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The effect of applying inquiry-based practicum method toward science process skills on topic related to pollen characteristics and embryogenesis stages of *Capsella* sp.

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Abstract

Science process skills can be improved through direct experience in an inquiry-based practicum. In general, science process skills can include some activities, like observing, comparing, predicting, classifying, measuring, using tools, communicating, and interpreting data. This study aims to determine the effect of implementing a structured inquiry-based practicum on the pollen characteristics and embryogenesis stages of *Capsella* sp. in improving science process skills possessed by students. The samples in this study were students who took the plant development course, for a total of 31 people. This type of research is qualitative and descriptive. The data collection technique uses a questionnaire in the form of a response questionnaire and student opinion toward the implementation of the practicum, as well as the results of the practicum reports. The results showed that the students' science process skills belonged to the Very High category based on the questionnaire data, and the completeness level reached about 100% in the evaluation of practicum reports with a class average value of 85.86 in six indicators. Based on the results of the questionnaire data and practicum reports, it was concluded that the structured inquiry-based practicum activity in the plant development course can affect students' science process skills positively.

Abstrak. *Keterampilan proses sains pada peserta didik dapat ditingkatkan melalui pengalaman langsung dalam kegiatan praktikum yang berbasis inkuiri. Keterampilan proses sains secara umum dapat meliputi aktivitas, seperti observasi, membandingkan, memprediksi, mengklasifikasikan, mengukur, menggunakan alat, mengomunikasikan serta menginterpretasi data. Penelitian ini bertujuan untuk mengetahui pengaruh dari pelaksanaan praktikum berbasis structured inquiry pada materi karakteristik polen dan tahapan embriogenesis dari Capsella sp. dalam meningkatkan keterampilan proses sains yang dimiliki oleh praktikan. Sampel dalam penelitian ini adalah mahasiswa yang mengambil mata kuliah perkembangan tumbuhan dengan total sebanyak 31 orang. Jenis penelitian ini adalah penelitian deskriptif kualitatif. Teknik pengumpulan data dilakukan dengan menggunakan kuesioner berupa angket respon dan tanggapan mahasiswa terhadap pelaksanaan praktikum, serta hasil laporan praktikum. Hasil penelitian menunjukkan bahwa keterampilan proses sains praktikan secara keseluruhan tergolong dalam kategori Sangat Tinggi berdasarkan data kuesioner, serta tingkat ketuntasan mencapai 100% pada penilaian laporan hasil praktikum dengan nilai rata-rata kelas mencapai 85,86 pada enam indikator. Berdasarkan hasil data kuesioner dan laporan praktikum, dapat disimpulkan bahwa kegiatan praktikum berbasis structured inquiry pada mata kuliah perkembangan tumbuhan dapat memberikan pengaruh positif terhadap keterampilan proses sains dari peserta didik.*

A. Introduction

Student learning outcomes in higher education are determined by the input quality from the student's school of origin. Online learning and the transition from online to offline learning experienced by first-year students are known to have an impact on learning outcomes in higher education. According to research by Ma et al. (2021), during the learning process in the COVID-19 pandemic era, 32.94% of students experienced post-traumatic stress disorder due to the epidemic. The majority of students (60.82%) felt that online education was not (10.76%) or less effective (50.06%) in terms of gaining knowledge and improving practical and communication skills. About 74.2% of final-year students said that the COVID-19 outbreak had a negative impact on their preparation for college entrance exams. It can be seen from the results of observation in the first-level course and is also in line with the research by Lestari (2023), which states that students' science process skills are in the low category after two years of implementing distance learning (PJJ) due to the pandemic.

Online learning (distance learning), implemented during the pandemic, has been proven to hinder students' understanding of the material being taught. Activities such as discussions or activities that involve direct participation, such as activities in the laboratory, are very limited, so this has an impact on reducing students' science process skills (Efriana, 2021; Husniyyah & Erman, 2022). According to Susanti et al. (2018), aspects of science process skills in prospective teacher students for the 2017–2018 academic year before the COVID-19 pandemic reached 72%, including the observation skill and the ability to communicate, classify, and predict.

Science process skills can include activities such as observing, comparing, predicting, classifying, measuring, using tools, communicating, and interpreting data (Lind, 1995; Widodo et al., 2010). According to Han (2013), process skills are known to be part of the cognitive domain (Hasanah & Shimizu, 2020). Research conducted by Rofiqoh & Martuti (2015) regarding the influence of practicum activities on science process skills and biology learning outcomes was carried out through a series of mushroom observation and tempeh-making experiments. Work experience in the laboratory has been proven to have a direct influence on intellectual abilities such as logical thinking and scientific process skills, which in turn will have a direct impact on avoiding errors in understanding concepts (Ismail & Jusoh 2002).

One learning model that applies the practicum method is inquiry-based learning (Widiana et al., 2019). Inquiry is often associated with investigative or experimental activities that involve the direct participation of students. Inquiry-based learning also allows students to build knowledge through the learning process. The main activities carried out in inquiry include identifying problems, making hypotheses, collecting and analyzing data, and drawing conclusions. Inquiry activities in the laboratory are known to also involve these stages in addition to making results reports and communicating findings (Sarwi et al., 2016). One type of inquiry that is relatively simple and easy to implement is a structured inquiry. The main characteristic of this inquiry is that the work procedures have been determined by the educator. It allows students to understand the stages of related procedures and improve their science process skills through direct (hands-on) experience (Banchi & Bell, 2008).

The research about the influence of implementing an inquiry-based practicum on biological topic such as pollen characteristics and embryogenesis stages of *Capsella* sp. toward scientific process skills has never been carried out before, so there is a need for an analytical study that specifically discusses this topic. In biology education, students really need basic skills in using laboratory equipment for certain purposes, such as observation and measurement (Widodo et al., 2019). Apart from that, the ability to understand and analyze information is also necessary to achieve certain learning goals.

The effectiveness of practicum activities in improving various skills and the quality of learning experiences might be influenced by the supporting facilities. The availability of adequate and well-functioning laboratory facilities and infrastructure is a very important aspect in determining the effectiveness of practicum implementation (Pareek, 2019). According to Okafor (2000), the availability of adequate laboratory facilities is also known to have a significant impact on students learning outcomes (academic performances). The absence of certain facilities or equipment, such as microscopes, may narrow the scope of knowledge that students can have and affect the application of the inquiry learning model (Pareek, 2019). One example of limited knowledge resulting from the absence of certain equipment, for example, is the limitation in analyzing the characteristics of certain objects caused by the absence of tools such as an electron microscope.

Based on these statements, research needs to be carried out regarding the effect of implementing a structured inquiry-based practicum on biological topic related to the pollen characteristics of several plants and the embryogenesis stages of *Capsella* sp. on improving science process skills based on questionnaire data and practicum results reports by biology education students.

B. Material and method

This research is a qualitative descriptive study that aims to determine the effect of carrying out a practicum in the plant development course on the science process skills possessed by students. The practicum activity carried out was the application of a structured inquiry-based learning model with the research subjects consisting of 31 students in the 4th semester of the 2021/2022 academic year who took the plant development course.

Instruments for collecting student SPS (science process skills) data consist of two types of instrument, such as questionnaires and report assessment rubric. There are two types of questionnaires used in this research. The first questionnaire given to measure student responses to practicum activity that developed SPS indicators. The first type of questionnaire is in the form of a closed questionnaire with a total of 10 questions answered using alternative answers that refer to the Likert scale.

The Likert scale is used to measure the attitudes and opinions of a person or group of people regarding an event (Riduwan, 2015). The Likert scale used in this research includes five alternative answer categories, namely Strongly Disagree (SD), Disagree (D), Fair (F), Agree (A), and Strongly Agree (SA). The response questionnaire data was processed using calculation in the form of percentage and then categorized based on the Riduwan (2015) classification table (Table 1). The questionnaire data validity test was carried out using SPSS at a significance level of α=0.05.

The second type of questionnaire is in the form of responses from students regarding the implementation of the structured inquiry practicum which includes eight indicators and filled in specific numerical quantities (percentage units), after that the average of each indicator will be determined and grouped into a specific category based on the classification of Arikunto (2002) (Table 2). Questionnaire data collection by students carried out after observing the characteristics of pollen from six different plant families and the embryogenesis stages in *Capsella* sp. A list of observed plant species from six families presented in Table 3.

Table 1 Interpretation criteria for response questionnaire data indicator

Value Range (%)	Criteria
≤ 80 — 100	Very High
≤ 60 — < 80	High
≤ 40 — < 60	Enough
≤ 20 — < 40	Low
0 — < 20	Very Low

Table 2 Interpretation criteria for student response indicator

Value Range	Criteria
80—100	Very Good
70—79	Good
60—69	Enough
< 59	Not Good

$$\% = \frac{n}{N} \times 100\% \text{..........................Formula 1}$$

Information:
% = Average percentage of respondents' answers (each indicator)
n = Total score obtained by respondents (each indicator)
N = Total expected score (maximal score each indicator)

The average percentage of student answer per question indicator calculated using the Formula 1. The report assessment rubric used to measure student SPS has six indicators (Table 4). The SPS indicators measured in this research include observation skills, tool usage, classification and measurement skills, and the ability to communicate and interpret data, adapted from Bahtiar & Dukomalamo (2019); Ongowo & Indoshi (2013). The data obtained from the practicum reports presented in a table (in average form) and interpreted.

Table 3 List of observed plant species

No.	Species Name	Family
1	*Ageratum conyzoides*	Asteraceae
2	*Tagetes tenuifolia*	
3	*Sphagneticola trilobata*	
4	*Mimosa Pudica*	Fabaceae
5	*Clitoria ternatea*	
6	*Leucaena leucocephala*	
7	*Allamanda cathartica*	Apocynaceae
8	*Plumeria acuminata*	
9	*Zephyranthes candida*	Amaryllidaceae
10	*Hymenocallis littoralis*	
11	*Allium victorialis*	
12	*Hibiscus rosa-sinensis*	Malvaceae
13	*Hibiscus schizopetalus*	
14	*Spathodea campanulata*	Bignoniaceae
15	*Tabebuia aurea*	

Table 4 Report assessment rubric for measuring science process skills

SPS Indicator	Source of Assessment
Observation	Based on the observation results presented in the report
Tool Usage	Based on the work steps and magnification of the microscope used to observe the sample
Classification	Grouping similarities and differences in pollen characteristics, especially from the same plant family
Measurement	From the pollen ratio (P/E) size data contained in the report
Data Communication	Based on the table of observation results presented in the report
Data Interpretation	Report discussion results, which include identification of pollen characteristics and embryogenesis stages in *Capsella* sp.

C. Results and discussion

The results of the response questionnaire data obtained show that there is a positive influence, which generally classified as Very High, from the implementation of practicum related to the pollen characteristics of several plants and the embryogenesis stages of *Capsella* sp. toward ten indicators contained in the response questionnaire list. The average percentage of the total response questionnaire results for all indicators is 82.5% and classified in the Very High category. The results of the response questionnaire data from the ten indicators presented in Table 5.

Interest indicators such as interest in participating in practicum and motivation in the practicum learning process through direct observation are known to show percentage values that are classified as Very High, around 85.2% and 83.8%. According to Safari (2003), indicators of interest can include feelings of enjoyment towards learning, interest in and focus on learning, as well as the desire from inside to be actively involved in learning activities. It is reinforced with statements by Yulaida (2015); Bayram et al. (2013), which state that inquiry-based practicum activity can increase students' motivation and learning outcomes. It is also known that practicum can provide a different atmosphere for studying science so that learning activities are not boring (Hofstein & Naaman, 2007). Besides indicators of interest in learning, other aspects such as independence can also be seen from the practicum's activity in providing plant samples belonging to certain plant families to be used in the practicum independently.

The indicator of student independence in providing plant samples for practical purposes is around 85.2% and classified in the Very High category. It is in accordance with the statement by Rofiqoh & Martuti (2015) that practicum activity requires active participation from students in realizing learning objectives.

Table 5 Student response questionnaire data on the science process skills indicator

No.	Indicator	Percentage	Category
1.	Interest in taking part in a practicum	85,2	Very High
2.	Improvement in certain skills (microscopic observation, microscope usage)	91,6	Very High
3.	Motivation in the practicum learning process through direct observation	83,8	Very High
4.	Ease of understanding topic related to *Capsella* embryonic development	81,9	Very High
5.	Improvement in the ability to identify and predict pollen characteristics in different plants	83,2	Very High
6.	Independence in providing materials or samples used in the practicum	85,2	Very High
7.	Ability to identify pollen diversity based on pollen characteristics (pollen shape, surface/exine type)	80,6	Very High
8.	Ability to measure pollen (determining the P/E ratio) with the help of a micrometer	71,6	High
9.	Ability to classify similarities and differences in pollen characteristics, especially pollen from the same family	75,5	High
10.	Improvement in cognitive ability (critical thinking) through preparing the observation result report	86,5	Very High

Table 6 Assessment of science process skills indicators based on practicum reports

SPS Indicator	Source of Assessment	Average Value
Observation	Based on the observation results presented in the report	85,8
Tool Usage	Based on the work steps and magnification of the microscope used to observe the sample	86,3
Classification	Grouping similarities and differences in pollen characteristics, especially from the same plant family	85,3
Measurement	From the pollen ratio (P/E) size data contained in the report	82
Data Communication	Based on the table of observation results presented in the report	86,8
Data Interpretation	Report discussion results, which include identification of pollen characteristics (pollen shape and exine type) and embryogenesis stages in *Capsella* sp.	89

Aspects of process skills, according to Rofiqoh & Martuti (2015); Wahyuni et al. (2017), which include various indicators such as observation, tool usage, analysis or identification, measurement, and classification, are also seen in this research. Aspects of the scientific process skills that can be seen from several indicators in this research include the ability to make observations in the form of microscopic observations; skills that include the use of laboratory equipment such as microscopes in practical work; the ability to identify and predict pollen characteristics in different plant types; the ability to identify pollen diversity based on certain characteristics such as shape and surface type; pollen measurement capability, which include determining the P/E ratio with the help of a micrometer instrument on a microscope; as well as the ability to classify and compare similarities and differences in pollen characteristics, especially pollen from the same family. Research related to the influence of practicum activity on science process skills in vocational program students was previously conducted by Wiwin & Kustijono (2018) using questionnaire data.

The indicator that includes the ability to make observation in the form of observing microscopic objects and skill in using laboratory equipment such as a light microscope is classified in the Very High category with a percentage value of 91.6%. This can also be seen from the average value of the practicum reports on the indicators of observation and tool usage, which are relatively high, around 85.8 and 86.3 (Table 6). In general, students are able to observe plant samples in the practicum, use a microscope, and then adjust the magnification according to the sample used.

Indicators of the ability to predict pollen characteristics in various different plant types (six plant families), as well as the ability to identify pollen diversity based on pollen shapes and surface types, are in the Very High category. The percentage values of these two indicators, respectively, are around 83.2% and 80.6%. In general, students have been able to identify pollen characteristics from around 15 plant species from six plant families based on characteristics such as pollen shape and surface/exine type. Obstacles in determining the pollen surface types might be caused by the limitations of the light microscope's capacity to provide a clear picture of pollen structure.

The surface type that is most clearly visible when observing with a light microscope is the echinate type, which is characterized by the presence of several spines on the pollen surface. The echinate surface type can be seen in the Asteraceae family, which includes *Ageratum conyzoides*, *Tagetes tenuifolia*, and *Sphagneticola trilobata*, as well as in the Malvaceae family, such as *Hibiscus rosa-sinensis* (Salamah et al., 2019; Umami et al., 2021). The characteristics of pollen in the Asteraceae and Malvaceae families, which are characterized by a circular (non-angular) pollen shape and an echinate surface type, also make those plant samples the easiest objects to analyze using only a light microscope.

The ability to classify similarities and differences in pollen characteristics possessed by students, especially pollen originating from the same plant family, is in the High category with a percentage of 75.5%. This is also reinforced by the average value of the practicum reports on the classification indicator, which reached a value of 85.3 and classified as a High category. These results show that carrying out practicum activity has a positive influence on students' ability to classify and compare similarities and differences found in pollen characteristics (shape and surface type), especially pollen from the same family. Members of plant species from the same family generally have some similarities in pollen characteristics, as seen in members of the Asteraceae and Malvaceae (see Figure 1).

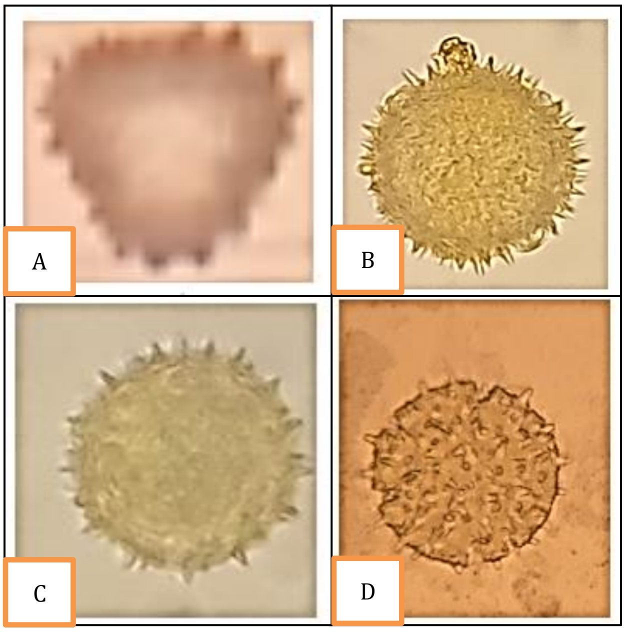

Figure 1
Pollen observation results on (A) *Ageratum conyzoides*, (B) *Tagetes tenuifolia*, (C) *Sphagneticola trilobata*, and (D) *Hibiscus rosa-sinensis*

Table 7 Pollen shape based on the P/E ratio according to Erdtman (1966)

Pollen Shape	P/E Ratio (x100)
Peroblate	<50
Oblate	50—75
Sub-oblate	75—88
Oblate-spheroidal	88—99
Spheroidal	100
Prolate-spheroidal	101—114
Sub-prolate	114—133
Prolate	133—200
Per-prolate	>200

Pollen measurement ability, such as determining the P/E ratio using a micrometer by students is classified into the High category with a percentage value of 71.6% and an average value on the measurement indicator of around 82 based on the report results. A list of pollen shapes based on the P/E ratio, according to Erdtman (1966) can be seen in Table 7. According to Ergűl et al. (2011), measurement ability is an important indicator of science process skills.

In general, the pollen shapes of most of the plant samples used in the practicum are classified as non-angular, except for *Clitoria ternatea* (Fabaceae), which is classified as angular (triangular). The difficulty encountered by students in determining pollen shape based on the P/E ratio is caused by inaccuracy in determining the length of the polar axis or equatorial diameter, resulting in errors in determining the P/E ratio and pollen shape. Cell or pollen measurement involving micrometer units (µm) is known to only use the aid of an ocular micrometer, so it is necessary to calibrate the objective micrometer against the ocular micrometer. Calibration activity must be carried out at each objective magnification that will be used (4X, 10X, 40X, or 100X). An example of pollen measurement using a micrometer can be seen in Figure 2.

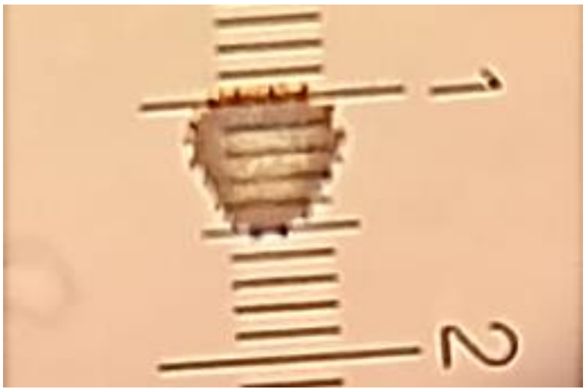

Figure 2
The example of pollen measurement using a micrometer

An improvement in understanding of the embryonic development topic in *Capsella* sp. and increasing cognitive abilities through preparing and making practicum results reports are known to be included in the cognitive aspect, which involves brain activity. These cognitive aspects include the ability to think, understand, and analyze the information obtained (Amizera, et al., 2022). The indicator of improvement in understanding topic related to embryogenesis stages in *Capsella* sp. through observation is classified into the Very High category with a percentage value of 81.9%. Overall, students have been able to identify the stages of embryogenesis in *Capsella* sp. through observation of the samples provided (see Figure 3). These results are in line with the statement, which states that practicum through direct experience can make students understand concepts better (Sormin, 2023) and can significantly improve learning outcomes (Hafizan et al., 2012).

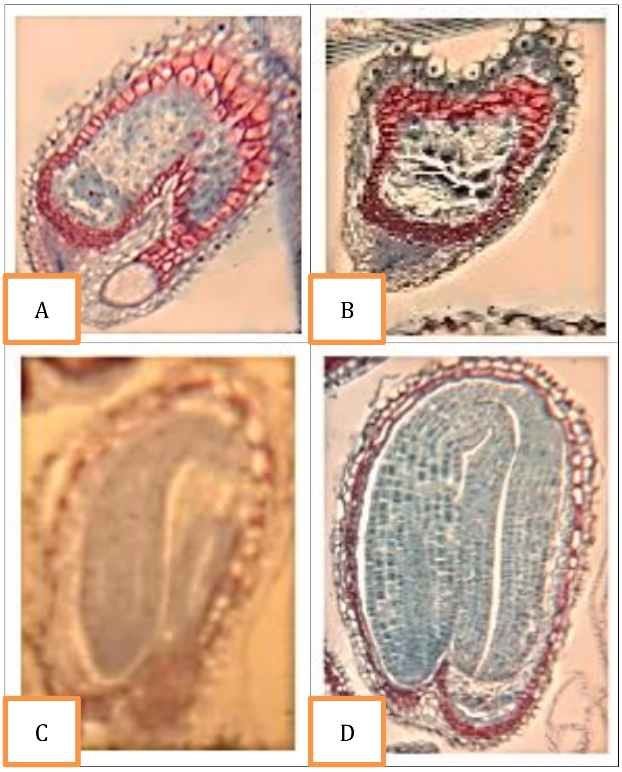

Figure 3
Observational results of the embryogenesis stages of *Capsella* sp., which include (A) Globular Stage, (B) Heart Stage, (C) Torpedo Stage, and (D) Mature Stage

In general, the stages of embryonic development in *Capsella* sp. can be divided into four stages, namely the globular stage, heart stage, torpedo stage, and adult/mature stage (Steeves & Sawhney, 2017). An indicator of increasing cognitive abilities possessed by students through preparing practicum reports is known to be in the Very High category (86.5%) based on response questionnaire data. It can also be seen from the average scores on communication and data interpretation indicators from practicum reports, which are also relatively high (86.8 and 89). These results show the great influence of preparing practicum reports on cognitive abilities, which require students to be able to think critically through combining or connecting various ideas, concepts, and procedures that have been studied, as well as the results and data which obtained, and then processing and analyzing this information in order to gain new knowledge or solve a problem (Al-Hashim, 2019; Nisa et al., 2018; Ozgelen, 2012). According to Pangastuti (2023); Hikmawati et al. (2020), writing a practicum report in inquiry-based learning is known to hone students' cognitive abilities.

Table 8 Student group report values in the practicum on pollen characteristics and embryogenesis of *Capsella* sp.

Class Average Value	Total Completion	
	Complete	Incomplete
85,86	31 (100%)	-

Practicum implementation generally went well and effectively. It can be seen from the average percentage of the total assessment of practicum responses to the eight practicum implementation indicators obtained, which is around 82.65% and classified into the Very Good category. Eight indicators used to determine the effectiveness of practicum implementation in supporting students' achievement of science process skills, include the effectiveness of practicum group division; provision of practicum materials; ease of finding practicum materials by students; ease of understanding and carrying out work procedures; smooth/seamless implementation of the practicum entirely; lecturer assistance during practicum; availability of tools that function properly; as well as the availability of adequate laboratory facilities and infrastructure (Table 9). Namira et al. (2020) have previously conducted research using student response data to examine variables that may impact practicum efficacy and seamless execution. It is well established that a number of factors contribute significantly to the success of the practicum, such as infrastructure and laboratory facilities availability, comprehension of practicum work procedures, and mentorship from educators.

Students are first divided into six groups, with each member numbering around five to six people, before carrying out the practicum. Each group was assigned to prepare plant samples from the same family, so that the total number of plant samples used consisted of six plant families. The difficulty encountered in providing practicum materials was probably caused by the fact that there is a group assigned to provide plant samples from plant families that are relatively rare in the environment around campus, such as plant species belonging to the Bignoniaceae family.

There are a few key performance indicators to be aware of during the practicum, including how smoothly students complete tasks and how well the lecturer mentors them. These two indicators are classified into the Very Good category with percentage values of 82.2% and 86.3%, respectively. Overall, students were able to understand and carry out the steps of work procedures well, starting from preparing the tools and materials needed, preparing a sample to be observed, using and adjusting the magnification of the microscopes, and carrying out measurement using a micrometer. It is also reinforced by the accuracy of the description of the procedural steps outlined in the practicum reports by students. The assistance provided by the lecturer during the practicum is also proven to be able to help students understand and carry out work procedures during the practicum.

Table 9 Student response data to indicators of practicum implementation effectiveness

No.	Observed Aspect	Percentage	Criteria
1.	Practicum group division	81,8	Very Good
2.	Provision of practicum materials by students	79,7	Good
3.	Ease of students finding practicum materials	76,9	Good
4.	Ease of students understanding and carrying out work procedures	82,2	Very Good
5.	Seamless execution of the practicum entirely	83,2	Very Good
6.	Mentoring by lecturers during practicum	86,3	Very Good
7.	Availability of tools that function properly	84,2	Very Good
8.	Availability of adequate laboratory facilities and infrastructure	86,7	Very Good

Indicators supporting the smooth and seamless implementation of practicum, such as the availability of well-functioning equipment and adequate laboratory facilities and infrastructure, are classified in the Very Good category with percentage values of 84.2% and 86.7%. Supporting facilities such as microscopes, laboratory facilities, and infrastructure are generally available and well-functioning. According to Parek (2019); Okafor (2000), the availability of adequate and well-functioning laboratory facilities and infrastructure is an important aspect in determining the smoothness and effectiveness of practicum implementation and has a positive impact on the learning outcomes (academic performances) of students. The overall practicum implementation, which went very well (83.2%), is known to be inseparable from the influence of various indicators. Indicators included in the planning (preparation) aspects or during the implementation of the practicum, as well as indicators supporting the implementation of the practicum, such as the availability of adequate facilities and infrastructure, also have a big influence on the smooth implementation of the practicum and the achievement of science process skills (Osman & Vebrianto, 2013).

Based on the research that has been carried out, it can be concluded that there is a positive influence from implementing structured inquiry-based practicum on the pollen characteristics and embryogenesis stages of *Capsella* sp. topic in improving practical science process skills, which are generally classified into the Very High category based on questionnaires data, as well as the assessment of practicum results reports, which reach a complete level of 100% with an average value around 85.86 (Table 8). It is in line with Balfakih's (2010) statement, which states that science process skills are intellectual skills that can be learned and developed through an effective learning process.

D. Conclusion

Overall, the practicum activity based on structured inquiry on the pollen characteristics and embryogenesis stages of *Capsella* sp., providing a positive influence on science process skills based on questionnaires data and practicum reports. Aspects of practical science process skills in general also classified in the Very High category supported by various supporting indicators for practicum implementation that influence the smoothness and effectiveness of practicum for 31 Biology education students (fourth term) in the 2021/2022 academic year who are taking plant development course.

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