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The Implementation Guided Inquiry Learning and Students' Science Process Skills on the Topic of pH Trajectory Determination of Natural Acid-Base Indicators

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A B S T R A C T

Science process skills (SPS) are the students' foundation for thinking scientifically, systematically, and critically to achieve a deep understanding of science concepts. This study aimed to analyze the implementation of guided inquiry learning and students' SPS in determining the pH trajectory of natural acid–base indicators. A one-shot case study design was used involving 98 eleventh-grade students divided into three learning groups at a public senior high school in Samarinda. Learning implementation was measured through observation, while students' SPS was assessed using tests, observations, and document analysis. Data were analyzed descriptively and inferentially using the Kolmogorov–Smirnov test for normality and the Kruskal–Wallis test for group differences. The results showed that teacher and student activities were in the excellent category (100% and 86–98%, respectively). The average SPS scores were in the fair category (69.31±5.20, 70.40±6.67, and 72.91±6.06). The Kruskal–Wallis test ($p=0.082$) indicated no significant difference among groups. Basic and procedural skills, i.e, observing, using tools and materials, and conducting experiments, developed very well, while higher-order thinking skills, i.e., interpreting, communicating, and formulating hypotheses, remained relatively low. Guided inquiry supports basic skills but requires reinforcement to improve higher-order scientific thinking skills.

1. Introduction

Science learning in the 21st century not only emphasizes mastery of concepts but also requires students to develop scientific process skills (SPS), a foundation for scientific thinking and problem-solving (Bao & Koenig, 2019; Gizaw & Sota, 2023). SPS includes the ability to observe, classify, measure, interpret data, formulate hypotheses, and draw conclusions based on empirical evidence (Idris et al., 2022; Irwanto, 2023). These skills play an important role in chemistry learning by enabling students to build knowledge through direct experience and meaningful scientific activities. However, research and educational evaluations indicate that science learning in schools is dominated by lecture methods and an emphasis on memorizing concepts. This condition causes low student involvement in scientific activities, leading to suboptimal development of students' SPS (Mushani, 2021; Irwanto et al., 2019). As a result, science learning tends to focus solely on cognitive achievement and provides less opportunity to develop scientific thinking skills comprehensively. One of the chemistry topics with great potential for developing students' SPS is acids and bases, particularly through activities that involve determining pH trajectories of natural acid-base indicators (Wahyuni et al., 2023; Fitriani et al., 2024). The use of natural indicators, the indicators derived from pigmented plant parts/organs, such as flowers, leaves and tubers, allows students to be directly involved in experimental activities. Through these activities, students can observe color changes, collect and interpret data, and relate their observations to the pH concept (Mukhtar et al., 2024; Oktaria et al., 2022). Learning using experimental methods based on natural resources has been proven to increase students' activeness, conceptual understanding, and scientific attitudes. (Nasution et al., 2025; Nadilla & Raida, 2025).

Although an experiment is often designed using an experimental and inquiry-based approach, its success is not solely determined by the media or teaching materials used, but also by the extent of its implementation in the classroom (Juhji, 2016; Sri & Hindriana, 2023; Mustika & Hamidah, 2025; Mayastika et al., 2026; Nuraini et al., 2025; Fitri & Aini, 2023). The implementation of learning refers to the extent to which the planned learning stages, from preliminary activities to core activities to closing activities, can be applied consistently and systematically in accordance with the learning syntax used (Setiawaty et al., 2023; Sugesti, 2016). In practice, activities are often not carried out optimally due to time constraints, ineffective classroom management, and the limited role of teachers in guiding the experiment (Masruhah et al., 2022; Huda, 2023). This situation meant that the scientific activities that should have been the core of the experiment did not proceed as expected (Nurfahzuni & Budiyanto, 2023; Oliveira & Bonito, 2023). Several studies show that low implementation of learning leads to suboptimal SPS development, even though learning has been designed based on experiments or inquiry (Purnamasari, 2020; Nurjanah et al., 2018; Resi et al., 2018; Meldayani et al., 2025).

However, previous studies have primarily focused on the effects of learning models or the use of acid–base indicators, including natural indicators, on cognitive learning outcomes and the enhancement of students' SPS (Salosso et al., 2018; Ischak et al., 2020; Wulandari et al., 2022; Nurjanah & Bahriah, 2024). Research specifically examining the implementation of learning and student learning outcomes in determining the pH trajectory of natural acid-base indicators remains limited and has received little attention. Moreover, quantitative research that investigated the relationship between the quality of learning implementation and measurable students’ SPS is still rarely conducted. Hence, further empirical research is warranted to address this gap.

Based on the above description, this study is aimed to analyze the implementation of guided inquiry learning and students’ SPS in determining the pH trajectory of natural acid-base indicators. Theoretically, this study is expected to enrich the study of chemistry learning and students’SPS development. In practice, the results of this study are expected to inform teachers in designing and implementing more effective, contextually relevant, student-centered, and scientific acid-base learning.

2. Methodology

This study is a quantitative experimental study aimed to analyze the implementation of guided inquiry learning and students' SPS in determining the pH trajectory of natural acid-base indicators. This study employed a pre-experimental one-shot case study design. In this design, a group is given treatment, and then the results are observed. The treatment, the independent variable in this study, is guided inquiry learning in determining the pH trajectory of natural acid-base indicators, which is carried out through experimental activities. The syntax of guided inquiry learning is orientation, presenting questions or problems, making hypotheses, designing and conducting experiments, collecting data, analyzing data, and making conclusions (Nurhaedah et al., 2022; Santi et al., 2024). The guided inquiry learning syntax and student activities are shown in Table 1. Meanwhile, the dependent variables in this study were the implementation of guided inquiry learning and students' SPS. The research subjects were 98 eleventh grade students who took chemistry as the elective subject, spread across three learning groups/classes at a public high school in Samarinda. One teacher taught one class, while one pre-service teacher taught two classes. In one class, students independently selected the samples during the observation stage. In the other two classes, the teacher or pre-service teacher provided the samples. The number of research subjects in each class, the educators in each class, and the steps of observing and selecting samples are shown in Table 2.

Table 1. Guided Inquiry Learning Syntax & Student Activities

Syntax	Student Activities
Orientation	Students read the theoretical basis (literature review) Students observe plants Student determine/select plants that can be used as natural acid-base indicators
Presenting questions or problems	Students formulate problems
Formulating a hypothesis	Students formulate hypotheses
Designing and conducting experiments	Students organize the experimental procedure and determine the tools and materials Students conduct the process of extracting/making natural acid-base indicators and test the color change of plant extracts in pH 1-14 solutions.
Collecting data	Students observe and record color changes.

	Students classify plant extracts as natural indicators of acid and/or alkali.
Analyzing data	Students present data in the form of tables or graphs.
Drawing conclusions	Students formulate conclusions.

Table 2. Number of Research Subjects (Students), Educators, and Sample Observation Activities in Each Class

Class	Number of students	Educators	Description
1	33	Pre-service teacher	Students independently selected the sample from their environment during the observation stage
2	36	Pre-service teacher	Students independently selected the sample from provided samples by the educator during the observation stage
3	29	Teacher	Students independently selected the sample from provided samples by the educator during the observation stage

The data on learning implementation were collected through classroom observation by using observation sheets. The implementation of the learning process was observed based on teacher and student activities designed according to the stages of guided inquiry learning, which include orientation, presenting questions or problems, formulating hypotheses, designing and conducting experiments, collecting data, analyzing data, and drawing conclusions.

Teacher and student activities were assessed using the Guttman scale (0–1) and the Likert scale (1–5), respectively, and were observed by six observers. The data on teacher and student activities were categorized according to the criteria presented in Table 3. Data on students' SPS were collected through tests, observations, and document analysis. The test consisted of 10 multiple-choice questions with five answer options, including one correct answer and four distractors. The items were developed based on ten SPS: observing, asking questions, formulating hypotheses, designing experiments, using tools and materials, predicting, classifying, interpreting, applying concepts, and communicating. Observations were conducted using a student's SPS observation sheet designed based on eleven SPS indicators: observing, classifying, interpreting, predicting, communicating, asking questions, formulating problems, designing experiments, using tools and materials, applying concepts, and conducting experiments. The observation sheet was assessed using a Likert scale (0–3) and was completed by six observers. Furthermore, document analysis was conducted using a student worksheet assessment sheet designed based on nine SPS indicators: observing, classifying, interpreting, predicting, communicating, asking questions, formulating problems, designing experiments, and applying concepts. The students' SPS scores were then categorized according to the criteria presented in Table 4 (Reza et al., 2021; Wola et al., 2023). Data analysis was conducted quantitatively. The analysis began with a normality test using the Kolmogorov–Smirnov test to determine the distribution of the data, followed by the Kruskal–Wallis test to examine differences in students' SPS across the three classes.

Table 3. Percentage and Categories of Teacher and Student Activities

% Teacher Activities	% Student Activities	Category
$0 \leq P < 20$	$20 \leq P < 36$	Very Poor
$20 \leq P < 40$	$36 \leq P < 52$	Poor
$40 \leq P < 60$	$52 \leq P < 68$	Fair
$60 \leq P < 80$	$68 \leq P < 84$	Good
$80 \leq P \leq 100$	$84 \leq P \leq 100$	Very Good

Table 4. Categories of Science Process Skills Scores

Assessment Criteria	Science Process Skills (X)	Category
$X \geq \bar{x} + 1,5\ \sigma$	$X \geq 80,26$	Very Good
$\bar{x} + 0,5\ \sigma < X \leq \bar{x} + 1,5\ \sigma$	$73,94 \leq X < 80,26$	Good
$\bar{x} - 0,5\ \sigma < X \leq \bar{x} + 0,5\ \sigma$	$67,62 \leq X < 73,94$	Fair
$\bar{x} - 1,5\ \sigma < X \leq \bar{x} - 0,5\ \sigma$	$61,29 \leq X < 67,62$	Poor
$\bar{x} - 1,5\ \sigma \leq X$	$X < 61,29$	Very Poor

$\bar{x}$ and σ are average and standard deviation of students' SPS, repectively

3. Results and Discussion

Implementation of Learning

The data on the implementation of guided inquiry learning in determining the pH trajectory of natural acid–base indicators in three classes of eleventh-grade students who selected chemistry as their elective subject at a public high school in Samarinda are presented in Figure 1.

The optimal implementation of learning plays an important role as a basis for developing meaningful scientific activities in the classroom (Fadly, 2017). The consistent high learning implementation across all classes demonstrates that the guided inquiry learning model can be applied consistently, despite differences in educators (teachers and pre-service teachers) and variations in treatment at the selected sampel/sample-determination stage (see Table 2). This indicates that teacher and pre-service teacher can carry out each stage of learning according to plan, ensuring that all students have equal opportunities to engage in scientific activities. This finding is in line with previous research, which states that a high level of learning implementation is associated with increased student activity during experimental activities (Royani et al., 2018; Lestari et al., 2018). Other studies also state that well-implemented guided inquiry learning can create a more interactive and structured learning environment (Ramadhan, 2021). Overall, the observation results indicate that the successful implementation of each stage of guided inquiry is important for maintaining the quality of learning. The high level of activity among teacher/pre-service teacher indicates clear direction and guidance, while the high level of activity among students indicates their direct involvement in learning activities. Thus, the excellent implementation of learning in this study demonstrates that the learning design has been carried out effectively and supports the achievement of scientific learning objectives.

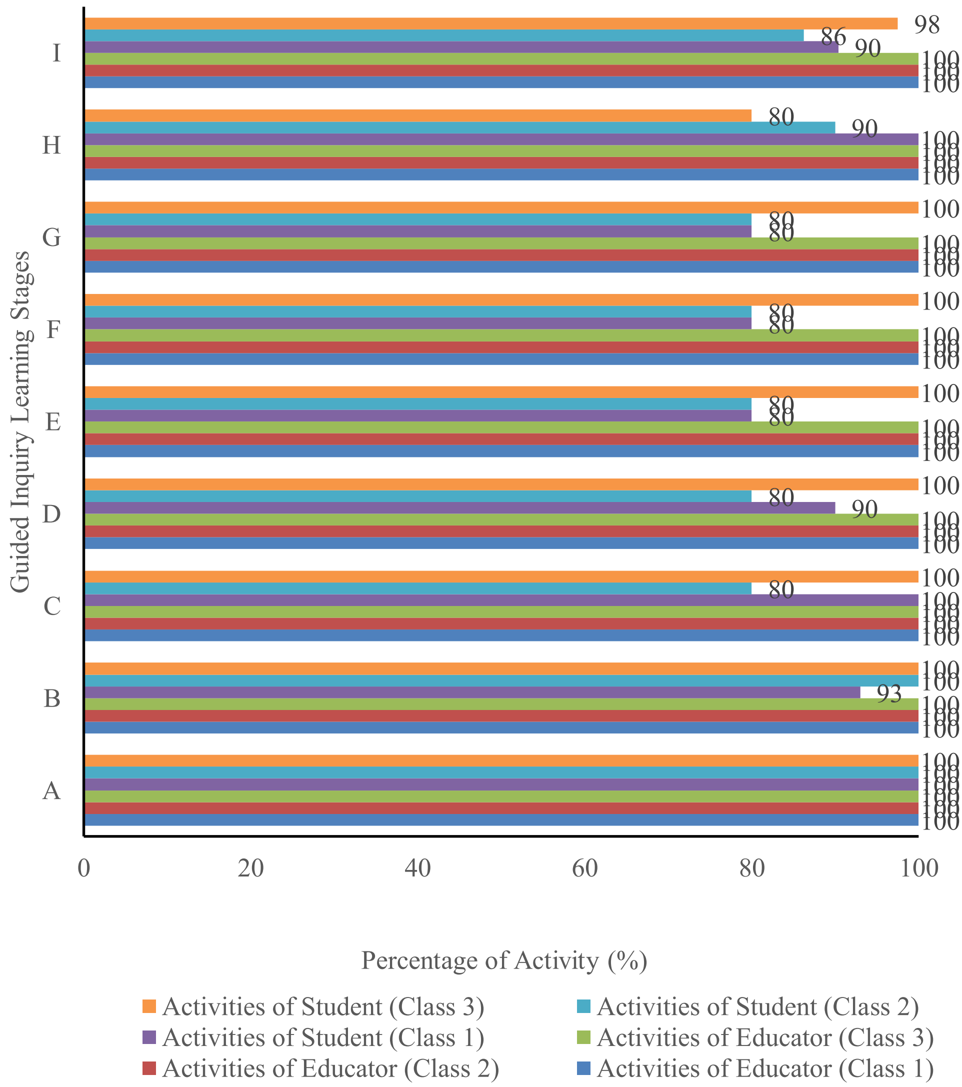


Figure 1. Implementation of Learning to Determine the pH Trajectory of Natural Acid-Base Indicators. A= orientation, B= presenting questions/problems, C= making hypotheses, D= designing experiments, E= conducting experiments, F= collecting data, G= analyzing data, H= making conclusions, and I= average activity scores

Figure 1 shows that the percentages of teacher and pre-service teacher activities in the three classes at each stage of guided inquiry learning, as well as their overall average activity, are in the very good category (100%). Similarly, the percentages of student activities in the three classes at each stage of guided inquiry learning are classified as very good, ranging from 80% to 100%. The average percentage of overall student activity across the three classes also falls within a very good range (86-98%). This shows that the implementation of guided inquiry learning in determining the pH trajectory of natural acid-base indicators, conducted by teacher/pre-service teacher and students in the three classes, aligns with the learning stages. The high percentage indicates that systematically structured learning planning increases active involvement among teachers and students during the learning process.

Science Process Skills

Students' SPS data on guided inquiry learning in determining the pH trajectory of natural acid-base indicators in three classes of eleventh grade students who programmed chemistry as their elective subject at a public high school in Samarinda is presented in Figure 2.

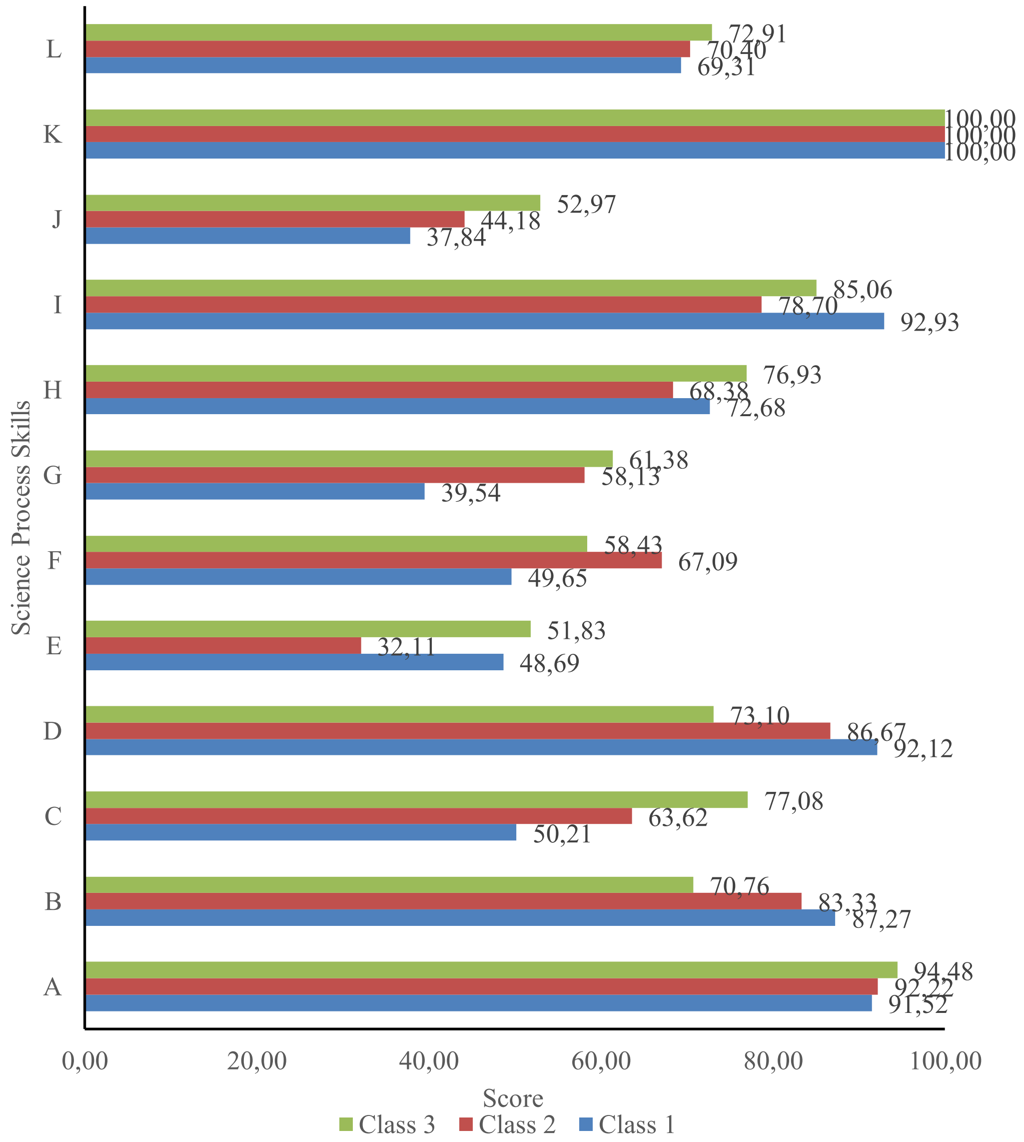


Figure 2. Science Process Skills Scores. A = observing, B= classifying, C= interpreting, D= predicting, E= communicating, F= asking questions, G= formulating hypotheses, H= designing experiments, I= using tools and materials, J= applying concepts, K= conducting experiments, and L= average science process skills score

From Figure 2, it can be seen that student' observation skill of all three classes is in the very good category (91.52-94.48). Based on the student worksheet assessment sheet, this skill was assessed in the experimental data section, where students were asked to accurately and systematically record the colors of natural indicators at pH 1-14 (see Figure 3). It shows that students correctly and accurately observe the changes in the color of natural acid-base indicators. These results are in accordance with the observation data carried out by the observer. The high score obtained because the experimental activities, students observed directly the process of natural indicator color changes when reacting with the acid and base solutions (pH 1-14). The observation process was real and could be seen directly, making it easier for students to understand. This finding aligns with research by Rahmawati et al. (2025), which shows that experiential learning significantly improves observation skills, as students are directly involved and interact with the scientific phenomena being studied.

a

b

c

Ekstrak Tanaman	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ket.
Bunga Asoka	merah muda	merah muda	agak merah muda	bening	bening	bening	bening	bening	bening	bening	agak kuning	agak kuning	kuning kecoklatan	kuning	Asam Basa

Ekstrak Tanaman	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ket.
Adam hawa (ungu)	Pink	merah muda	ungu muda	ungu muda	Bening	bening	hijau muda	hijau	hijau	hijau	hijau	hijau	hijau	kuning	Asam Basa

Ekstrak Tanaman	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Ket.
Bunga Telang	merah muda	ungu	ungu	ungu	Biru tua	Biru muda	Biru keunguan	Biru kehijauan	Biru	Biru gelap	Biru kehijauan	Biru tosca	hijau gelap	hijau kecoklatan	

Figure 3. Student Answer from student worksheet for students' observation skill: a = Class 1, b= Class 2, and c= Class 3

Grouping (classification) skill of students in classes 1 and 2 are in the very good category (83.33-87.27), while the skill of students in class 3 is in the fair category (70.76). Based on the student worksheet assessment sheet, this skill was assessed by the student's ability to classify plant extracts as natural acid and/or base indicators based on the color changes in the experimental results table. This shows that most students were able and well in classifying plant extracts as natural acid or base indicators (see Figures 4.a-b). However, students of class 3 were not yet fully developed in the classification skill (see Figure 4.c). This result is in line with observations made by observers. This difference occurred because of variations in students' initial ability to understand the concepts of acids and bases, including the interpretation of changes in the indicator color. These differences in conceptual understanding also affected the accuracy of their classification. In addition, classification skill depends not only on the ability to observe, but also on students' ability to accurately connect observation data to the concepts of acid and base properties. This aligns with research by Wariani & Hayon (2025), which found that initial conceptual ability influences students' accuracy in classifying experimental data.

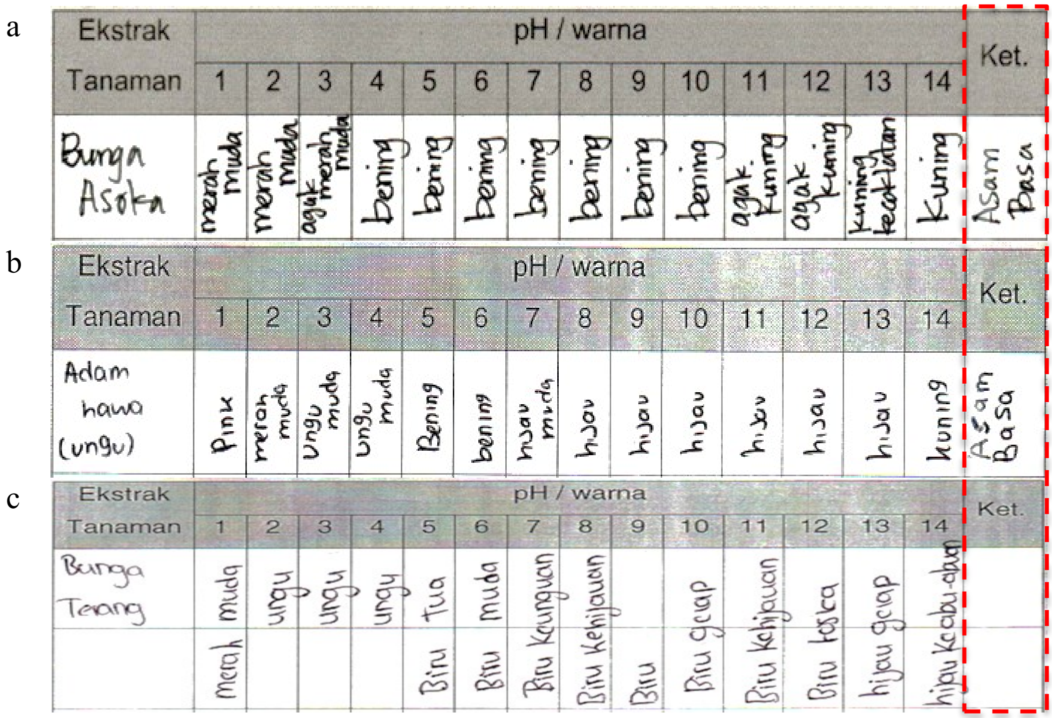


Figure 4. Student answer from student worksheet for classifying skill: a= Class 1, b= Class 2, and c= Class 3

Interpretation skill of students in classes 1 and 2 are in the very poor (50.21) and poor (63.62) categories, respectively, while the skill of students in class 3 is in the good (77.08) category. Based on the student worksheet assessment sheet, this skill was assessed through the determination of the pH trajectory and its scientific reasoning, as well as the preparation of conclusions based on the experimental results. In line with the results of the document analysis, the observation results also showed similar results. The low scores of students in classes 1 and 2 indicate that students are not yet able to determine the pH trajectory, nor are they able to include complete explanations or arguments (see Figures 5.a-b). Interpreting data is a high-level thinking skill because it requires combining observational data with relevant theoretical concepts. Students are not only asked to recognize that a color change has occurred, but they also have to explain the meaning of the change based on appropriate concepts and pH ranges. These findings are consistent with previous research stating that scientific interpretation skills tend to develop more slowly than observation skills, as this process requires students to integrate conceptual understanding with logical reasoning simultaneously (Rendi et al., 2024). However, students in class 3 were able to determine the pH trajectory and provide explanations or arguments. This shows that students in class 3 did not merely observe, but were able to relate their observations to theoretical concepts about acid-base characteristics and the range of color changes of the natural indicators. It indicates that their scientific thinking skills have developed better than those of students in classes 1 and 2. The students in class 3 were able to explain the relationship between color changes of the extract and specific pH ranges coherently and logically, supported by data obtained from the experiment (see Figure 5.c). This finding aligns with previous research showing that inquiry-based learning helps students more easily understand the relationship between experimental data and the scientific concepts being studied (Dewi, 2016).

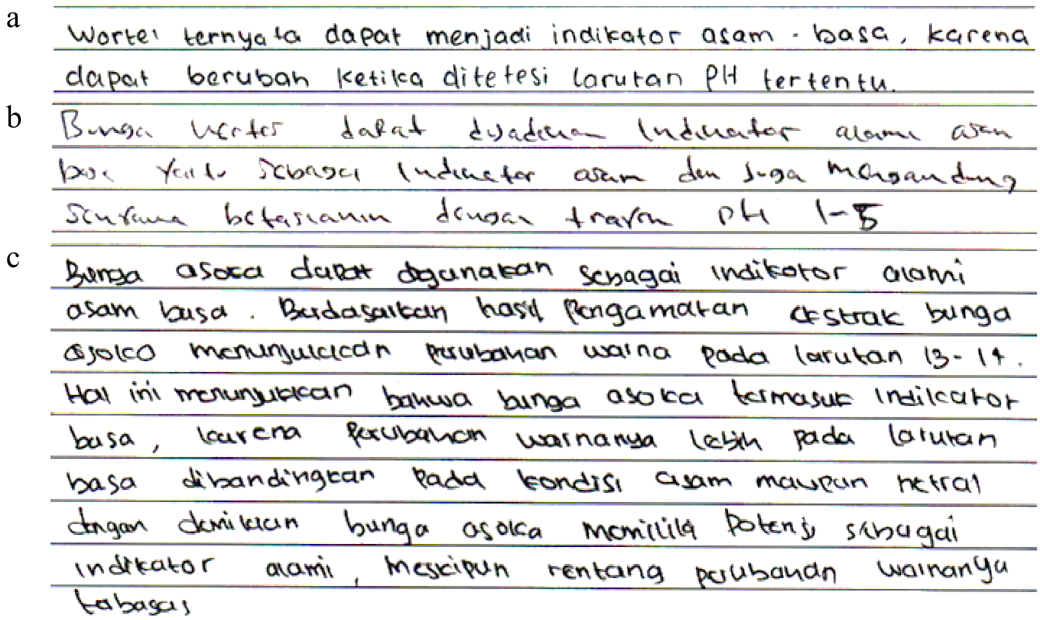


Figure 5. Student answer from student worksheet for interpreting skill: a= Class 1, b= Class 2, and c= Class 3

The prediction skill of students from classes 1 and 2 is in the very good category (86.67-92.12), while the skill of students from class 3 is in the fair category (73.10). Based on the student worksheets assessment sheet, this skill was assessed when students were asked to predict plants that can be used as natural acid-base indicators based on physical characteristics such as the appearance and color of the plant, and give appropriate reasons that align with theoretical principles (see Figures 6.a-b). The high students' achievement in classes 1 and 2 shows that students are able to use their prior knowledge of pigments and the physical characteristics of plants to make logical predictions before the experiment is conducted. Meanwhile, the students' achievement in class 3, which is in the fair category, shows that some students are still not able to fully relate the physical characteristics of plants to their compounds that can change their color at certain pH ranges (see Figure 6.c). It means that teacher/pre-service teacher need to provide more intensive guidance to the students in class 3 in connecting the physical characteristics of plants to the possibility of them being used as a natural acid-base indicator. This condition can also be seen through observations where students in classes 1 and 2 could predict samples well, but in class 3, there were still groups of students who were less precise in selecting (predicting) samples. This result shows that prediction skill is strongly influenced by the depth of students' conceptual understanding and their ability to connect theoretical knowledge with the experimental context. Research by Nurillahi et al. (2024), states that the application of guided inquiry learning, particularly through the prediction stage before the experiment is conducted, can improve forecasting skill by encouraging students to activate and utilize their prior knowledge.

a b c

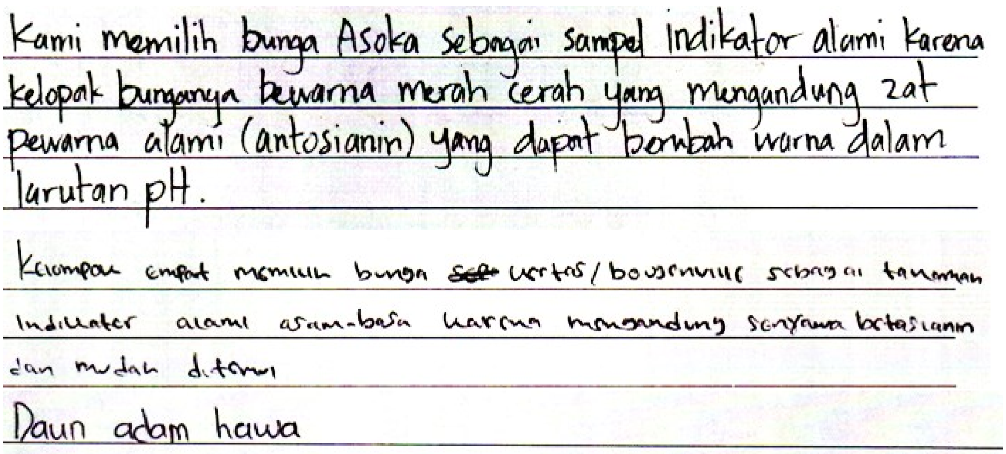


Figure 6. Student answer from student worksheet for forecasting skill: a= Class 1, b= Class 2, and c= Class 3

Communication skill (32.11-51.83) and concept application skill (37.84-52.97) of students in all three classes are in the very poor category. Based on the student worksheet assessment sheet, this skill was assessed through students' ability to present the results of their discussions (see Figure 7). The low student achievement shows that most students were still not accustomed to presenting their observations and scientific arguments systematically and based on data. Many answers remained descriptive, merely explaining what happened without providing in-depth analysis or supporting scientific explanations. In addition, students were not yet fully able to relate the experimental data to the theories they had learned, so their reports did not demonstrate a complete and systematic scientific thinking process. This condition is also supported by the results of observations, where students faced difficulties in formulating the discussions. These findings are consistent with previous research, which indicates that scientific communication is often a weakness in science learning when it is not practiced through the preparation of reports based on clear evidence or data. Without focused practice, students face difficulties in conveying their observations and scientific arguments systematically and accurately (Mufidah, 2019).

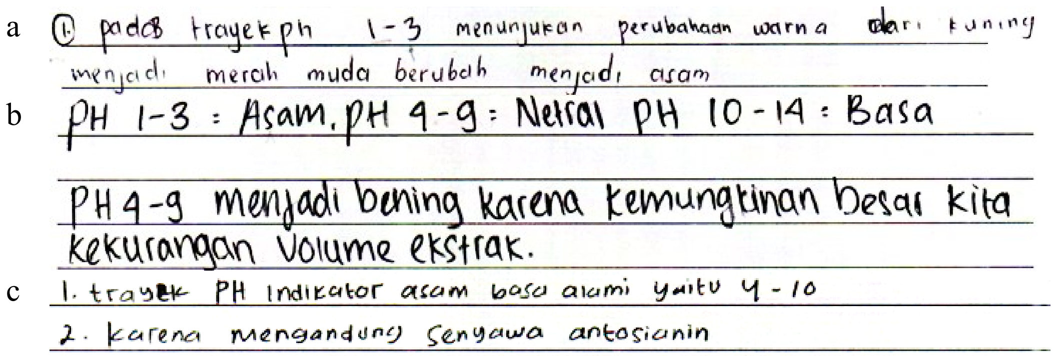


Figure 7. Answer sheet for assessing students' work in communicating and applying concepts: a= Class 1, b= Class 2, and c= Class 3

The student's skill in asking questions in all three classes is categorized as very poor (49.65-67.09). Based on the student worksheet assessment sheet, this skill was assessed in the problem formulation section, where students were asked to formulate research questions relevant to the experiment. The low students' achievement indicates that students are still unfamiliar with formulating operational scientific questions that focus on investigative activities. Some of the questions are still general and do not clearly show the relationship between the variables (see Figure 8). This is in line with the results of observations, which show that students faced difficulties in formulating appropriate and precise problems. This condition indicates that the ability to question scientifically has not developed optimally, and students still need to get used to questioning skills. This aligns with the research by Puspitasari et al. (2025), which found that questioning skill develops when learning consistently provides students with opportunities to explore and engage in open discussion. In a comfortable situation to express curiosity, students have the courage to ask critical, directed, and phenomenon-based questions.

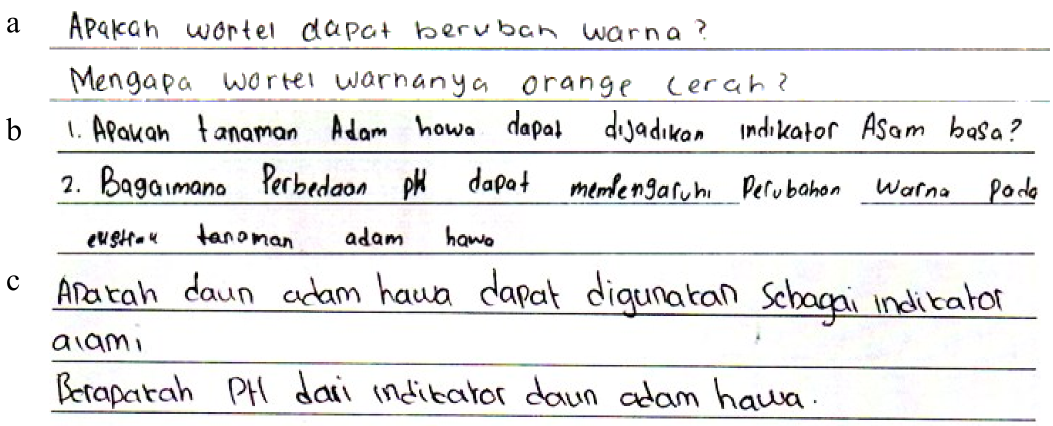
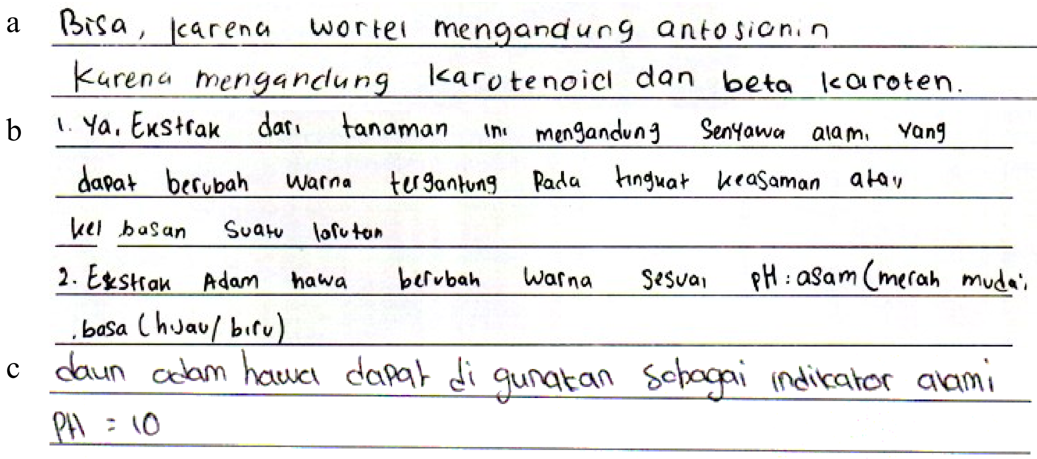


Figure 8. Student answer from student worksheet for asking questions skill: a= Class 1, b= Class 2, and c= Class 3

The students' skill in formulating hypotheses in all three classes was categorized as very poor (39.54-61.38). Based on the student worksheet assessment sheet, this skill was assessed when students wrote their preliminary answers to the problems they had formulated. The low scores indicate that the students did not fully understand the structure of a hypothesis, which must clearly state the cause-and-effect relationship. Many of the hypotheses remain general, lack specificity, or fail to align with the formulated problem (see Figure 9). Students' low ability to formulate hypotheses was also observed through observation. This condition confirms that the skill of formulating hypotheses does not develop automatically but requires repeated and focused practice and training. This aligns with the research by Hani'ah & Fadly (2022), which states that the student's ability to formulate hypotheses develops gradually through continuous inquiry practices. The high intensity of students in the process of formulating problems, identifying variables, and predicting cause-effect relationships results in their good ability to formulate logical, specific, and in line with the investigation goal hypotheses.


a Bisa, karena wortel mengandung antosianin karena mengandung karotenoid dan beta karoten.

b 1. Ya. Ekstrak dari tanaman ini mengandung senyawa alami yang dapat berubah warna tergantung pada tingkat keasaman atau kebasaan suatu larutan

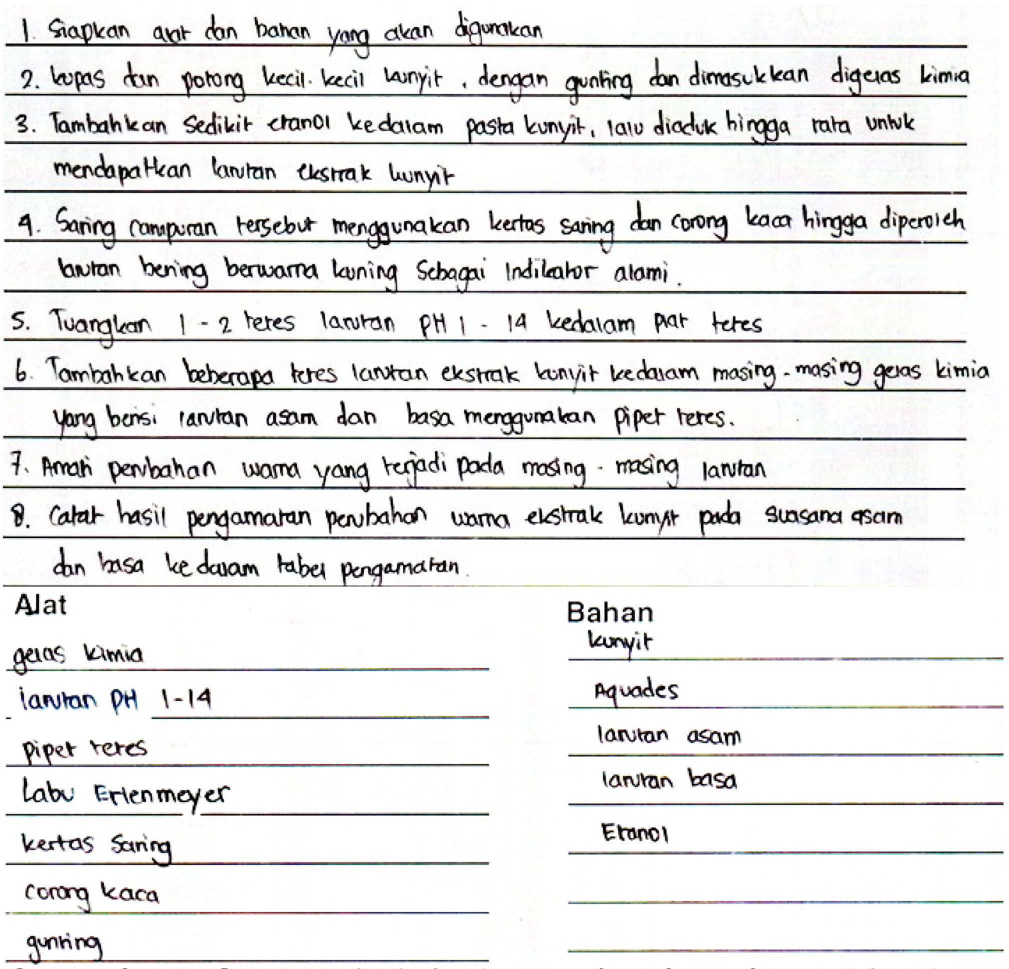
2. Ekstrak Adam hawa berubah warna sesuai pH: asam (merah muda), basa (hijau/biru)

c daun adam hawa dapat di gunakan sebagai indikator alami PH = 10

Figure 9. Student answer from student worksheet for formulating hypotheses skill: a= Class 1, b= Class 2, and c= Class 3

The skill in designing experiments of the students from classes 1 and 2 were in the fair category (68.38-72.68), while the students from class 3 was in the good category (76.93). Based on the student worksheet assessment sheet, this skill was assessed by the accuracy and completeness of the writing of the tools, materials, and procedures that would be used in the experiment (see Figure 10). The highest score in class 3 indicates that the students were able to compile procedures coherently and systematically, although they still need improvement in the accuracy and completeness of deciding the tools and materials. Meanwhile, students in classes 1 and 2 were still unable to compile the procedures coherently and systematically. They lacked accuracy and completeness in deciding the tools and materials, which shows that, in these classes, the teacher/pre-service teacher guidance intensity in providing directions and examples for procedure development still needs improvement, so that students better understand the logical sequence of work and the objectives of the experiment. These results are in line with the observation results, which show that students were still not perfect in compiling procedures and determining complete experimental tools and materials. These findings align with previous research indicating that providing appropriate scaffolding in inquiry-based learning can improve students' ability to design experiments coherently and logically. Through step-by-step guidance, clear examples, and targeted feedback, the sequence of procedures and the relationship between steps in experimental activities were easier understood by the students (Muhammad et al., 2026).

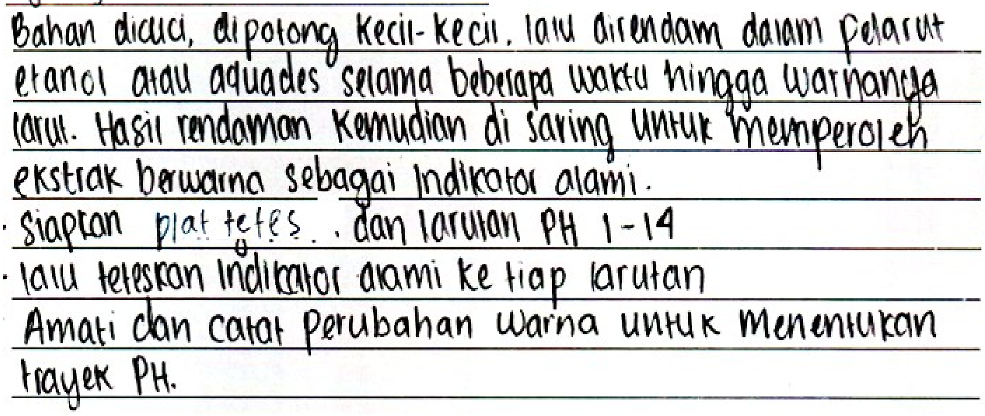
a



1. Siapkan alat dan bahan yang akan digunakan
2. kupas dan potong kecil-kecil kunyit, dengan gunting dan dimasukkan digelas kimia
3. Tambahkan sedikit etanol kedalam pasta kunyit, lalu diaduk hingga rata untuk mendapatkan larutan ekstrak kunyit
4. Saring campuran tersebut menggunakan kertas saring dan corong kaca hingga diperoleh larutan bening berwarna kuning sebagai indikator alami.
5. Tuangkan 1 - 2 tetes larutan PH 1 - 14 kedalam plat tetes
6. Tambahkan beberapa tetes larutan ekstrak kunyit kedalam masing-masing gelas kimia yang berisi larutan asam dan basa menggunakan pipet tetes.
7. Amati perubahan warna yang terjadi pada masing-masing larutan
8. Catat hasil pengamatan perubahan warna ekstrak kunyit pada suasana asam dan basa ke dalam tabel pengamatan.

Alat	Bahan
gelas kimia	kunyit
larutan PH 1-14	Aquades
pipet tetes	larutan asam
Labu Erlenmeyer	larutan basa
kertas saring	Etanol
corong kaca	
gunting	

b

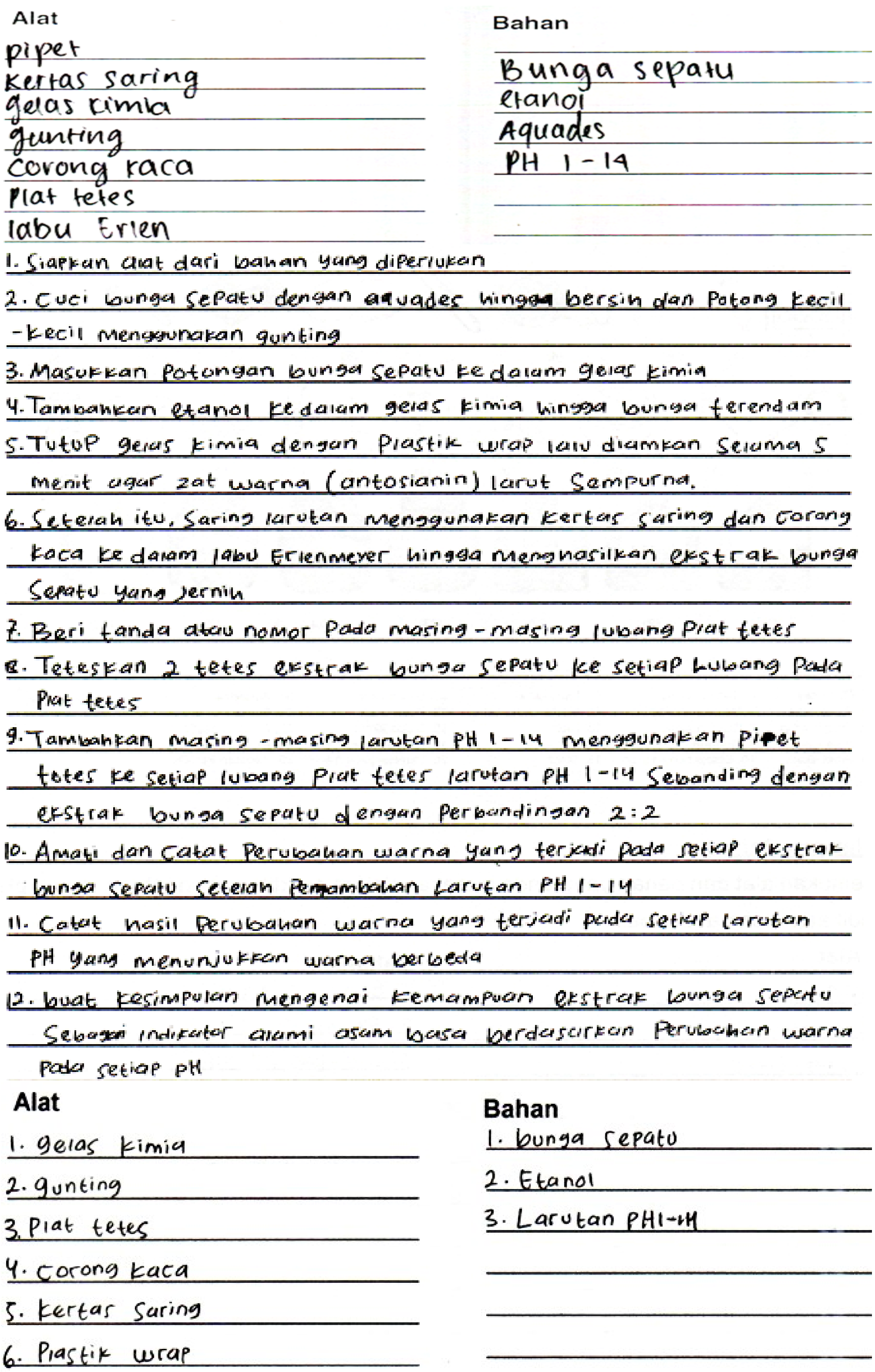


Bahan dicuci, dipotong kecil-kecil, lalu direndam dalam pelarut etanol atau aquades selama beberapa waktu hingga warnanya larut. Hasil rendaman kemudian di saring untuk memperoleh ekstrak berwarna sebagai indikator alami.

- Siapkan plat tetes. dan larutan PH 1 - 14
- lalu teteskan indikator alami ke tiap larutan

Amati dan catat perubahan warna untuk menentukan trayek PH.

c



Alat
pipet
Kertas saring
gelas kimia
gunting
corong kaca
Plat tetes
labu Erlen

Bahan
Bunga sepatu
etanol
Aquades
PH 1 - 14

1. Siapkan alat dari bahan yang diperlukan
2. Cuci bunga sepatu dengan aquades hingga bersih dan Potong kecil -kecil menggunakan gunting
3. Masukkan Potongan bunga sepatu ke dalam gelas kimia
4. Tambahkan etanol ke dalam gelas kimia hingga bunga terendam
5. Tutup gelas kimia dengan Plastik wrap lalu diamkan selama 5 menit agar zat warna (antosianin) larut sempurna.
6. Setelah itu, saring larutan menggunakan kertas saring dan corong kaca ke dalam labu Erlenmeyer hingga menghasilkan ekstrak bunga sepatu yang jernih
7. Beri tanda atau nomor Pada masing - masing lubang Plat tetes
8. Teteskan 2 tetes ekstrak bunga sepatu ke setiap lubang Pada Plat tetes
9. Tambahkan masing - masing larutan PH 1 - 14 menggunakan pipet tetes ke setiap lubang Plat tetes larutan PH 1-14 sebanding dengan ekstrak bunga sepatu dengan perbandingan 2:2
10. Amati dan catat Perubahan warna yang terjadi pada setiap ekstrak bunga sepatu setelah Penambahan larutan PH 1 - 14
11. Catat hasil Perubahan warna yang terjadi pada setiap larutan PH yang menunjukkan warna berbeda
12. buat kesimpulan mengenai kemampuan ekstrak bunga sepatu sebagai indikator alami asam basa berdasarkan Perubahan warna Pada setiap pH

Alat
1. gelas kimia
2. gunting
3. Plat tetes
4. corong kaca
5. kertas saring
6. Plastik wrap

Bahan
1. bunga sepatu
2. Etanol
3. Larutan PH1-14

Figure 10. Student answer from student worksheet for designing experiments slkill: a= Class 1, b= Class 2, and c= Class 3

The skill in using tools/materials of student from class 2 was in the good category (78.70), while students from classes 1 and 3 were in the very good category (85.06-92.93). This skill was evaluated from observation on the students' ability to use tools and materials appropriately, safely, and according to their intended function during the experiment. The observation results show that students have been able to correctly prepare and use laboratory equipment. They conducted experiments in groups regularly and effectively. This high achievement is influenced by the use of simple equipment and structured guidance during guided inquiry learning, thus students were easier to understand how the tools work and conduct experiments correctly. These findings align with previous studies, which indicate that inquiry-based experiments improve the accuracy of students in using equipment and material, as a result of direct experiences through repeated, focused practice during experiments (Syamsu, 2017).

The students skill for conducting experiments across all three groups were rated very good (100). The skill was evaluated on the extent to which students were able to conduct experiments according to the prepared procedures. Based on the observations, students were seen to carry out each step of the experiments sequentially and complete the experiment orderly. They were also able to make corrections or take appropriate actions when conducting experiments, even though there were still errors in the experimental design that needed to be corrected/completed. This also shows that students can use their logical abilities with guidance and direction from a teacher/pre-service teacher. These results indicate that procedural guidance in the guided inquiry learning model effectively trains students' psychomotor skills. This finding aligns with previous research indicating that structured experiments under teacher supervision improve students' accuracy in conducting experiments (Keliata & Choirunnisa, 2021).

Overall, the average students' SPS across the three classes was in the fair category (69.31-72.91), and no significant differences were found between the classes, as shown in Table 5. This indicates that differences in educators and treatment at the sample determination stage did not have a significant effect on overall students' SPS achievement. Although there were variations in treatment at the sample-determination stage and differences among educators, statistically, the students' SPS achievements were relatively homogeneous. Several factors can explain the absence of these differences. First, the implementation of learning in the three classes was very good and relatively balanced, so that the quality of learning implementation did not differ significantly. Second, although students in class 1 selected samples independently, while students in classes 2 and 3 received samples prepared by the teacher/pre-service teacher, the core inquiry activities were carried out in the same way. This meant that the effect on students' SPS was not significant. These findings are in line with research by Royani et al. (2018), which shows that minor differences in experimental situations or scenarios do not always result in significant differences in students' SPS, especially if the learning model and quality of guidance provided are relatively equivalent. In addition, (Kriswantoro et al., 2025) state that the main factor driving the increase in students' SPS is consistency in implementing inquiry steps, not only technical differences in experimental activities. Thus, the absence of significant differences in student SPS between classes indicates that a consistently implemented guided inquiry learning model produces relatively equivalent student SPS achievements, even though there are technical differences in the sample determination stage.

Table 5. Comparison of Science Process Skills

Class	Science Process Skills
1	69,31 ±5,20[a]
2	70,40 ±6,67[a]
3	72,91 ±6,06[a]

The same letters indicate no significant difference

The results of this study show a consistent pattern: basic and procedural skills, such as observing, using tools and materials, and conducting experiments, developed better than higher-order thinking skills, such as interpreting data, communicating results, and formulating hypotheses. In other words, although the implementation of learning has been successful, the development of higher-order thinking skills still requires additional strategies, such as scientific argumentation exercises, reflective discussions, guidance in data analysis, and problem-solving-based tasks. Thus, guided inquiry learning on the material of determining the pH trajectory of natural acid-base indicators has been implemented effectively and optimally, and has developed basic and procedural skills in the science process. However, to improve higher-order scientific thinking skills, there needs to be continuous reinforcement of scientific analysis, interpretation, and communication.

This study has several limitations that should be considered when interpreting the findings. First, this study employed a pre-experimental one-shot case study design without a control group; therefore, it cannot establish a strong causal relationship between the implementation of guided inquiry learning and the improvement of students' SPS. Second, the study was conducted in one school with a limited number of participants, which may limit the generalizability of the findings to other schools with different contexts and characteristics of students and schools. Third, the study was carried out over a relatively short period and focused on a single topic, namely determining the pH trajectory of natural acid–base indicators. As a result, the study does not capture the long-term development of students' SPS. In addition, the assessment of student SPS focused on observation technique and document analysis technique by assessing student worksheets; although multiple observers were involved to enhance the reliability of the assessment, the possibility of subjective judgment cannot be completely eliminated. Furthermore, due to the limitations of time, tools, materials, and the number of observers, the observation and student worksheets assessments were conducted at the group level rather than individually, which may have affected the accuracy of the evaluation of each student's SPS.

Based on the study's results and limitations, several suggestions for further research and learning practices are offered. For future research, it is recommended to use a stronger design, such as a true- or quasi-experimental design with a control group, so the effect of the learning model on students' SPS can be analyzed more deeply. Research should also be conducted across schools with diverse backgrounds and over a longer period of time, so that students' SPS development can be continuously monitored. In learning practices, educators are suggested to pay specific attention to higher-order thinking skills, such as interpreting data, communicating results, and formulating hypotheses, through scientific argumentation practices, reflective discussions, and evidence-based report writing. In addition, individual observation and students' worksheets assessment are needed to ensure the data obtained is more comprehensive.

4. Conclusion

Based on the study's results, it can be concluded that the implementation of guided inquiry learning in determining the pH trajectory of natural acid-base indicators was carried out very well across all stages of learning. The optimal implementation shows that the planning and implementation of learning have been carried out systematically and consistently by the educators, both of teacher and pre-services teacher. Thus, the research objective to analyze the implementation of learning and students' science process skills (SPS) have been achieved. In general, students' SPS achievements were in the fair category and did not show significant differences between classes. Basic and procedural skills, such as observing, using tools and materials, and conducting experiments, developed very well. However, higher-order thinking skills, such as interpreting data, communicating results, asking questions, and formulating hypotheses, remain relatively low. These findings indicate that although the guided inquiry model is effective in supporting scientific activities and basic skills, strengthening learning strategies is still needed to optimize scientific analysis, interpretation, and communication.

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