worksheets that are feasible and tested on a limited basis to 36 students to obtain data on student responses, observations of student activities and critical thinking skills on the worksheets developed.

Define Stage (Defining)

At the defining stage, it is carried out to establish and define the terms of learning. Analysis of the curriculum, students, tasks, concepts and specifications of indicators is carried out at the stage of defining.

Design Stage (Planning)

At the design or planning stage, the activities carried out are designing and choosing a format for teaching materials, namely in the form of worksheets to be developed. Then

proceed with the process of designing the student worksheet as a whole. The student worksheet developed consists of 3 worksheets with buffer solution material and there are sub-sub material studied. The student worksheets developed to follow the stages of inquiry according to Joyce (2015).



Figure 1. Main Student Worksheet Cover (Left), Sub-title 1 Student Worksheet Cover (Center) and One of the Critical Skills Indicators in the Worksheet (Right)

Develop Stage (Development)

The development stage aims to obtain student worksheets that are feasible in terms of validity, practicality and effectiveness of the student worksheets developed.

Worksheet Validity

The purpose of validity is to determine the outcomes of validation about the feasibility of the worksheet developed. This worksheet is valid in terms of both its content and its construct validity. These validation outcomes are presented in the form of mode ≥ 3 which is said to be valid, but taking the mode value on each worksheet 1,2,3 is also done for each aspect of content and construct validity. The validation results from data are displayed as follows in Table 4 :

Table 3. Recap of Content and Construct Validity

No.	Aspects assessed	Validation Result	Category
Content Validity			
1.	Suitability of buffer solution sub-materials with Learning Outcomes	5	Very Valid
2.	Suitability of buffer solution sub-materials with Content	5	Very Valid
3.	Suitability of buffer solution sub-material with Learning Objectives	5	Very Valid
4.	The correctness of the phenomenon with the material	5	Very Valid
Construct Validity			
1.	Suitability of worksheet content with the guided inquiry learning model	4	Valid
2.	The suitability of worksheet content with critical thinking criteria	5	Very Valid
3.	Conformity of worksheet with Language Criteria	4	Valid

No.	Aspects assessed	Validation Result	Category
4.	Conformity of worksheet with Presentation Criteria	5	Very Valid
5.	Conformity of worksheet with Graphics Criteria	5	Very Valid

Table 4 presents a recap of the results of content and construct validity per aspect. For content validity as a whole from numbers 1 – 4 get a mode score of 5 which means very valid. For construct validity as a whole from numbers 1 – 5 get a mode score of 5 which means very valid. In construct validity, number 1 is the construct validity of conformity with the guided inquiry model which gets a mode score of 4 declared valid. From the validation results, it can be stated that the worksheet developed is in accordance with the guided inquiry syntax which is indicated by loading the guided inquiry syntax according to Joyce (2015) which includes a confrontation with the problem, data gathering-verification, data gathering-experimentation, organizing and formulating explanation, analysis of the inquiry process. In construct validity, number 2 is the construct validity of conformity with critical thinking criteria which gets a mode score of 5 declared very valid. From the results of this validation, it can be stated that the worksheet developed is in accordance with the indicators of critical thinking skills used, namely there are 4 components according to (Facione, 2016). In construct validity, number 3 is the construct validity of the suitability of the worksheet with linguistic criteria getting a mode score of 4 declared valid. In construct validity, number 4 is the construct validity of the suitability of the worksheet with presentation criteria getting a mode score of 5 declared very valid. In construct validity, number 5 is the construct validity of the suitability of worksheet with graphic criteria getting a mode score of 5 declared very valid. The worksheets developed are adjusted by paying attention to the linguistic components based on the guidelines for developing teaching materials that were adapted from Revita (2017) and Prastowo (2014) respectively. The worksheets developed are adjusted by paying attention to the graphical and presentation components.

The developed worksheet is according to the findings of the construct validity score and content validity score, which have fulfilled the qualifying conditions, the claim is deemed valid by obtaining a mode 5 and categorized as very valid.

Worksheet Practicality

The percentage of student responses and student activity observation sheets provide evidence of the practicality. Three observers participated in the learning process and fill in the student activity observation sheet when students used worksheets 1-3 to get the percentage results from the activity observation. The response questionnaire was completed by students using worksheet 3 after the learning process was complete and after completing the posttest to obtain the percentage results from the student questionnaire.

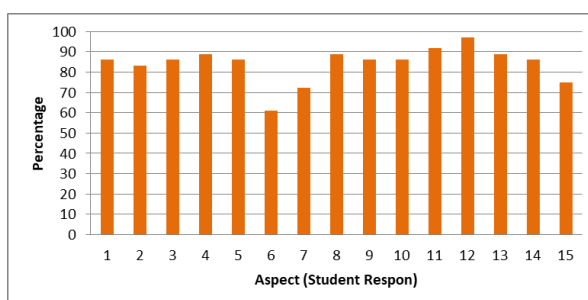


Figure 2. Student Response Percentage Results

Student response data supports the results of student activity observations on relevant activities as many as 14 activities. The student response questionnaire received an average score of 83.88%, which was declared very practical. The results of student response data that support student observation results show that the worksheets developed can improve students' understanding of buffer solution material. This is also in line with the research of Utari, et al (2018) which states that students give a positive response or response to the use of worksheets on buffer solution material. Data from student activity observations on learning using the developed worksheets are shown in Table 5.

Table 4. Student Activity Observation Results

No.	Aspect	Percentage (%)		
		1st meeting	2nd meeting	3rd meeting
1.	Relevant Activity (14 activities)	86.90%	86.90%	95.23%
2.	Irrelevant Activity	33.33%	33.33%	16.66%

The information in Table 5 above displays the student activities seen when using the worksheet during meetings 1 to 3 and the activities were repeated. In meetings 1, 2, and 3, respectively, the percentage of relevant activities was 86.90%, 86.90%, and 95.23% which were categorized as very practical. Student observation is very important during learning activities. According to (Sardiman, 2018), learning activities will not take place without student activity. The worksheets were designed based on data from the percentage of student answer surveys and student activity observations, and were deemed practical since more relevant student activities were seen than unrelated ones of student response questionnaires are $\geq 61\%$ (Riduwan, 2016).

Worksheet Effectiveness

Effectiveness can be seen according to the outcomes of the assessments of students critical thinking abilities. The purpose of the critical thinking test was to gauge students critical thinking skills by doing it before learning (pre-test) using the developed worksheets and after learning (post-test) using the developed worksheets. Identifying whether or not the data obtained are normally distributed, data on the outcomes of critical thinking skills based on pre-test and post-test scores are then calculated using the *n-gain score*. The data from the pre-test and post-test results are then tested for normality using the Kolmogorov-Smirnov test on SPSS 25. The Wilcoxon Signed Rank test is used as a nonparametric test if the data are not regularly distributed. The following are the results of students' *pretest* and *posttest* data along with the *n-gain score* in Table 6

Table 5. *N-gain Sore* Results

No.	Pre	Post	<i>N-gain</i>	Category
1.	47.5	83.75	0.69	Medium
2.	46.25	87.5	0.76	High
3.	60	100	1.00	High
4.	27.5	46.25	0.25	Low
5.	43.75	78.75	0.62	Medium
6.	45	56.25	0.20	Low
7.	36.25	77.5	0.64	Medium
8.	51.25	91.25	0.82	High
9.	58.75	90	0.75	High

No.	Pre	Post	<i>N-gain</i>	Category
10.	52.5	80	0.57	Medium
11.	45	83.75	0,70	High
12.	52.5	92.5	0.84	High
13.	60	100	1.00	High
14.	21.25	37.5	0.20	Low
15.	42.5	83.75	0.71	High
16.	60	80	0.50	Medium
17.	46,25	85	0.72	High
18.	53.75	87.5	0.72	High
19.	52.5	83.75	0.65	Medium
20.	26,25	47.5	0.28	Low
21.	42.5	85	0.73	High
22.	46.25	91.25	0.83	High
23.	61.25	96.25	0.90	High
24.	60	90	0.75	High
25.	53.75	93.75	0.86	High
26.	32.5	66.25	0.50	Medium
27.	21.25	42.5	0.26	Low
28.	51.25	91.25	0.82	High
29.	42.5	83.75	0.71	High
30.	46.25	87.5	0.76	High
31.	32.5	47.5	0.22	Low
32.	52.5	86.25	0.71	High
33.	55	96.25	0.91	High
34.	50	86.25	0.72	High
35.	35	81.25	0.71	High
36.	42.5	62.5	0.34	Medium

Table 6 above shows that guided inquiry-based worksheets can improve students' critical thinking skills as evidenced by the improvement in critical thinking skills test results, with 22 students or 79.65% of the *n-gain* score acquired in the top tier, 8 students or 56.80% in the medium category, and 6 students or 24.16% in the bottom category. Accordingly, the outcomes of previous research state that the critical thinking skills test has increased after using guided inquiry-based worksheets by getting score of 0.52-0.93 of *n-gain* in the moderate range to high (Sari & Nasrudin, 2022). The results of Mahmudah & Yonata (2020) also state that critical thinking skills get an *n-gain* of 0.795 with a high category, indicating that the activity sheet developed is effective. According to other studies the outcome of student critical thinking abilities' high category *n-gain* score shows that the STEM-based guided inquiry paradigm is successful in enhancing these abilities (Isdianti dkk., 2021).

Analyzing critical thinking abilities is not only acted upon on each learner but also carried out each critical thinking skills indicator used on the worksheets developed.

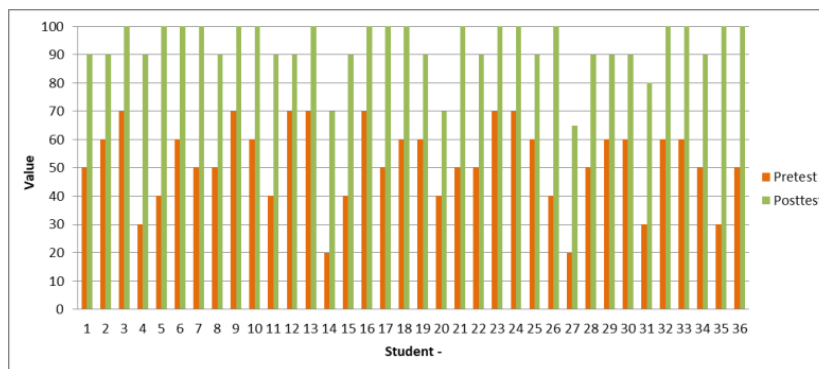


Figure 3. Interpretation Indicator Test Chart

Interpretation indicators get a score of *n-gain* with moderate to high category achievements. According to (Facione, 2016), interpretation is a person's ability to understand and explain the meaning of data, assessments, rules, procedures, problems, or phenomena. The interpretation indicators in the worksheet are such as formulating problems, mentioning experimental variables, writing down tools and materials, and writing down the results of observation data, but in the pretest and posttest only formulating problems, mentioning experimental variables, and write down experimental steps. This interpretation indicator has increased from the pretest results, which means that it has been trained well. This can happen because students have been given similar questions on worksheets so that students can construct their knowledge to find new, more detailed concepts according to the principle of constructivism, namely, learning is a search for meaning.

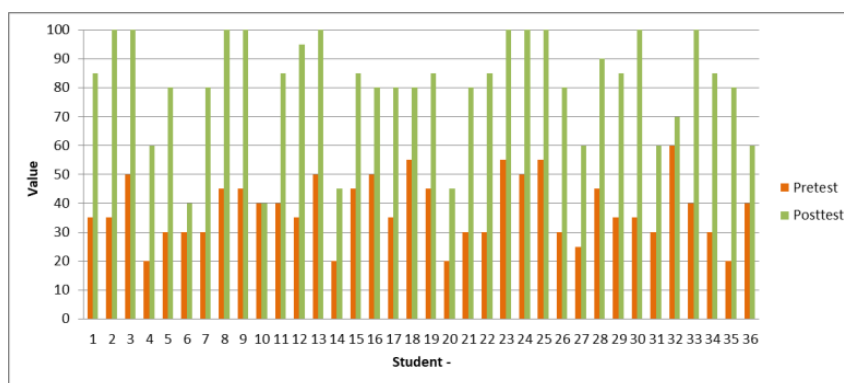


Figure 4. Inference Indicator Test Chart

Inference indicators get *n-gain scores* in the low, medium, and high categories. According to (Facione, 2016), the inference is an activity of finding and collecting important elements needed in making conclusions and making conjectures or hypotheses, and considering relevant information. The inference indicators in the worksheet are such as writing hypotheses and writing conclusions based on the experiments that have been carried out and in the pretest-posttest the questions given are the same as in the worksheet. This inference indicator is quite an improvement from the pretest results, which means that it has been trained quite well. Inference indicators get low to high category achievements because students have limited time to do the *pretest*.

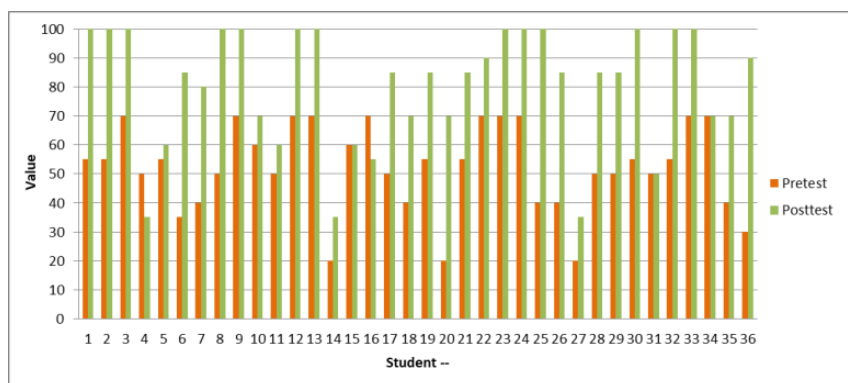


Figure 5. Analysis Indicator Test Chart

Analysis indicators get *n-gain* scores in the low, medium, and high categories. According to (Facione, 2016), analysis is an activity of identifying relationships or interrelationships between questions, statements, concepts, descriptions, and other forms. The analysis indicators in the worksheet are such as analyzing data from experiments that have been carried out such as calculating the pH of buffer solutions and in the pretest-posttest the questions given are the same as in the worksheet. This analysis indicator is quite an improvement from the pretest results, which means that it has been trained quite well. Analysis indicators get low to high category achievements due to students being less careful, too brief in giving answers, and limited time in answering questions. This is supported by the results of previous research which states, if the analysis indicator gets a percentage of the sufficient category, it means that some students are less able to analyze poor questions about a problem (Setianingsih et al., 2019).

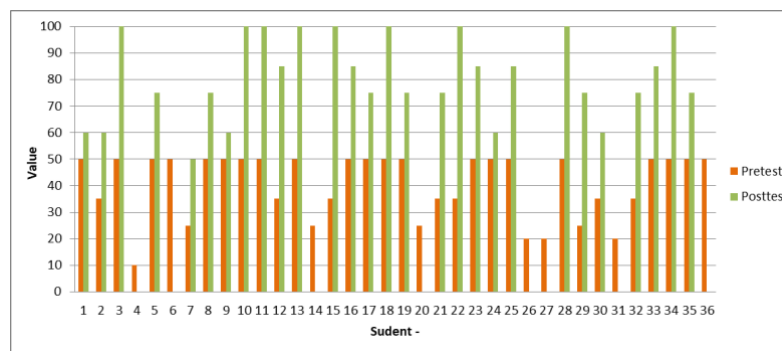


Figure 6. Explanation Indicator Test Chart

Explanation indicators get *n-gain* scores in the low, medium, and high categories. According to (Facione, 2016), the explanation is a person's ability to explain the results of his thinking or reasoning accompanied by the reasons for a justification accompanied by strong evidence, based on, considering the conceptual, methodological, and evidential sides. Explanation indicators in the worksheet are such as linking phenomena at the beginning of learning with experiments that have been carried out so that the initial phenomena presented can be proven through practical experiments and in the pretest-posttest the questions given are the same as in the worksheet. This explanation indicator is quite an improvement from the pretest results, which means that it has been trained quite well. Explanation indicators get low to high category achievements because students do not answer the questions completely so they do not show the reasoning process occurs. Another factor is that students are too brief in giving answers and time constraints.

Then after calculating the n-gain of pretest and posttest scores, a normality test made use of the Kolmogorov-Smirnov Test, but the resulting data were not normally distributed so a nonparametric test is performed with the Wilcoxon Signed Rank Test. The outcome of the nonparametric test for pre-test and post-test data can be seen in Table 7 below

Table 6. Results of Wilcoxon Signed Rank test

Aspect		N	Mean Rank	Z	Asymp, Sig. (2-tailed)
Pretest –	Negative Ranks	0	0.00	-5.238 ^b	0.000
Posttest	Positive Ranks	36	18.50		

Given the information above, the Sig. result using the Wilcoxon Signed Rank test is $0.000 < 0.05$, which suggests the results of the pretest and posttest differ significantly (Suyanto & Gio, 2017). Based on the hypothesis statement, the guided inquiry-based worksheet developed can be used to train students' critical thinking skills on buffer solution material.

Based on the data presented in Tables 6 and 7 above, it shows that if the worksheet is declared effective. The worksheets developed for this study obtained an n-gain percentage of 79.65% in the high category, 56.89% in the medium category and 24.16% in the low category.

• CONCLUSION

From the analysis and discussion's finding of the worksheet development research data, the conclusion that the worksheets is worth developing by getting valid to a very valid category on content and construct validity getting a mode score 5. With regard to practicality, it gets a practical based on the typical student answer questionnaire category of 83.88% and and observations of relevant student activities were greater than irrelevant activities at meetings 1, 2, and 3 by 86.90%, 86.90%, and 95.23%. In terms of effectiveness, the effective category is based on the results of the pretest and posttest n-gain assessment to train students' critical thinking skills, with an average percentage of 79.65% in the high category, 56.80% in the medium category and 24.16% in the low category.

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