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Enhancing students' science process skills through macrozoobenthos-based worksheets: An inventory study at Rancabuaya Beach, West Java

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ABSTRACT

This study aims to increase students' science process skills (SPS) using student worksheets based on the results of the macrozoobenthos inventory at Rancabuaya Beach, West Java. This research was conducted in the even semester of the 2024/2025 academic year at a university in Bandung, West Java. This study employed a quasi-experimental pretest-posttest control group design with purposive sampling of 44 students enrolled in the ecology practicum course. SPS improvement was assessed using the N-Gain criterion for science process skills improvement, encompassing seven indicators: observing, classifying, interpreting, planning experiments, using tools and materials, applying concepts, and communicating. The results show that in the experimental class, SPS increased substantially, with an average N-Gain of 0.79, which was higher than in the control class (0.64, moderate). The most substantial increase was in planned experiments and in the use of tools and materials, with N-Gain 0.85, while communication showed the lowest increase with N-Gain 0.75. These results show that the experimental class experienced a significant increase in SPS indicators with student worksheets integrated with the local macrozoobenthos inventory. The implications of this research expand knowledge on the importance of incorporating local biodiversity in biology learning to improve science process skills, enrich learning media innovations, and provide a theoretical and practical foundation for the development of contextual science education.

Keywords: Macrozoobenthos, science process skills, student worksheets

INTRODUCTION

Science learning is learning that emphasises the emergence of a direct experience (Ritonga et al., 2020). The process of learning science should be able to develop the skills of thinking and understanding nature scientifically (Sitepu & Afni, 2024). Science process skills are present as cognitive and intellectual skills that are applied during science learning to help understand and solve scientific problems (Nwuba et al., 2022).

Science Process Skills (SPS) play a crucial role in modern education because they are the basis for the development of critical thinking, problem-solving, and scientific inquiry skills in students (Apeadido et al., 2024). Mastering SPS teaches students to understand scientific concepts and to hone their logical and systematic approaches to directly addressing various situations. These skills are particularly relevant to the demands of the 21st century, which emphasise the importance of innovation, creativity, and independence (Koomson et al., 2024).

SPS is closely related to 21st-century skills, especially in critical thinking, computational thinking, and inquiry-based learning (Azzahra et al., 2024) and is part of the skills to build knowledge through discovering facts, solving problems, and conducting experiments in the 21st century (Ngozi, 2021). This finding is driven by human curiosity. In the process, SPS are an important tool for investigating and exploring nature, thus helping to understand the world more deeply (Gizaw & Sota, 2023).

To support the development of SPS, exploratory learning is often employed as an instructional approach that actively engages students in scientific inquiry. Exploratory learning is one of the learning strategies that makes students actively learn, improving their understanding abilities through observation, discovery, search, and research activities (Patras et al., 2022). This strategy aims to involve students as a whole in the problem-solving process (Rose et al., 2024). Through exploratory learning, students gain many opportunities to build their own knowledge through processes and skills that relate initial knowledge to the learning experience they have experienced (Masloman et al., 2023).

Knowledge of the exploration process in the environment includes the identification of facts and phenomena (Pangkey et al., 2022). It is important to develop the relationship of concepts with facts, phenomena, and problems in the surrounding environment as a unit of learning materials. The ecology practicum course is a compulsory course with a Macrozoobenthos topic that examines the interactions between living things and their environment. The environment displays natural phenomena around us, so it should be used in learning.

The main issue in the implementation of the ecological practicum lies in the lack of optimisation in practicum instructions and learning processes (Safnowandi, 2024). The limited practicum activities cause the development of scientific attitudes, understanding of the process, and the ability to apply knowledge in daily life, to be maximised (Abu et al., 2025).

In addition, based on interviews with two lecturers in the Ecology practicum, it was found that limitations in media and learning tools can pose significant obstacles. As a result, practicum-based learning objectives are not effectively achieved, and students miss out on opportunities to gain meaningful learning experiences and acquire the necessary skills (Malahayati & Sholikhah, 2023). The availability of teaching materials can help educators design lessons and help students master learning materials. Teaching materials are a compilation of learning materials sourced from various well-organised learning sources (Sitepu & Afni, 2024).

The learning outcomes of the Macrozoobenthos material in the ecology practicum at one of the universities in Bandung enable students to master the concept and carry out Macrozoobenthos practice using technology to train the skills and process responsibly. Macrozoobenthos material was chosen as an observation object because it acts as a bioindicator of water quality, so that learning becomes more contextual, meaningful, and in accordance with real environmental issues (Apriana, 2024; Kesuma et al., 2022; Tovar-Gálvez, 2021). One of the local potential sites that can be used as a learning resource in the macrozoobenthos practicum is the Rancabuaya beach area. This area has an ecosystem rich in marine organisms (Sriwahjuningsih & Raharjo, 2022). In addition, the advantage of Rancabuaya Beach is that it has a tidal zone to become a complete ecosystem, such as seagrasses, mangroves, and coral reefs (Paujiah et al., 2018).

The inventory of macrozoobenthos not only introduces students to the richness of local biodiversity, but also trains them in conducting direct observations, recording data, classifying, and interpreting findings based on the principles of science process skills (Parida et al., 2024; Tarigan et al, 2025). This potential is particularly relevant to the integration of learning tools such as student worksheets.

Student worksheets are assignment sheets given by lecturers for students to complete. Student worksheets serve as a guideline for students' learning, helping them understand the concepts behind the activities (Susanti et al., 2025). Student worksheets arranged contextually are expected to foster students' interest and enthusiasm for learning lessons (Nurahmawati et al., 2025).

This guide, in the form of student worksheets, helps students understand the material and ensures that practicum activities align with the intended learning principles. This shows the importance of developing relevant student worksheets to support active, contextual, and engaging biology learning (Dewanti et al., 2024; Hidayanti et al., 2020; Parida et al., 2024).

An innovation that can solve this problem is using student worksheets based on the local diversity of the macrozoobenthos inventory in Rancabuaya Beach, Garut Regency. This student worksheet will make students directly involved in the learning process, to make students active, creative, and fun, because it involves them directly in acquiring their knowledge (Indriyani & Ita, 2020). Previous research has focused more on the media development aspect, while the integration between local biodiversity inventory and improving science process skills has not been widely studied (Fauziyah & Pramadi, 2025; Naufal et al., 2024; Krisnawati & Fitriani, 2020).

Macrozoobenthos inventory on Rancabuaya Beach has previously been carried out in the river estuary and coastal areas to obtain nutrient conditions in sediments and to determine their influence on the existence of macrozoobenthos (Rizal et al., 2017). The existence of previous research on macrozoobenthos inventories provides a strong basis for carrying out the inventory and using it as material for the preparation of worksheets based on local potential, so that learning with local potential helps students in a learning context and provides a hands-on learning experience (Fara et al., 2023).

Therefore, this research is important for filling the gap between using student worksheets aligned with local potential and students' science process skills, which are crucial during the learning process. This study aims to improve students' science process skills by using worksheets based on the local diversity of the macrozoobenthos inventory.

METHOD

This study employed a pretest–posttest control group design, in which the participants were divided into two groups: an experimental group that used the student worksheets and a control group that used conventional modules. The macrozoobenthos students' worksheets, based on inventory and diversity at Rancabuaya Beach, were implemented to improve students' science process skills.

This research was conducted in an ecology practicum course for undergraduate students in the biology education program at one of the universities in Bandung, West Java. Samples were selected using purposive sampling techniques and divided into experimental and control classes, with 22 students in each.

This study was conducted in the even semester of the 2024/2025 academic year. The student worksheet was used in the experimental class, while the control class used only conventional teaching materials. This learning activity is carried out in two stages: face-to-face classes and field practicum classes.

The design of the method in this study is shown in Table 1.

Table 1. Quasi-experimental method

Subject	Pre-test	Treatment	Post-test
Class A	O_1	X_1	O_2
Class B	O_3	X_2	O_4

(Source: Sukmadinata, 2017)

Description:
Class A = Experimental class
Class B = Control class
O_1, O_3 = Pre-test
O_2, O_4 = Post-test
X_1 = Using student worksheets
X_2 = Without using student worksheets

Location and inventory of macrozoobenthos

The inventory research was conducted in December 2024 in the Rancabuaya Beach area, Purbayani Village, Caringin District, Garut Regency, West Java (Figure 1). The macrozoobenthos inventory was carried out in coastal areas between the seawater limits at high and low tide, also called the intertidal zone. The sampling location was selected qualitatively using a purposive sampling approach. Samples were collected from three stations: station I (7°32'00"S 107°28'45"E), station II (7°32'05"S 107°28'46"E), and station III (7°32'10"S 107°28'48"E).

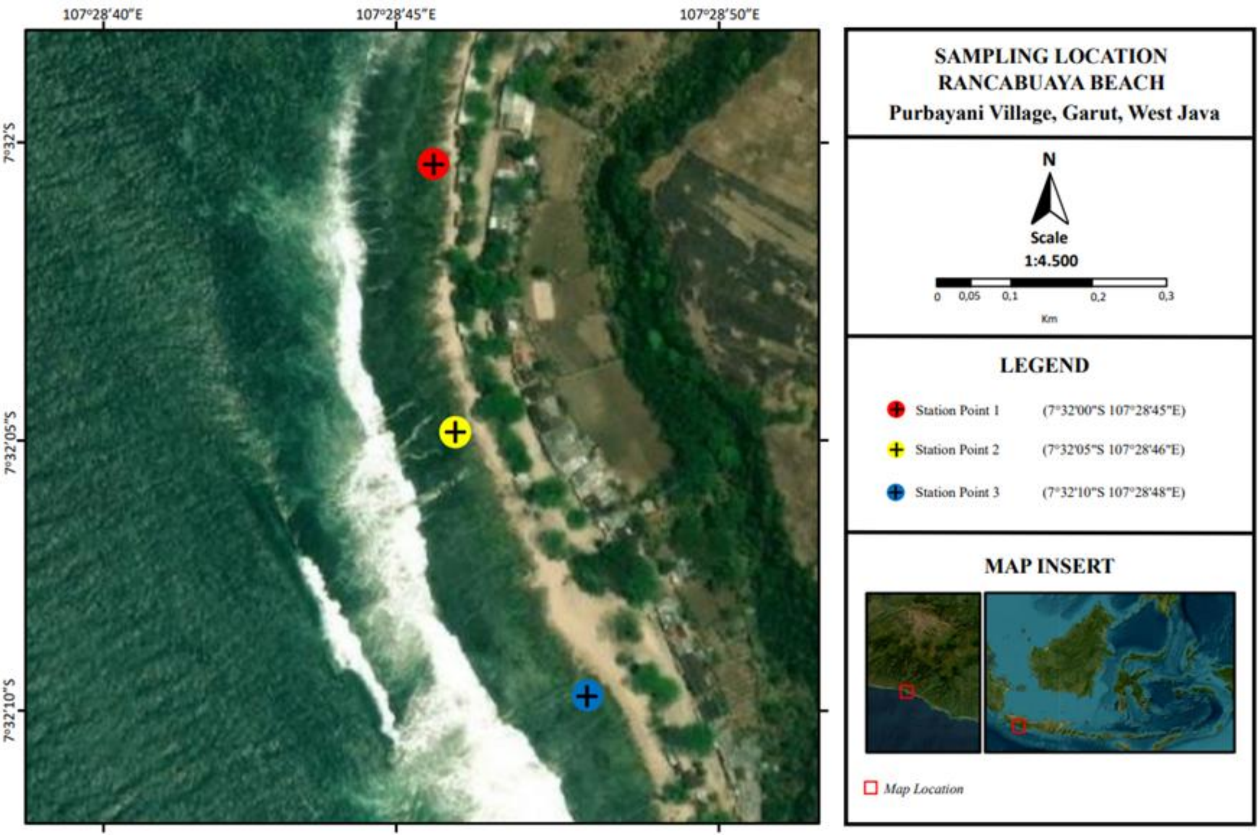

Figure 1. Location sampling at Rancabuaya Beach, Purbayani Village, West Java, Indonesia.

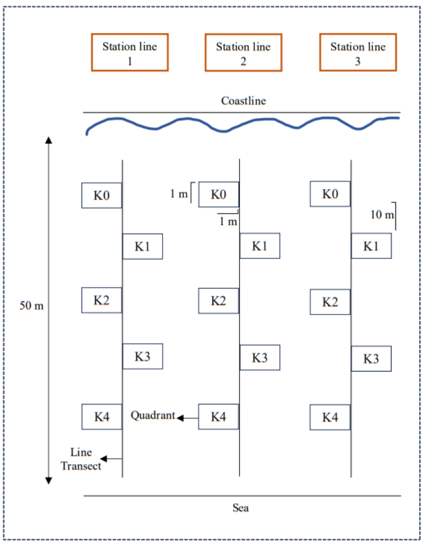

Figure 2. The macrozoobenthos collection scheme uses quadratic transects.

Samples were taken using the quadrat transect method with 1x1m square plots (Figure 2). Five plots were placed in each transect (station) (Safitri et al., 2024). Macrozoobenthos samples were collected manually using hand spoons and gloves (hand collection) (Salwiyah et al., 2022; Purnama et al., 2019).

Macrozoobenthos identification was carried out at the Advanced Laboratory of Biology Education at the State Islamic University of Sunan Gunung Djati Bandung. Macrozoobenthos identification is based on sources such as the "World Register of Marine Species" (https://www.marinespecies.org), Carpenter & Niem (1988), Dharma (2005), and Fauchald (1977).

The research procedure is divided into three stages below (Sumiati et al., 2024).

1. **Preparation stages**
   a. Inventory of macrozoobentos composition at Rancabuaya Beach, Garut Regency, using the quadrat transect method (Figure 2).
   b. The inventory results are used as material for the preparation of student worksheets.
   c. Conduct student worksheets validation and readability tests before use.
   d. Preparing learning tools in the form of Semester Learning Plans for ecology practicum courses on macrozoobenthos materials.
   e. Compile research instruments in the form of pretest and posttest questions, and conduct validity and reliability tests of instrument questions.
   f. Determine the population and sample using purposive sampling techniques.
   g. Group the sample into two groups: the experimental group using student worksheets and the control group using the regular module.
2. **Implementation stage**
   a. Provide a pretest to both groups to determine SPS before treatment.
   b. The experimental class studied the material using student worksheets based on the SPS through an macrozoobenthos inventory, while the control group studied the same material using conventional modules.
   c. Briefing and implementation of field practicum on Macrozoobenthos material.
   d. A posttest will be given to both groups to measure SPS after treatment.
3. **Data analysis stage**
   a. The questions' validity and reliability were tested by the IBM SPSS Statistics 27 application.
   b. Calculate the average and increase of pretest and posttest scores on SPS questions for each group using the N-Gain formula (Lestari & Yudhanegara, 2018).

$$N - Gain \; = \frac{Posttest - Pretest}{Skor\ max - Pretest}\ x\ 100\%$$

The N-gain value obtained is then interpreted into three criteria:

Table 2. N-Gain criteria

Range	Criteria
G<0.3	Low
0.3< G ≤ 0.7	Moderate
G>0.7	High

(Source: Lestari & Yudhanegara, 2018)

   c. Conducting an average descriptive analysis and N-Gain scores of pretest and posttest students.

The results of the questions' validity and reliability test showed that 21 of 28 questions were valid and reliable. In the pretest-posttest, questions were used using seven indicators of science process skills.

Before being used, the student worksheet was validated by three expert validators: media experts, material experts, and teaching lecturers. The aspects assessed in the media validation included presentation feasibility and graphical feasibility. The material validation aspects included content feasibility, feasibility of integrating science process skills (SPS), language appropriateness, and presentation feasibility. Meanwhile, the lecturer's validation aspects included media presentation, content feasibility, and language appropriateness. The results of the media expert validation were 78%, the material expert validation 83%, and the lecturer validation 92%. Based on each of these expert validations, the criteria for student worksheets are categorised as very feasible with a percentage of 76%-100% (Marneli & Susanti, 2023). Thus that student worksheets can be used in Macrozoobenthos practice.

The pretest is conducted before learning is implemented to measure students' initial abilities. After that, the experimental group used student worksheets to learn, while the control group used conventional modules. After the treatment, a posttest is carried out to measure changes in science process skills. The research instrument is an SPS essay question consisting of seven indicators of science process skills.

The data obtained were analysed using N-Gain to compare the pretest and posttest results between the experimental and control groups (Lestari & Yudhanegara, 2018). This analysis aims to identify skill improvement between the two groups in science processes. In addition, the data from the analysis are complemented by an average descriptive analysis and comparisons with the pretest and posttest data.

RESULTS AND DISCUSSION

The results of the macrozoobentos inventory were used to develop student worksheets, while the pretest and posttest data were used to measure the increase in SPS among Biology education students using SPS-based student worksheets. The following are the results of the inventory and statistical analysis.

Inventory of macrozoobenthos at Rancabuaya Beach

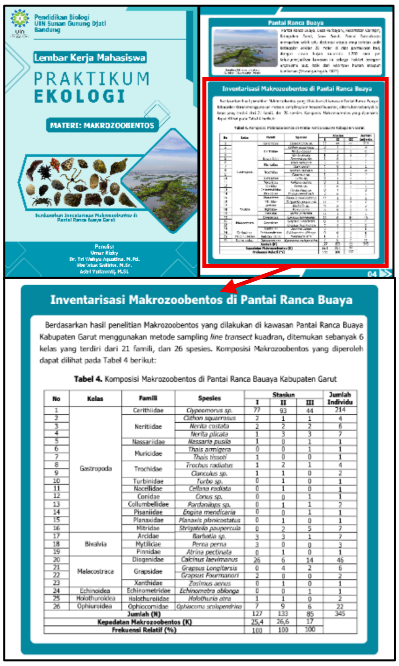

Figure 3. The results of the inventory are used as material for the preparation of student worksheets

The inventory results identified 26 species, 21 families, and six classes of macrozoobenthos: Gastropoda, Bivalvia, Malacostraca, Echinoidea, Holothuroidea, and Ophiuroidea. Across the three stations, a total of 345 individuals were found.

The results of the macrozoobenthos inventory were used to develop the macrozoobenthos student worksheets (Figure 3). Learning that is compiled based on the results of an inventory of local potential can provide a fun and non-boring teaching and learning process (Parida et al., 2024).

Statistics descriptive

The following Table 3 presents a statistical description of students' average and N-Gain SPS scores in the control and experimental classes.

Table 3. Overall SPS N-Gain results

Class	Average		N-Gain	Interpretation
	Pretest	Posttest		
A	43.32	88.73	0.79	High
B	41.64	78.45	0.64	Moderate

Description:
A = Experimental class
B = Control class

Based on Table 3, the analysis results show that out of 44 students, the average pretest score of the regular class was 41.64, while the average posttest score was 78.45. In contrast, the experimental class obtained an average pretest score of 43.32 before and after being given the treatment in the form of student worksheets, the average posttest score increased to 88.73. The overall N-Gain score was 0.79, which falls into the high category, indicating improved science process skills.

The student worksheets, developed based on science process skills, include group discussions and practicum activities on macrozoobenthos inventory and seven SPS indicators to encourage students to develop active learning, contextual, and scientific activities. Science process skills can motivate students to develop basic experimental skills, learn to use scientific approaches, and help them understand topics through practical learning (Hiğde & Aktamış, 2022; Naibaho & Khairuna, 2025; Perdana et al., 2022; Yildiz & Yildiz, 2021). Practicum activities and group discussions can improve science process skills (Atikah & Haryanto, 2025). Table 2 shows seven SPS indicators used in the pretest-posttest questions.

Improving science process skills in the experimental class involves student worksheets that contain activities based on science process skill indicators, which can facilitate learning. Science process skills-based worksheets can be effectively used in learning and can improve students' science process skills (Naibaho & Khairuna, 2025). The use of Worksheets through scientific activities serves to see the activeness of students in solving a problem independently, critically, theoretically, and scientifically, so that they can improve science process skills (Sari et al., 2023).

The science process skill indicator in student worksheets and test questions uses seven indicators, as shown in Table 4.

Table 4. SPS indicator

Indicator	Description
Obseving	Using as many sensory tools as possible to express the properties of an object
Planning the Experiment	Determine the tools, materials, and steps to be implemented in the experiment
Using tools & materials	Using and knowing the reasons for using tools and materials
Classifying	The process of grouping objects based on the similarity of characteristics
Interpreting	Connecting patterns or observations through temporary inference
Applying concepts	Using concepts that have been learned in new situations
Communicating	Converting the form of presentation into empirical data of experimental results with graphs, tables, or diagrams

(Source: Suja, 2020)

The scores of the pretest and posttest questions were analysed using the normalised gain calculation because the initial test score (pretest) and the final test score (posttest) differed in value. The N-Gain results are shown in Table 5.

Table 5. N-Gain results of each SPS indicator

Indicator	A		B	
	N-gain	Category	N-Gain	Category
Observing	0.80	High	0.61	Moderate
Planning the Experiment	0.85	High	0.62	Moderate
Using tools & materials	0.85	High	0.70	High
Classifying	0.82	High	0.81	High
Interpreting	0.79	High	0.54	Moderate
Applying concepts	0.76	High	0.56	Moderate
Communicating	0.75	High	0.57	Moderate

Description:
A = Experimental class
B = Control class

These results explain the potential of student worksheets, based on the inventory of local biodiversity using SPS, to improve students' science process skills more effectively than conventional modules. These improvements are supported by several advantages of student worksheets, shown by the improvement of students' science process skills measured using the seven SPS indicators described below.

Observing

Observing skills increased N-Gain to 0.80 in the experimental class, which is in the high category. This shows that students have been able to use their five senses to collect observed data (Kurniawati, 2021; Mirian, 2023; Suwardi, 2024). The developed worksheets include figures based on the results of macrozoobenthos inventories to provide students with an initial concept before practicum learning. Teaching materials equipped with pictures can support learning, stimulate students to analyse and process information, and have a positive effect on improving student understanding (Daulay et al., 2020).

Planning the experiment

Planning the experiment became the highest indicator of improvement in the experimental class with an N-Gain value of 0.85, higher than the control class, which reached 0.62. This increase occurred because the student worksheets, which were explicitly designed, led students to be actively involved in each stage of planning the experiment. Activities in student worksheets require students to identify variables, determine variables, and formulate hypotheses among variables (Gizaw & Sota, 2023; Mirian, 2023). Through this, students are encouraged to conduct experiments or investigations, which can improve their intellectual abilities and are closely related to the skill aspect of the science process (Sasmitha et al., 2023).

Using tools & materials

Use of tools and materials skills in the experimental class yielded an N-Gain of 0.85, while the control class was 0.70. Both classes were categorised as showing high improvement. Both classes are familiar with the use of tools and materials from practicums in the previous semester, so students can understand the procedures for using tools and materials during the practicum. Based on this, students can use them according to procedures, know the reasons for their use, and gain previous experience in using tools and materials (Ningrum et al., 2022; Rusmini et al., 2021). During exploratory learning, students can read physics and chemistry parameters well, and student worksheets contain activities that can facilitate students to use the tools and materials used (Nurfitriani et al., 2025).

Classifying

The classification indicator showed relatively similar improvement between the experimental and control classes, namely with N-Gain 0.82 and 0.81, both of which are in the high category. This occurred because each class was directly involved in understanding the activities of grouping and comparing the characteristics of macrozoobenthos. Where students can group and differentiate by identifying the observable types of a group of objects (Ningrum et al., 2022; Ramadhan et al., 2023). In exploratory learning using student worksheets, students can classify the types of macrozoobenthos by observing morphological features and comparing them with references. Classification indicators have an important role in organising information and identifying patterns. The lack of implementation of these indicators can create gaps in efforts to develop higher-level thinking skills (Kar et al., 2025).

Interpreting

The use of student worksheets in the experimental class resulted in a significant increase in interpretation skills with an N-Gain of 0.79 compared to the control class, which was only 0.54. This occurred because exploratory learning used Student Worksheets containing hypotheses, calculations, and experiments with images, graphs, or tables that can help students develop their interpretation skills (Astuti et al., 2025; Jannah et al., 2024; Koomson et al., 2024; Masloman et al., 2023). So that students are able to identify patterns, relationships, and associations in data obtained from learning (Angelia et al., 2022; Gizaw & Sota, 2023).

Applying concepts

The skill of applying concepts has increased with an N-Gain 0.76 in the experimental class, which is in the high category. This was achieved by students using worksheets that introduced the concept of macrozoobenthos as a local resource, so that students could learn theory through direct practice. The use of worksheets and observations can help students interpret concepts according to their prior understanding and knowledge (Ningrum et al., 2022). Therefore, students have been able to find answers or solutions to new problems, namely by applying their knowledge (Masruhah et al., 2022).

Communicating

Among the improvements in SPS indicators, communication skills were the lowest improvement indicator in the experimental class, with an N-Gain of 0.75, while the control class had an N-Gain of 0.57. This occurred because students did not optimally transform the information obtained into tables, graphs, and diagrams (Inayah et al., 2020). In addition, the analysis of the information on the student worksheets answers shows that students' ability to properly process information from various sources remains lacking (Jayanti, 2021). The experimental class still showed an increase in the high category compared to the control class. In this indicator, students were trained to present observation data, answer questions, and explain their findings both orally and in writing by drawing logical conclusions based on evidence (Kar et al., 2025; Masloman et al., 2023; Masruhah et al., 2022).

The role of SPS in science learning

Science Process Skills (SPS) have an important role in science learning because they help students not only understand concepts, but also experience firsthand the process of how knowledge is obtained (Khairunnisa et al., 2020; Pacala, 2025). Through SPS, students are trained to acquire, develop, and apply scientific concepts, principles, laws, and theories in the form of mental, physical, and social abilities through the perspective of scientists (Putri & Novita, 2024).

SPS indicators by observing, classifying, interpreting data, formulating hypotheses, and communicating findings (Gizaw & Sota, 2023; Gültekin & Altun, 2022; Surya, 2020). This makes science learning more meaningful, active, and student-centered. In addition, the implementation of SPS encourages the development of critical thinking skills, curiosity, and scientific attitudes needed in dealing with problems in daily life (Angelia et al., 2022).

The role of student worksheets in science learning

Student worksheets can be a means to direct, facilitate, and increase student involvement in the science learning process (Nelson & Tarigan, 2022). The structure of the student worksheet contains conceptual knowledge, scientific steps, and students' active activities to master the required competencies (Bare & Sari, 2021; Fajarianingtyas & Hidayat, 2022; Murtalib et al., 2022; Utami & Aryani, 2024). So that the content can be arranged in the form of pages or sections that can provide step-by-step guidance, helping students understand theoretical concepts, practical experiments, and science process thinking activities (Indayati, 2020; Khairuna, 2023; Rizky et al., 2025) . Student worksheets based on local potential are presented in Figure 4.

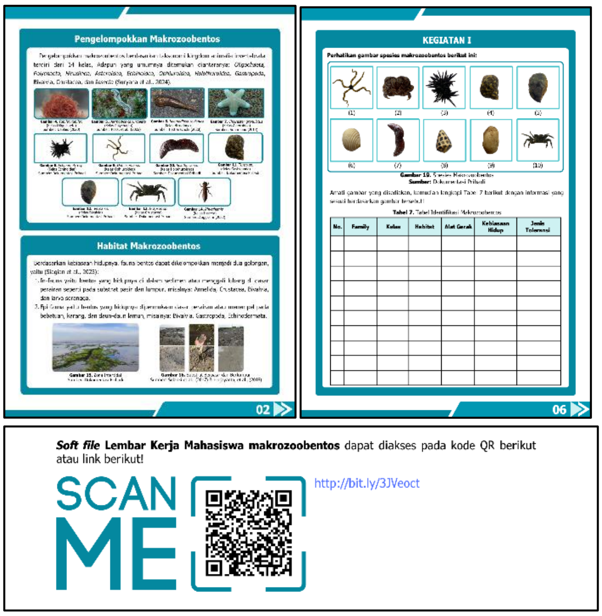

Figure 4. SPS-based stude nt worksheet design based on local potential inventory.

In addition, student worksheets were developed based on the results of local biodiversity inventories and based on science process skills integrated into student activities. The use of local materials in the environment around students will have the potential to develop students' creativity and awareness of the environment (Nelson & Tarigan, 2022).

The above description shows that student worksheets can improve science process skills by facilitating active and exploratory learning, especially for students in Biology education. Local potential-based worksheets are an important strategy for increasing the relevance of teaching materials and creating a meaningful, contextual learning experience for students (Wilujeng et al., 2024). The limitations of this research do not include other ecological materials, such as materials for analysing plankton community structure; the student worksheets used are still in printed form, and this research only emphasises improving science process skills.

CONCLUSION

This study concluded that using macrozoobenthos students' worksheets based on the inventory of local potential can increase student SPS in the experimental class, with the highest indicator in planning the experiment and the lowest in communicating.

For further research, it is recommended that the scope of materials available to develop student worksheets based on local biodiversity can be expanded. student worksheets can be integrated electronically to facilitate access, and research should expand into other thinking skills.

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