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Development of Guided Inquiry-Based Chemistry Instructional Materials to Train Science Process Skills

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ABSTRACT

The purpose of this research is to produce guided inquiry learning tools that are feasible in terms of validity, practicality, and effectiveness in training students' science process skills in acid-base material. This study refers to the Research and Development (R&D) research design. The device was implemented in class XI MIA I and XI MIA II Bani Ali Mursyad PSM Banaran with a total of 58 students. The results of this study indicate: (1) The validity of the device is in the very good category: the learning implementation plan (RPP) is in the very good category, the student worksheets (LKPD) are in the very good category, the syllabus is very good, the assessment sheets are in the very good category. (2) The practicality of learning devices is in the very practical category based on the results of the implementation of the lesson plans. (3) The effectiveness of learning devices is categorized as effective based on the N-gain test of student learning outcomes. (4) Achievement of process skills based on the results of LKPD and observation sheets categorized as skilled. Based on the results of the research, it shows that the learning tools are in the very good category, very practical, effective and skilled so that the learning tools are feasible to use.

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INTRODUCTION

Science Process Skills (SPS) is a scientific method that involves training individuals to discover something through experimentation or trial. SPS is the mental, physical, and competency abilities used for practical science and technology learning, such as problem-solving, individual development, and social development (1). As one of the learning approaches, Science Process Skills (SPS) is designed to enable learners to discover facts and construct concepts and theories in their learning. Learners are directed to engage in scientific activities during the learning process, thus making them actively involved in learning activities as they experience acquiring the concepts they are studying.

SPS must be trained to the learners to give them the experience and skills to use scientific methods in developing their existing knowledge. Based on preliminary research conducted at MA Bani Ali Mursyad PSM Banaran in October 2022, interviews with several learners revealed that acid-base materials were difficult due to the numerous theories that needed to be learned and memorised. Additionally, learners had difficulty determining the properties of a solution, leading them to rely on memorisation. Therefore, learners expected concept-based learning without memorisation. In terms of Science Process Skills for acid-base materials, the following indicators were observed: 73.53% of learners were unable to identify the phenomena, 88.24% were unable to formulate the hypotheses, 55.88% were unable to determine the variables correctly, 35.29% were unable to collect the data, 64.7% were unable to analyse the data, and 67.64% were unable to write accurate conclusions.

The low level of science process skills in this study was attributed to the lack of understanding and knowledge among teachers in implementing science process skill-oriented learning activities and the lack of teaching materials to guide teachers and learners in learning science process skills.

Improving science process skills is necessary to develop learners' abilities in chemistry learning by cultivating social and physical skills to enhance knowledge. Improving science process skills can be achieved by implementing a learning model that encourages learners to search, discover, and understand the subject matter. One such model is guided inquiry-based learning.

Guided inquiry is an inquiry-based learning approach used in science education. The stages of guided inquiry learning align with the indicators of science process skills, starting from presenting problems that cannot be easily explained by the teacher, followed by learners making observations and reaching conclusions. However, the teacher controls the questions posed, hypotheses formulated, and what the learners observe.

The advantages of guided inquiry-based learning include its effectiveness in increasing learners' motivation by actively involving them in discovering concepts or understanding topics presented by the teacher. Additionally, learners' curiosity is heightened throughout the learning process (2).

The guided inquiry model can train science process skills through its inherent learning stages. The learning stages of the guided inquiry model encourage learners to observe, classify, make predictions, explain, measure, and draw conclusions (3).

Science process skills using guided inquiry are closely related to the learning of natural sciences. Natural sciences involve systematically seeking knowledge about the natural world. This is intended to ensure that learners not only possess knowledge in the form of facts, concepts, or principles but also develop a process of discovery and conclusions (4).

The components of science process skills emphasize the development of skills, acquisition of knowledge, and communication of acquired knowledge. Science process skills are needed to utilize and understand science (Gagne, 3). Science process skills need to be implemented in the learning process, especially in chemistry learning, due to the rapid development of scientific knowledge. It is not feasible to teach all facts and concepts verbally to learners. Therefore, learners are required to discover and develop knowledge, as well as independently find concepts and principles. However, in reality, learners' science process skills are not adequately trained.

According to Sudjana (4), the success of teaching and learning can be measured from two aspects: the learning process and learning outcomes. Teaching success lies in the learning process, while learners' learning outcomes are the result of their learning. To achieve these outcomes, a learning model is needed to build knowledge, concepts, and skills in learners through the process of discovery and investigation.

The active involvement of learners in activities such as observation, questioning, data collection, association, and communication builds their knowledge independently and fosters their thinking processes. Therefore, the success of learning can be seen not only from learners' learning outcomes but also from their activities, including their participation in observing, asking questions, answering teacher-provided questions, expressing opinions, and conducting experiments to solve problems. However, in reality, the learning process does not actively engage learners, and thus learners' science process skills remain untrained. Based on the above description, it can be concluded that a learning tool is needed to train science process skills. Hence, research entitled "Development of Guided Inquiry-Based Chemistry Learning Tools to Train Science Process Skills in Acid-Base Topics" is necessary.

Based on the aforementioned problem background, the research questions can be formulated as follows: 1) How valid is the developed learning tool in terms of content and construct criteria?; 2) How practical is the developed learning tool in terms of the implementation of Lesson Plans (RPP) and learners' activities during the learning process using the developed learning tool?; 3) How effective is the developed learning tool in terms of learners' science process skills and learners' responses? This research aims to produce a guided inquiry-based learning tool that is valid, practical, and effective in training learners' science process skills in acid-base topics.

RESEARCH METHOD

This research follows the Research and Development (R&D) design. The research will produce a learning tool oriented toward guided inquiry, consisting of a syllabus, Lesson Plans (RPP), Student Activity Sheets (LKPD), and assessment sheets for learners' science process skills. According to Sukmadinata & Nana Syaodih (2015), the research and development process consists of (1) preliminary study, (2) model development, and (3) testing. This research will only focus on the development phase. The subjects of this research are the guided inquiry-based learning tools for training science process skills in acid-base topics. The implementation of these tools will take place in classes XI MIA I and XI MIA II at Bani Ali Mursyad PSM Banaran, involving a total of 58 learners. The research is conducted at MA Bani Ali Mursyad PSM Banaran because teachers have been developing learning tools in all subjects since the implementation of the 2013 curriculum, with a duration of three meetings during the 2022-2023 academic year.

The instruments used in this research are a Validation Sheet for Learning Tools; an Observation Sheet for Lesson Implementation; an Observation Sheet for Learners' Activities, and an Assessment Sheet for Science Process Skills, with data collection techniques consisting of 1) Validation technique; 2) observation, and 3) test technique. The data analysis techniques used in this research are as follows.

1) Validation analysis by direct assessment by experts

The validation is performed by three chemistry education lecturers from Surabaya State University. The validated instruments measure aspects based on supporting theories, and the experts will provide suggestions and comments on these instruments. The validity of the instrument's content is also examined using Aiken's V validity theory (Retnawati, 2016: 18).

$$V = \sum s \ / \ [n\ (c - 1)]$$

Description:

V = instruments validity = $r - l_0$
r = Score that was given by the examiner
lo = Score of lowest validity
n = total examiner
c = Score of highest validity

Table 1. Scoring criteria of learning tool's validity

r score	Interpretations
0,00 – 0,11	Not eligible
0,12 – 0,20	Eligible with Some Considerations
0,21 – 0,35	Eligible
0,36 – 1,00	Very Eligible

(Djatmiko, 2018)

The reliability formula that was used to find the instrument's reliability in which the scores are not 1 and 0, for example, in the case of open-ended questions. The Cronbach's Alpha formula is as follows.

$$r11 = \left[\frac{k}{(k-1)}\right]\left[1 - \frac{\sum \sigma_b^2}{\sigma_1^2}\right]$$

(Arikunto, 2013)

Descriptions:
r11 = Instrument's reliability
k = Total number of questions
$\sum \sigma_b^2$ = Total number of variants
σ_1^2 = Question variants

2) Analysis of lesson plan implementation
This analysis is used to determine the feasibility of syntax during the learning process conducted by teachers. The implementation of the lesson plan is observed using a lesson plan implementation observation sheet. This observation sheet contains implementation (yes or no) and assessment score criteria ranging from 0-4.

Table 2. Score criteria of lesson plan's feasibility

Score	Criteria
4	Very Good
3	Good
2	Less Good
1	Not Good
0	Not Performed

(Adapted from Riduwan, 2012)

Based on the table of criteria for the score of lesson plan implementation, data obtained from observations are further analyzed by finding the mode of the scores given by the observers. Next, the calculation of the percentage of agreement is performed to determine the similarity of values provided by the three observers. Reliability is calculated using the following formula:

$$Percentage\ of\ Agreement\ (R) = \left|1 - \frac{A-B}{A+B}\right| \times 100\%$$

(Borich & Gary, 1994)

Descriptions:
R = Reliability coefficient
A = Assessment results by observers who give high scores
B = Assessment results by observers who give low scores

An assessment instrument for instructional materials is considered reliable if the percentage of agreement obtained is ≥ 75% (Borich & Gary, 1994). Based on the criteria in Table 3.2, instructional materials are considered practical if they obtain a score ≥ 3 or the minimum best category.

3) Analysis of science process skills
This analysis is used to describe the achievement of each learning indicator calculated using the following formula.

$$Science\ Process\ Skills\ Score = \frac{Score\ Gained}{Maximum\ Score} \times 100$$

Table 3. Conversion of science process skills scores

Score Interval	Categories
93 - 100	A (Very Good)
84 - 92	B (Good)
75 – 83	C (Enough)
< 75	D (Not Enough)

(Ministry of Education and Culture, 2016)

Learners are considered to have been trained in science process skills if their science process skills score reaches a minimum of 75 with a grade of C. Assessment of the attitude aspect of science process skills can be calculated using the following formula.

$$Expert's\ Score = \frac{Score\ Gained}{Maximum\ Score} \times 4$$

Students are considered to have been trained in science process skills if their science process skills score reaches a minimum of 75 with a grade of C.

Table 4. The score criteria for the attitude aspect

The score intervals.	Categories
3,51 ≤ score ≤ 4,00	A (Very Good)
2,51 ≤ score ≤ 3,50	B (Good)
1,51 ≤ score ≤ 2,50	C (Enough)
≤ 1,50	D (Not Enough)

(Ministry of Education and Culture, 2016)

The difference in students' science process skills between pretest and posttest is analyzed using the n-gain score formula as follows.

$$(g) = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}}$$

Descriptions:

(g) : Gain score
S_{post} : Post-test score
S_{pre} : Pre-test score
S_{max} : Maximum score

Table 5. Criteria of normalized gain

N-Gain Score	Categories
0,7 ≤ n-gain	High
0,3 ≤ n-gain ≤ 0,7	Medium
n-gain ≤ 0,3	Low

(Hake & Richard R, 1999)

4) The Kruskal-Wallis test

This test is a nonparametric test used to determine the statistical significance of differences between two or more groups of independent variables on a dependent variable with a numeric (interval/ratio) or ordinal data scale. When conducting hypothesis testing, it is necessary to compare the P-value with the significance level (α) of the test. The significance level (α = 0.05) is used with the criteria to reject H0 if the P-value is < α, and to accept H0 if the P-value is > α.

RESULTS AND DISCUSSION

Lesson plan validity

The validity of the instructional materials is based on the validation results of the syllabus, lesson plan (RPP), student worksheets (LKPD), and Science Process Skills Assessment Sheets as presented in table 6.

Table 6. The results of the validation of instructional materials

No	Instructional Materials	Average Score	Categories
1	Syllabus	3.51	Very Good
2	Lesson Plan (RPP)	3.54	Very Good
3	Student Worksheets (LKPD)	3.47	Very Good
4	Science Process Skills Assessment Sheets.	3.45	Very Good

The practicality of instructional materials

The practicality of instructional materials based on the observation results of three assessors of lesson plan implementation is as follows.

Table 7. Results of the practicality of instructional materials

Phase	Assessment Aspects	Average	Categories
	INTRODUCTION		
I	Orienting students toward problems	96%	Very Practical
	MAIN ACTIVITIES		
II	Preparing investigations and guiding.	88%	Very Practical
III	Students conduct investigations and guidance.	89%	Very Practical
IV	Students make predictions and reflect.	88%	Very Practical
V	Problem-solving	89%	Very Practical
	CLOSING		
VI	Summarizing the learning and reminding.	88%	Very Practical
	Students study the next material.	92%	Very Practical
Overall percentage.		**89.07%**	Very Practical

Effectiveness of instructional materials

The effectiveness of instructional materials based on the assessment results of science process skills of 58 students before and after using the instructional materials is presented in table 8.

Table 8. Results of the effectiveness of instructional materials

Average Pre-test Score	Average Post-test Score	*N-gain*	Category
3.56%	43.28%	0,41	Effective

Achievement of science process skills

The achievement of science process skills based on the results of student worksheets (LKPD) includes formulating hypotheses, identifying variables, analyzing data, and drawing conclusions. Table 9 presents the results of science process skills achievement (products).

Table 9. Results of analysis of science process skills achievement

No	Science Process Skills	Average	Categories
1	Formulating hypotheses	3.29	Very Skilled
2	Variable Identification	3.26	Very Skilled
3	Analysing	2.58	Very Skilled
4	Drawing Conclusion	3.04	Very Skilled
	Average	3.04	Very Skilled

The achievement of science process skills in collecting data and organizing equipment and materials is shown in table 10.

Table 10. Results of analysis of science process skills achievement

No	Conducting Experiments	Average	Categories
1	Assembling equipment and materials	3.06	Skilled
2	Collecting data	3.63	Very Skilled
3	Organizing equipment and materials	3.38	Skilled
	Average	3.36	Skilled

Discussion

Validity of instructional materials

Based on the validation results by three validators, the lesson plan (RPP) that has been developed scored 3.51, categorized as very good. This is supported by several factors. The developed instructional plan uses a guided inquiry model aimed at developing science process skills. This is in line with the statement by Suhartono et al. (2014) that an inquiry-based instructional plan emphasizes science process skills. Similar opinions are also expressed by Kurniawati et al. (2016) that guided inquiry learning aims to improve science process skills and emphasizes the use of scientific steps in the learning process.

Based on the validation results from the three validators, the average scores for the format, language, and content of the student worksheets (LKPD) are 3.54, categorized as very good. The strong assumption is that the LKPD is categorized as very good because (1) the framework of the student worksheets developed aligns with Majid and Rochman's statement (2014) that generally the framework of student worksheets consists of the title of the experiment, the objectives, the equipment and materials, the steps, and several questions. (2) The developed student worksheets align with Prasojo's study (2016), which states that LKPD contains experiment activities and questions.

The average scores for the validation of the assessment sheets in terms of aspects are 3.47, categorized as very good. The developed assessment sheets could be said good learning outcome test sheets have instructions written in a simple form with short sentences, contain questions to be filled in by students, and provide space for students to write their answers (Majid & Rochman, 2015).

The practicality of instructional materials

Based on the observation of the implementation of the instructional plan, the average score for the implementation of the lesson plan is 89.07%, categorized as very practical. The achievement of the instructional plan is strongly assumed to be due to several factors: (1) The student worksheets (LKPD) and teaching materials developed facilitate students in the learning process. This aligns with Daryanto and Dwicahyono's (2014) statement that a well-prepared instructional plan influences the creation of student worksheets and teaching materials by teachers, leading to the preparation of learning facilities and facilitating student learning as the instructional plan is developed by the teacher. This is also in line with the opinion of Rismawati et al. (2017), stating that the teacher's role is as a facilitator during the experiment. The teacher's task is to guide students throughout the experiment according to the procedure in the student worksheets.

Effectiveness of instructional materials

Based on the pretest and posttest learning outcome test data, the N-gain score obtained is 0.41, categorized as effective. However, based on the individual mastery calculation, there are no students who have reached the minimum score of 70. This results in the failure to achieve the mastery level classically. Therefore, the finding of the effectiveness of the instructional materials is not in line with the achievement of student learning mastery. This is highly possible considering that the gain score obtained in this study is at the lower level (almost at the lower limit) of the effective category group.

The low learning outcomes of students in the posttest, which failed to achieve classical mastery, are strongly suspected to be caused by the implementation of the fifth phase of inquiry-based learning, which is reflecting on the learning problem by guiding students in discussing the application of the material in the reinforcement student worksheets. The implementation in this aspect is not maximized due to the limited time available, which is mostly used for the experiment in the third and fourth phases of inquiry-based learning. As a result, the allocation of time to train the application of concepts/principles obtained from the discovery becomes shorter. This session ideally aims to train problem-solving skills for students, both at the C3 and C4 levels in Bloom's taxonomy. Thus, the Learning Outcome Test (THB), which is dominated by questions at that level, cannot be solved well.

The characteristic conditions of students who are "new" to the science process skills are the main factors causing the delay in the implementation of inquiry-based learning. Referring to the book "Engaging Children in Science" by Howe & Jones in 1993, inquiry-based and discovery-based learning is essentially at level II. Level II autonomy can only be achieved when students have the basic skills required in the learning process. In the context of this research, the students who were the subjects of the study should have had previous experience related to science process skills. Therefore, the implementation of inquiry/investigation does not require a long time. If the above prerequisites are not met, a long time for the implementation of the inquiry will occur, as in the study by Rismawati (2017). The study found that teachers had difficulty adjusting the predetermined time due to the lack of time in the guided inquiry learning process. The same research findings were also reported by Sari et al. (2016), stating that the constraint encountered was that students were not accustomed to working on inquiry-based student worksheets that contained science process skills, resulting in learning activities exceeding the allocated time.

Achievement of science process skills

Overall, the average achievement of science process skills based on the results of the student worksheets (LKD) is 3.04, categorized as skilled. This is strongly suspected to be caused by several factors: (1) The developed LKPD can support students in practicing science process skills because the developed LKPD is composed of questions to develop science process skills such as formulating hypotheses, identifying variables, analyzing data, and making conclusions. This aligns with the opinion of Kurniawati et al. (2016), stating that a suitable combination of instructional media for guided inquiry learning is LKPD, with the hope that students' science process skills will improve based on scientific steps with the involvement of students in discovering concepts. This is also in line with Prasojo's opinion (2016), stating that LKPD is a guide for students that contains activities and questions to be answered by students to carry out experiments or solve problems in learning, to make learning activities student-centered. (2) The developed student worksheets can serve as a guide and reference for students in the learning process. This aligns with Sadia's statement (2014) that a somewhat detailed student worksheet helps the inquiry process and the student worksheet contains stages with instructions or guidelines designed by the teacher. This assessment aligns with the research findings by Pujiningrum & Admoko (2017), indicating that guided inquiry learning can improve science process skills possessed by each student. Thus, through the development of guided inquiry-based chemistry instructional materials, it is hoped that students' science process skills in the topic of acids and bases can be trained.

CONCLUSION

The study results demonstrate exceptional ratings across various aspects of the learning tools. The device's validity, covering the learning implementation plan (RPP), student worksheets (LKPD), syllabus, and assessment sheets, all achieved a 'very good' classification. Additionally, the assessment of practicality, based on the lesson plan implementation, also garnered a 'very practical' rating. The effectiveness of the learning tools was deemed 'effective' according to the N-gain test measuring student learning outcomes. Moreover, the attainment of process skills, evaluated through LKPD and observation sheets, was categorized as 'skilled'. Overall, these findings distinctly position the learning tools in the 'very good' category, confirming their practicality, effectiveness, and proficiency, thereby affirming their suitability for use.

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