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Analysis of Science Process Skills in the Guided Inquiry Learning Model of Biotechnology Materials

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ABSTRACT

Scientific Process Skills (SPS) are essential competencies for students to face 21st-century challenges. However, learning processes in schools often overlook the development of these skills. One learning model considered effective in enhancing SPS is the Guided Inquiry model. This study aims to identify the profile of students' SPS through the Guided Inquiry learning model on biotechnology material and to determine differences in SPS between students who experience Guided Inquiry learning and those who receive conventional instruction. The research was conducted in 2024 at a senior high school in Depok using a quasi-experimental method with a posttest-only control group design. The sample consisted of two-phase E classes selected through simple random sampling, each assigned as the control and experimental groups. Data collection used both test and non-test instruments: a posttest to assess SPS outcomes and an observation sheet to monitor SPS during learning. The results show that students' SPS in the Guided Inquiry model vary across indicators, with the highest average score in communication (87.61%) and the lowest in prediction (49.52%). Independent Samples T-Test analysis revealed a significance value of 0.000 (< 0.05), indicating a statistically significant difference in SPS between the experimental and control groups. These findings suggest the Guided Inquiry model effectively enhances students' scientific process skills in biotechnology learning.

Keywords: Guided Inquiry, Science Process Skills, Biotechnology

Introduction

Educational changes in Indonesia aim to direct students' skills and activities, such as studying and practicing. In addition, student activity is also considered, namely, how involved and enthusiastic they are in participating in learning. The most significant change is in the curriculum goals, namely the goals of the educational program, where the educational experience that was previously focused on educators (*Teacher-centered*) is transformed into student-focused learning (*Student-centered*), with a learning plan or design that provides quality student growth opportunities (Permendikbudristek, 2022). Education plays an important role in the development and upskilling of the 21st century. In order to be able to answer the challenges of the 21st century, developing individual skills is considered very important (Apriliani et al., 2022). 21st century skills are referred to as the 4Cs, including: 1. *Collaboration*, namely the ability to collaborate; *Communication*, namely the ability to communicate; *Creativity and Innovation* namely the ability to create and innovate; and *Critical Thinking and Problem Solving*, namely the ability to think critically and solve problems (Andriyatno et al., 2023; Zulfiani et al., 2023). Mastering the 21st *Century Skill* is very important because the 4Cs are *soft skills* that are much more needed and sought after than *hard skills* (Makhrus et al., 2018). To meet the demands of the 21st century, it is important to equip students with abilities and skills to be utilized in life when participating in society, nation, and state (Elvanuari et al., 2024). One of the expected skills is science process skills.

Scientific process skills are the capacity of individuals to utilize thoughts, thoughts, and activities earnestly and productively to achieve a particular result (Gürses et al., 2015). Looking at the current era that continues to experience development every day, it is necessary to instill skills in students, one of which can be achieved through learning that focuses on Scientific Process Skills (SPS). This is because SPS is a mandatory and fundamental ability possessed by students in the era of globalization, which will provide convenience and readiness for students to face competition between humans in the present and future (Darmaji et al., 2020).

Although Scientific Process Skills (SPS) are important in 21st-century learning, research shows that students still have low skill levels, especially in biology, where memorization is more dominant than practice and problem-solving. Implementing Kurikulum Merdeka (The Independent Curriculum) that emphasizes scientific skills has also been ineffective due to the lack of integration of inquiry-based learning methods. Previous research has shown that guided inquiry models can improve the skills of science processes, scientific communication, and learning outcomes (Fitriyani et al., 2017; Pramesti et al., 2020), but their implementation in biology learning is still limited, especially in the era of Kurikulum Merdeka (The Independent Curriculum).

Scientific process skills are needed in 21st-century learning because they can support students in developing their research skills and their investigation or analysis skills (Darmaji et al., 2020; Puspa et al., 2024). Especially in biology learning, a discipline that is thick with scientific matters, the characteristics of biology learning are not only memorization and memorization of theories and formulas, but also accompanied by a practicum in which various problems must be solved by students (Ika, 2018).

Biology is a field of science that studies various processes, from solving problems to concluding results. This process reflects a skill known as Scientific Process Skills (SPS). However, the problem that occurs with students is still low Scientific process skills. One of the causes is the lack of encouragement for students to solve their problems, and students are not directly involved in learning. Learning tends to be teacher-centered. In addition, Elvanisi (2018) stated that the lack of Scientific process skills among students today is one of the effects of teachers' lack of attention to students' SPS (Elvanisi et al., 2018).

The strategy for learning recovery in a specific period, where the emergence of Kurikulum Merdeka (The Independent Curriculum) is one of the efforts of public authorities or the government to overcome these problems. In the Kurikulum Merdeka, students are introduced to "Independent Learning." The recovery of the learning process is carried out through learning under the guidance of teachers, with the aim of helping students readjust themselves and avoid putting too much pressure on students regarding the demands of the new curriculum (Nugraha, 2022).

Every change in the curriculum certainly affects other aspects of education, so teachers need to continue to search, improve, and adjust so that everything can harmonize and achieve curriculum goals. Changes in the curriculum also affect changes in existing materials, one of which is the learning of Biology concepts of Biotechnology, which in the previous curriculum was taught in grade 12; now, in the Kurikulum Merdeka (The Independent Curriculum), it is taught in grade 10.

Biotechnology requires a lot of concentration and understanding because it is usually more relevant or applicable, conceptual, and abstract, especially conventional biotechnology, which takes longer to learn (Riani et al., 2015). So, there needs to be an appropriate model so that students can more easily master Biotechnology materials.

It is important to implement appropriate learning models so that students can easily understand and master the material and improve their scientific process skills (SPS). One of the models that can be applied is guided inquiry. Learning with an inquiry model provides a method to build a student's intelligent reasoning and reflective thinking cycle (Patimapat et al., 2019).

The guided inquiry model is a learning model in which each element has similarities with the elements of Scientific Process Skills (Suwardani et al., 2021). This is evidenced by the syntax of guided inquiry according to Trianto, which aligns with the syntax of Scientific Process Skills according to Harlen (1992) and Rustaman (2005). The syntax of guided inquiry includes raising problems, speculating, designing experiments, running experiments, processing information, and making conclusions (Faisal et al., 2020). Meanwhile, the indicators of Scientific Process Skills according to Harlen and Rustaman are observing, classifying, interpreting, predicting, asking, hypotheticating, designing experiments, using material tools, applying principles, and conveying them.

The guided inquiry model is one of the models that encourages students to learn through active or dynamic participation and understanding of concepts and principles (Pramesti et al., 2020). This type of inquiry is usually used for students who have no experience using inquiry methods. More guidance is given at first, and then it is gradually reduced (Budiyono & Hartini, 2016; Zulfiani, 2022).

The guided inquiry model helps students learn how to deal with problems independently and think critically. This model facilitates the development of students' Scientific Process Skills (SPS), encouraging them to engage in the learning process actively. Teachers generally ask students questions during learning so that they can continue to develop, which can move students' logical reasoning and stimulate their scientific thinking, ensuring that students' minds are always encouraged to keep thinking. The guided inquiry learning model has also proven to improve students' scientific process skills significantly (Faisal et al., 2020).

The results of initial interviews with students and Biology teachers at one of the senior high school in Depok in 2024 showed that although the school had adopted the Kurikulum Merdeka (that prioritizes skills, especially Scientific Process Skills (SPS), there were still obstacles in learning, such as the absence of laboratories for practicums and learning models that were less appropriate for biotechnology material. In addition, teachers have not measured students' SPS. This study is needed to analyze students' SPS in the guided inquiry learning model on biotechnology material.

Methods

The type of research used is experimental research. This research method uses a quasi-experimental design. The design used in this study is *a post-test-only control group design.* This design emphasizes the comparison of treatments between the control group and the experimental group. The experimental group was the class that was subjected to implementing the Guided Inquiry Learning Model, while the control group did not receive any such treatment. The stages/syntax of the Guided Inquiry Learning model implemented in this study were raising problems, speculating, designing experiments, running experiments, processing information, and making conclusions (Faisal et al., 2020).

The population of the group that is the focus of this study is students in Phase E of one of the senior high schools in Depok in 2024. This study employed a simple random sampling technique. Data were collected using both test-based and non-test-based methods. The test approach was implemented by administering a posttest, which was used to measure scientific process skills and was analyzed using IBM SPSS version 26—the posttest questions comprised 16 valid items from 25 items adjusted to the scientific process skill indicators. Table 1 presents the test instrument blueprint for assessing Scientific Process Skills.

Table 1. The test instrument blueprint for assessing Scientific Process Skills (according to Harlen (1992) and Rustaman (2005))

No.	Aspects of Scientific Process Skills	Question Item Number	Total Number of Items
1.	Observation	1.2	2
2.	Classification	3.4*.5	3
3.	Interpretation	6.7.8*.9*	4
4.	Prediction	10.11*	2
5.	Asking questions	12.13*	2
6.	Hypothesizing	14.15	2
7.	Planning experiments	16.17.18*.19*	4
8.	Using tools and materials	20*.21	2
9.	Applying concepts	22*.23	2
10.	Communicating	24.25	2
	Total	25	

*Invalid items

The posttest data is processed based on the assessment rubric that has been created. The rubric score is between 0 and 3. The results obtained from the calculation are used to determine the category of science process skills based on each aspect.

Table 2. Scale of Measurement of Scientific Process Skills Aspects Post-test Results (Arikunto, 2021)

No.	Score Interval	Category	Letter
1.	81-100%	Excellent	A
2.	61-80%	Good	B
3.	41-60%	Enough	C
4.	21-40%	Less	D
5.	0-20%	Very Less	E

The non-test approach is carried out through observation using the Observation Sheet. The data obtained through this approach were considered secondary data, serving to strengthen the primary data on students' Scientific Process Skills (SPS) gathered through tests. The observation sheet (Table 3) was developed based on aspects of Scientific Process Skills (SPS) as outlined by Harlen (1992) and Rustaman (2005), aligning with the same SPS components used to construct the test instrument. Observations were made on students during learning, including when students were carrying out practicums. Therefore, the observation of students' SPS was conducted at the group level. The observation sheet was given a checklist (√) mark in the ≤ column of 50% (if less than some students in the group did the Scientific Process Skills aspect) and ≥ 50% (if some or more or all students in the group did the Scientific Process Skills aspect) (Table 8).

Table 3. The rubrics of the Scientific Process Skills' Observation sheet

No.	SPS (Science Process Skills) Aspect	Observed Aspect
1	Observation	Observing, examining, or physically sensing conventional biotechnology products on display
2	Classification	Taking notes from observations of practicum products
		Identifying similarities and differences in the resulting practicum products
		Identifying characteristics of the resulting practicum products
		Comparing data obtained from the practicum results
3	Interpretation	Relating observations of conventional biotechnology practicum products to existing theories
		Drawing conclusions from the practicum activities
4	Prediction	Using observation results to predict possible outcomes
5	Questioning	Formulating questions related to what, why, and how
		Asking for explanations
6	Hypothesizing	Formulating hypotheses based on the problem statement
7	Designing Experiments	Selecting tools or materials to be used in the experiment
		Determining variables in the experiment of conventional biotechnology product creation
		Selecting targets to be measured, observed, and recorded in the experiment
8	Using Tools and Materials	Using predetermined tools/materials
9	Applying Concepts	Implementing conventional biotechnology concepts and discussing them
10	Communicating	Presenting information based on actual experiment data in the form of tables, graphs, images, or illustrations
		Communicating experimental results to others verbally or in writing
		Discussing experiment results

Results and Discussion

The research results on students' scientific process skills can be seen in the following description.

1. Results of the Scientific Process Skills (SPS) test for students

Table 4. Description of Posttest Results: Data from the Experimental Class and the Control Class

Data Concentration and Dissemination	*Posttest*	
	Experimental Classes	Control Classes
Maximum Value	89.58	79.16
Minimum Value	45.83	39.58
Mean	72.41	60.59
Median	72.91	62.50
Mood	79.16	39.58
Variant	118.30	150.97
Standard Deviation	10.87	12.28

Data Concentration and Dissemination	*Posttest*	
	Experimental Classes	**Control Classes**
Range	43.75	39.58

Table 4 shows that the results of the posttest of the experimental class obtained a maximum score greater than that of the control class, as well as the minimum value. The average posttest score in the control class was lower than in the experimental class. Mean and Mode also showed that the experimental class had higher values than the control class. The standard deviation of the experimental class is lower than that of the control class, which means that the student score data obtained by students in the experimental class tends to be closer to the average score, so the experimental class has a lower variance as well.

The normality test was conducted to assess normality in samples from a normally or abnormally distributed population using the Shapiro-Wilk test.

Table 5. Normality Test Results

Shapiro-Wilk Statistics	*Posttest*	
	Experimental Classes	**Control Classes**
Sig	0,.165	0.098
a	0.05	0.05
Information	0.165 > 0.05	0.098 > 0.05
Decision	Normal	Normal

Table 5 shows the results of the Normality Test in the experimental and control classes of the Sig value. > 0.05, the population data is usually distributed. The homogeneity test aims to determine whether the data used is homogeneous or not. In this case, the researcher conducted a homogeneity test using the *Levene* test. The results of the homogeneity test can be seen in Table 6.

Table 6. Homogeneity Test Results

Levene Statistic	***Post-test***
Sig	0.280
a	0.05
Information	0.280 > 0.05
Decision	Homogeneous

Table 6 shows that if the value of sig. 0.280 > 0.05, the data is declared homogeneous. The results of the prerequisite test were declared normal and homogeneous so that the parametric statistical test could be continued. The hypothesis test used in this study is the Independent Samples T-Test, which tests the average difference between two unrelated groups. Testing was conducted using IBM Statistics SPSS 26. The test results can be seen in Table 7.

Table 7. Independent Samples T Test Results

	Posttest (Independent Samples *T-Test*)
Sig. (2-tailed)	0.000
α	0.05
Decision	H1 accepted

Based on Table 7, the value of sig. 0.000 < 0.05 or the T value of calculation = 4.263 > T table = 1.995, then H1 is accepted, which means that there is a difference in the Scientific Process Skills of students in the experimental and control classes. The experimental class is a class that is given guided inquiry model treatment, and the control class is the original class, according to the conditions that schools commonly carry out.

2. Student's Scientific Process Skills (SPS) Profile based on Posttest

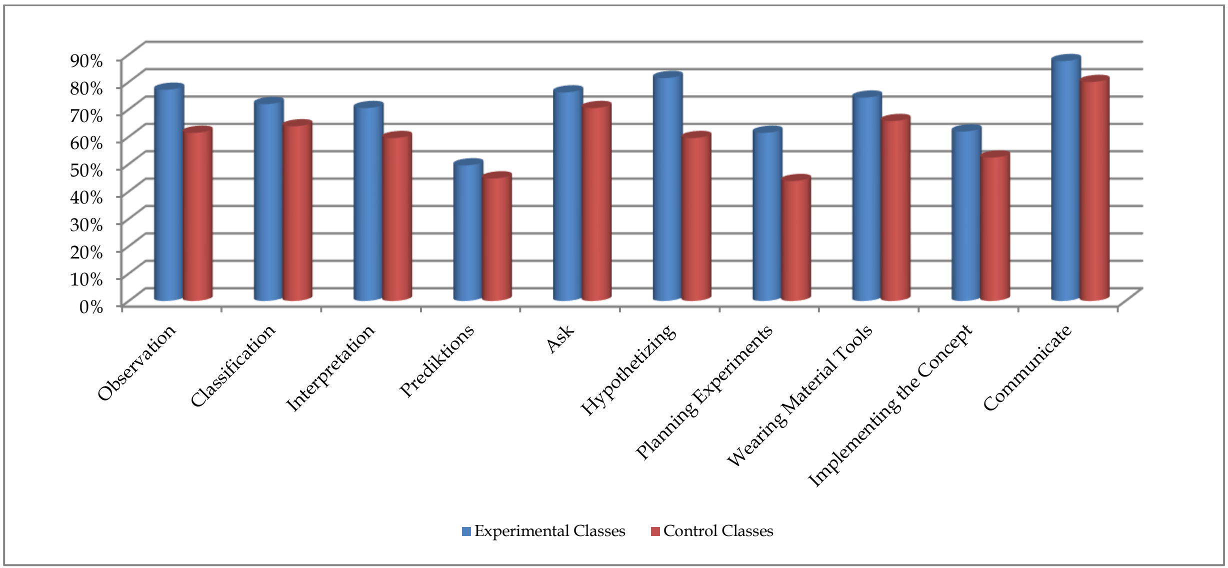

Figure 1. Percentage of Students' Scientific Process Skills (SPS) based on Posttest

Figure 1 shows that the average percentage of Scientific Process Skills in the experimental class is in the good category, 75.53%, and the average percentage of Scientific Process Skills in the control class is in the fair category, 60.13%. The highest aspect of Scientific Process Skills in the experimental and control classes is the same: communicating with percentages of 87.61% and 79.99%. The lowest aspect in the experimental class is the prediction aspect, with a percentage value of 49.52%; the lowest aspect in the control class is the aspect of designing experiments, with a percentage value of 43.80%.

3. Results of Analysis of Students' Scientific Process Skills (SPS) based on Observation Sheets

Observations were made on students during learning, including when students were carrying out practicums. Therefore, the students' SPS was observed at the group level. There are seven student groups: Group 1, Group 2, Group 3, Group 4, Group 5, Group 6, and Group 7. Table 8 presents the results of the SPS observations for each student group in the experimental class (with the Guided Inquiry Model).

Table 8. Results of Student SPS Observation with Guided Inquiry Model

Aspects	Feasibility													
	Group 1		Group 2		Group 3		Group 4		Group 5		Group 6		Group 7	
	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %	<50 %	>50 %
1a		√		√		√	√			√		√		√
2a		√		√		√		√	√		√			√
2b		√		√	√		√		√			√		√
2c		√		√		√		√		√		√	√	
2d		√		√		√		√		√		√	√	
3a		√	√		√			√	√			√		√
3b		√		√		√		√		√		√		√
4a		√		√	√		√		√		√		√	
5a		√		√		√		√		√		√		√
5b	√		√			√	√			√		√		√
6a		√		√		√		√		√		√		√
7a		√	√			√		√		√		√	√	
7b	√			√		√		√	√		√			√
7c	√			√	√			√		√		√	√	
8a		√		√		√		√		√		√		√
9a		√		√		√	√		√			√	√	
10a		√		√		√		√		√		√		√
10b		√		√		√		√		√		√		√
10c	√			√	√			√	√		√		√	

Aspect Code:

Observation

1a See, notice, or touch conventional biotechnology products displayed

Classification

2a Make notes from the results of observations of practicum products made
2b Finding similarities & differences in the resulting practicum products
2c Demonstrate the characteristics of the manufactured practicum products
2d Comparing data obtained from the practicum results

Interpretation

3a Linking the results of observations of biotechnology practicum products made with existing theories
3b Draw conclusions from the results of the activity

Predictions

4a Utilizing the results of observations to determine the likelihood of occurrence

Ask

5a Formulate questions related to what, why, and how
5b Ask for an explanation

Hypothetizing

6a Develop a hypothesis based on the formulation of the existing problem

Planning Experiments
7a Choosing tools or materials to be used in the experiment
7b Determining variables in experiments to make conventional biotechnology products
7c Choosing a target to measure, observe, and record in an experiment
Wearing Material Tools
8a Use specified tools or materials
Implementing the Concept
9a Implementing conventional biotechnology concepts and discussing them
Communicate
10a Display information based on real data from experiments in a table, graph, image, or illustration format
10b Communicating the results of the experiment to others, either orally or in writing
10c Discuss/discuss results

Table 8 shows variation in the scientific process skills that emerged from each group when learning using the guided inquiry model. Only few aspects and sub-aspects can appear in the whole group, namely; The interpretation aspect of the sub-aspect concludes the results of the activity; The element of asking sub-aspects formulates questions related to what, why, and how; Aspect of using material tools; The aspect of communicating sub-aspects (a) displaying information based on real data from experiments in the format of tables, graphs, images, or illustrations, and (b) conveying the results of experiments to others either orally or in writing.

The data analysis (Figure 1) showed that all aspects of scientific process skills in the experimental class were higher than those in the control class. This indicates that guided inquiry can provide a better understanding for students and enhance their scientific process skills. By implementing inquiry-based learning, which aligns with the SPS syntax, students are trained to apply their skills directly during the learning process. This finding is consistent with research showing that classes using the guided inquiry model help students better understand learning concepts, leading to higher final learning outcomes (Lovisia, 2018). Similarly, research by Mutrovina & Syarief (2015) found that students who were taught using the guided inquiry model improved scientific process skills and learning outcomes.

The research results also indicate that scientific process skills in the experimental class were higher than in the control class, as inquiry-based learning provides more opportunities for students to develop their skills during the learning process. According to Novitasari et al., (2017), guided inquiry is a constructivist learning approach that allows students to form knowledge through active participation, guided by the teacher's instructions in the form of statements, worksheets, or modules. This is also supported by the observation results presented in Table 8. In section 5a, students formulated investigative questions, and in section 6a, they developed hypotheses. Activities 5a and 6a represent constructive actions in which students actively build understanding of the concepts being studied.

Additionally, a study by Siahaan et al. (2021) found that students who used guided inquiry demonstrated better scientific process skills than those taught using conventional learning models, as the syntax of guided inquiry closely aligns with the syntax of scientific process skills. The stage of raising problems in the guided inquiry learning model covered questioning in scientific process skills. To enable students to raise questions, the steps implemented involved the aspects of Observation, Classification, and Interpretation within the framework of Scientific Process Skills. In the following stage of the Guided Inquiry Learning model, students make speculations, which align with and fulfill the hypothesizing aspect of Scientific Process Skills. Subsequently, the stages of designing experiments, running experiments, processing information, and drawing conclusions within the Guided Inquiry Learning model facilitate the development of Scientific Process Skills, particularly in designing experiments, using tools and materials, and applying concepts.

This proves that by applying the guided inquiry model, students can be effectively guided to explore their knowledge, develop individual problem-solving abilities, and ultimately become independent, dynamic, active, and competent individuals based on the information and insights they have (Amijaya et al., 2018). Inquiry-based learning allows students to understand better what they are learning, leading to long-term retention of the knowledge they acquire (Van Hoe et al., 2024).

The posttest data, which represents the outcome of the learning process, indicates that the highest aspect in the experimental class is the aspect of communication (Figure 1). Communication, a component of scientific process skills, refers to the ability to convey research findings to others in various forms, such as in writing (e.g., pictures, graphs, tables) or orally (Senisum, 2021). This finding is supported by observations made during the learning process (Table 8), where students in each group could present their experimental results in front of the class by displaying tables and images of the products they created. Each group member actively participated by stepping forward to explain the experimental results presented in the tables. Therefore, it is unsurprising that the communication aspect shows the highest percentage. This is further supported by research conducted by Riska Fitriyani, Sri H., and Eko B.S. (2017), which found that the communication indicator achieved a score of 3.43 out of 5, indicating that communication skills in the inquiry-based approach are developed progressively throughout the learning process, from writing reports to presenting research findings. Similarly, inquiry-based learning has effectively enhanced students' communication skills (Rizki et al., 2021).

The prediction aspect is the lowest profile of scientific process skills, with a percentage of 49.52% based on the posttest results (Figure 1). This low achievement in the prediction aspect is consistent with the observation results, which indicate poor performance in this area (Table 8). Only two of the seven groups demonstrated complete performance in the prediction aspect. Similar findings were reported in the research by Mumtaza & Zulfiani (2023), which showed that students' achievement in the observation and prediction aspects was still lacking, based on the analysis of student worksheets. When making predictions, students have difficulties understanding and are less careful in analyzing the cases provided. Predicting is an important skill for students to anticipate or infer what will happen in the future based on predictions of trends, patterns, or specific information (Ningsih et al., 2020).

Conclusion

It can be concluded that the students' scientific process skills profile through the guided inquiry model on the concept of biotechnology shows a range of variations, namely adequate, good, and very good. The highest aspect is communication, with a posttest result of 87.61%, supported by observations of student activities in class during presentations. The lowest aspect is prediction, with a posttest result of 49.52%, supported by observations of student activities in class when making predictions.

There was a significant difference in scientific process skills between the experimental and control classes, as evidenced by the Independent Samples T-Test hypothesis test results.

The results showed a significance value of 0.000 < 0.05 and a T-count of 4.263 > T-table of 1.995, thus H1 is accepted.

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