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Enhancing integrated science process skills: Is it better to use open inquiry or guided inquiry model?

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ABSTRACT

This study aimed to examine the effectiveness of implementing a real object-based open inquiry model towards integrated science process skills of 10th- grade students in the material of plants (Plantae). This study used quasi-experimental research with nonequivalent control group pretest-posttest design. This study's population was all 10th- of Senior High School S of Yogyakarta, Indonesia, in the academic year grade students of 2018/2019. The technique sampling used in this study was random cluster sampling. The samples consisted of 30 students in the experimental class using the open inquiry model and 30 students in the control class using the guided inquiry model. The instrument used in this study was an essay test consisting of four questions that represent the aspects of science process skills. Analyze data use the independent-sample t-test. The results indicated a significant difference between the means of science process skills post-test of the 10th-grade students in the material of plants. The percentage of N-gain score in the experimental class categorized to low was 0%, categorized to moderate was 17%, and categorized to high was 83%. The most influential aspect of integrated science process skills in the experimental class is communication with 95,33. To sum up, the open inquiry learning model is useful in the 10th-grade students' integrated science process skills, particularly the aspect of communication in plants' material.

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INTRODUCTION

Learning Biology can help more engaging by observing biology objects as a real object Musyaddad & Suyanto, 2019: Djamahar, Ristanto, Sartono, & Darmawan, 2020). Students will obtain the learning experience directly so that the observed objects will help them learn the concept (Miharja, Hindun, & Fauzi, 2019; Noviyanti, Rusdi, & Ristanto, 2019). However, rapid advancement in technology brings an impact on education (Hidayati, Pangestuti, & Prayitno, 2018; Kalogiannakis & Papadakis, 2019). Several biology materials might be practical teach using technology such as the material related to objects that cannot be seen by the naked eyes (invisible). The examples of invisible objects are blood circulation, respiratory mechanism, cells, DNA, etc. If the students observe the objects which can be seen by naked eyes (visible) such as plants (Plantae), animals (Animalia), and other real objects, the students better observe the biology objects directly.

Students' active participation during the learning process determines their achievement in absorbing information and knowledge (Karsai & Kampis, 2010; Leasa, Sanabuky, Batlolona, & Enriquez, 2019). The materials' delivery is not teacher-oriented but based on students' active participation in the teaching and learning process (Holden, 2015). Further, the student's learning achievement is about knowledge mastery and skills in observing, analyzing, solving a problem, and making a task (Ambarsari, 2013). As a result, activities and products from students' learning can get assessed.

Science process skills are the tools needed in learning science and technology, such as problem-solving and students' development and in society, such as mental skill, physical skill, and competency skills (Inayah, Ristanto, Sigit, & Miarsyah, 2020; Akinboola & Afolabi, 2010). The students will experience in-depth learning in biology if they involve their intellectual or cognitive skills (minds-on), manual skills (hands-on), and social skills (heart on) (Rustaman, 2016). The integrated science process skills include identifying and defining a variable, collecting and modifying data, manipulating data, recording data, formulating a hypothesis, designing a problem, or conducting experiments (Karamustafaoğlu, 2011). Several skills in process skills consist of essential skills and integrated skills (Dimyati & Mudjiono, 2002).

A learning method that only leads students to memorize in verbal may cause them to recognize many scientific terms by rote. Besides, the students' scientific concepts and principles bring them to saturation to learn science by rote. These are inline with biology learning that has many scientific concepts and principles. Accordingly, the students are required to master the basic concept of the materials. The science process skills consisted of observing, classifying, measuring, concluding, predicting, and communicating the students who can conduct the research result. Particularly in science learning, the teaching and learning process only concerns memorizing the facts, principles, and theories (Trianto, 2014). Guritno (2015) stated that integrated science process skills are an advanced process from necessary science process skills to understand science. The students need to master necessary science process skills to improve their science process skills. Consequently, the students should have those two skills to achieve the science process skills. However, based on the information from a biology teacher at Senior High School S of Yogyakarta, Indonesia, students of 10th grade still depend on the teacher's instruction in the learning process using whatever the model used in the learning activity.

Each individual is suggested to have science process skills because according to Ambarsari (2013), science process skill is very applicable in daily life. The implementation is not only within the scope of a scientist but also in broader implementation. Everyone can design a concept, investigate a problem, determine an alternative solution, and conclude a problem. Therefore, the science process skill is needed for every student to provide life in the community. Ariani, Hamid, and Leny (2015); Handriani, Harjono, and Doyan (2016); Harahap, Manurung, Marbun, and Mihardi (2016) summarized that biology learning by implementing inquiry-based learning could improve students' science process skills and students' achievement at senior high school.

Science process skills are needed to develop and train to start from the school's learning process, integrated into subject learning. A suitable learning model to empower students' science process skills is the Llewellyn inquiry learning model (Akhiruddin, 2016). An inquiry is proper learning in developing four-aspects targeted by the government because this learning model is suitable for science learning characteristics. Each stage in the inquiry model, based on scientific work, will develop the students' attitude and skill. Inquiry learning involves the students in open issues, which are student-centered and involves the students in hands-on activities (Colburn, 2000). Several studies generally indicated that inquiry learning gives positive effects on the development of science process skills (Ergül et al., 2011; Şimşek & Kabapınar, 2010).

An inquiry is also defined as an investigation. Jacobsen (2009) stated that learning by investigation allows the students to learn the materials related to particular problems and problem-solving strategies in the future. Furthermore, if the inquiry learning process continues, the students can achieve meaningful learning results and achieve instructional objectives (Goode & Halbritter, 2019; Harahap, Ristanto, & Komala, 2020). Open inquiry more emphasizes students to work independently, starting from searching for a problem to solve it. In contrast, guided inquiry enables students to get fully helped and instructed by the teacher (Harahap et al., 2020; Adiqka, 2015). The successful implementation of the open inquiry learning model, according to Anders (2003), is that the students can easily describe what they have conducted during the investigation. The students can make mistakes in the learning process, but they can find the solutions independently by mistakes. Consequently, based on the statement earlier, the students are assumed to solve the problem they faced in the problem or different learning material the next day.

METHODS

Research Design

The type of this study was a quasi-experimental research with nonequivalent control group pretest-posttest design. The structure of the research design in this study can be seen in the following Table 1.

Table 1

Experimental Research Structure Design

Group	Pretest	Treatment (x)	Postest (O)
Experiment	O_1	XA	O_2
Control	O_3	XB	O_4

Description:

XA : Open Inquiry

XB : Guided Inquiry

O_1 : Pretest experiment

O_3 : Pretest control

O_2 : Postest experiment

O_4 : Postest control

Population and Samples

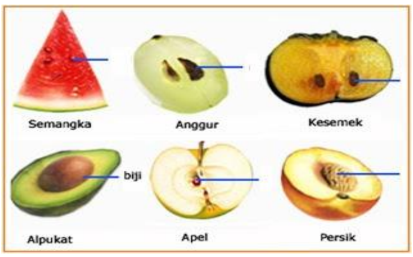
This study's population were all 10th- grade students of Senior High School S of Yogyakarta, Indonesia, that the school has six classes in the academic year of 2018/2019. This study's sampling technique was random cluster sampling, and both of the sample classes are assumed homogenous. The two classes had 30 students for each class. The first class was chosen as an experimental class implementing an open inquiry model based on the real object. The second class was chosen as a control class, implementing a guided inquiry model based on the real object.

Instrument

The instrument for collecting the data was an essay test examining students' integrated science process skills. The instrument of integrated science process skill consisted of four questions. Each question represents one aspect of integrated science process skills. The aspects of integrated science process skills are planning experiments, experimenting, analyzing, and communicating. The instrument test consisted of pretest and post-test. The pretest was conducted to know the students' initial knowledge before they got treatment, while the post-test was conducted to know the students' skills after they got treatment. The instrument has been doing with validity and reliability test. The validity of this instrumented test was obtained by measuring the sensitivity index of the items. The result of measuring the items' sensitivity index was that the mean score of the sensitivity index of the items at the experimental class was 0,65, categorized as good. In contrast, in the control class, the mean score was 0,493, categorized as low. The item test, which has a sensitivity index of 1,0, will not be answered by the students who have not studied yet. However, they who have studied can do the test well. It can be concluded that the students in the experimental class were better in answering the item test compared to the students in the control class. The instrument's reliability test was that the r-value was 0,707147 (r > 0,60). In other words, the items were considered consistent, so that the items of the test distributed to the students have sufficient reliability. Based on the kappa index, the value of 0,37 was categorized as fair. The questions distributed to the students have met the reliability requirements. The indicators of integrated science process skills are presented in Table 2.

Table 2

Indicators of Integrated Science Process Skills Test

Aspects	Indicator Questions	Item Test
Planed experiment	Students can plan an investigation of a particular plant in order to classify it in the divisio of certain seed plants.	All of these fruits have seeds in them. What is the observation procedure to classify the fruits? 
Experimenting	Students can carry out investigation procedures in the classification of fern divisio.	
Analysis	Students can analyze the data on the results of different leaves in the nail plants based on their function.	The following is a photo of observations of ferns that have known the types of leaves. Make an analysis related to these two leaves!

		
Communication	students can communicate the conclusions of observations of sporangium morphology of ferns.	

Procedure

This study consisted of three stages, namely (1) measuring before the experiment by giving the same pretest to both experimental groups to know the initial condition which is related to the dependent variable, (2) experimenting that giving a treatment by implementing open inquiry learning model in the experimental class and guided inquiry learning model in the control class, and (3) measuring after experimenting, that giving a post-test regarding the material and giving same question weights to experimental class and control class. These aimed to see the students' different scores before and after implementing a real object-based open and guided inquiry learning model.

Data Analysis Techniques

The analysis of inferential statistics was carried out using an independent sample t-test. The test was used to know the difference between the experimental and control classes in this study. Then, the N-gain score was also used to improve students' integrated science process skills in the learning process. The test data in this study used SPSS software version 20. This study's normality test used the Kolmogorov-Smirnov test assisted using SPSS software version 20, presented in Table 3.

Table 3

Normality Test Results of integrated science process skills

Unit of Analysis	Class	Sig.	Significance Level	Description
ISPS	Open Inquiry	0,052	P > 0,05	Normal distribution
	Guided Inquiry	0,052	P > 0,05	Normal distribution

The normality test results in Table 3 indicated that the data of integrated science process skills both in the class of open inquiry and guided inquiry were considered normal. The homogeneity test in this study used the Levene test assisted with SPSS software version 20. The result of the homogeneity test on the integrated science process skills is presented in Table 4.

Table 4

Homogeneity Test Results of Integrated Science Process Skills

Unit of Analysis	Class	Sig.	Description
ISPS	Open Inquiry	0,131	Homogeneous
	Guided Inquiry	0,061	Homogeneous

The scores of significance are higher than the scores of probability that is 0,05. It indicated that the data of integrated science process skills both in the class of open inquiry and guided inquiry have the same variance or were considered homogenous.

RESULT AND DISCUSSION

The result data of measuring students' integrated science process skills were analyzed in descriptive analysis using SPSS software version 20, presented in Table 5.

Table 5
The value of pre-test and post-test integrated science process skills Students Experimental and Control Group

Analysis Unit	Class	Varians			
		Mean	Maksimum	Minimum	STDEV
Pretest ISPS	Open Inquiry	21.5000	30.00	5.00	4.76156
	Guided Inquiry	31.6667	45.00	15.00	10.93345
Postest ISPS	Open Inquiry	83.0557	90.00	75.00	4.28978
	Guided Inquiry	67.8333	80.00	55.00	6.78275

As seen from the difference in integrated science process skills, the score was high (15.22). The absolute difference obtained from the integrated science process skills was very high. Implementing open inquiry and guided inquiry learning influences the final result of integrated science process skills.

An independent sample t-test was conducted because the normality and homogeneity test results have met the parametric test requirements. This test was carried out to see the independent variable (open inquiry and guided inquiry) on the dependent variable (integrated science process skills). The results of the independent sample t-test in this study can be seen in Table 6 below.

Table 6
The results of independent sample t-test on integrated science process skills

	Equal variances assumed	F	Sig.	t	df	Sig. (2-tailed)
Postest_ISPS	Levene's Test for Equality of Variances	1.174	.283			
	t-test for Equality of Means			-8.986	58	.000

Based on Table 6, the significance value (2-tailed) is 0,000 < 0.05. There is a significant difference between the post-test scores of students' integrated science process skills in the experimental and control classes. The N-gain score also supported the result of the independent sample t-test. The result of the N-gain score is presented in Table 7.

Table 7
Results of N-Gain Score of Integrated Science Process Skills in Experiment and Control Group

Class	Average value		Enhancement	N-Gain Score	Category
	Pretest	Posttest			
)pen Inquiry	21,50	82,67	61,17	0,78	High
;uided Inquiry	31,67	67,83	36,17	0,52	Moderate

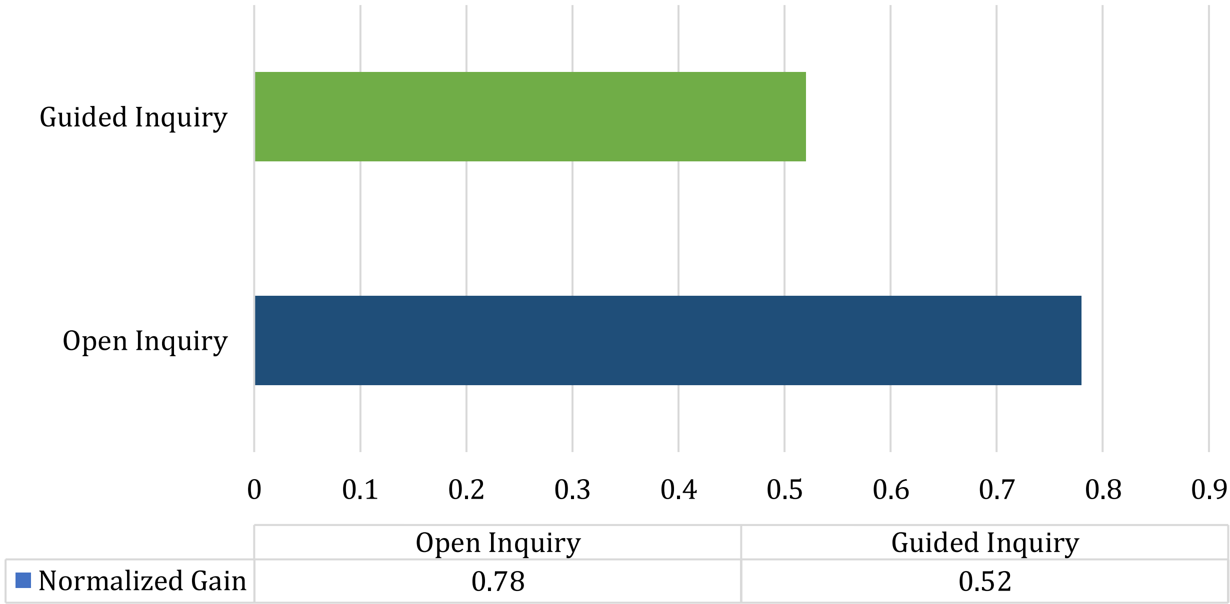
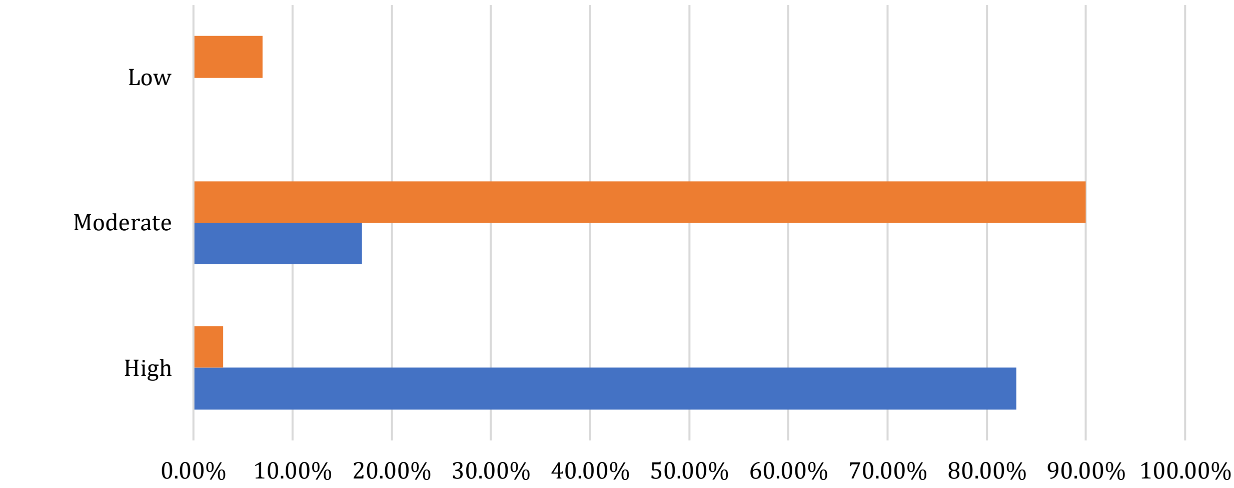


Figure 1. Graphic Comparison of N Value - Gain Score for Integrated Science Process Skills in Experiment Class and Contorl Class

Based on the N-gain score in Table 7 and Figure 1, the N-gain score of open inquiry class was 0,78 and categorized as high, while the N-gain score of guided inquiry class was 0,52, categorized as moderate. The results supported the independent sample t-test result, and it can be concluded that the open inquiry learning model has influenced the most on the integrated science process skills. The percentages of each category can be seen in Figure 2.

Figure 2 showed that the percentage of N-gain score in the open inquiry class was 83% (high category) and in the class of guided inquiry was 3% (high category). The moderate category in the guided inquiry class is considered higher (90%), whereas the open inquiry class's moderate category is only 17%. However, in the low category, the experimental class was not included in that category (0%), while the guided inquiry was included in the low category (7%). These percentages indicated that open inquiry class could improve the students' integrated science process skills rather than guided inquiry class.

The results in this study are supported by Zion (2008) that the open inquiry learning model is better than the guided and structure inquiry model. Open inquiry can help students deepen their understanding of what they investigate. The mastery of students' process skills is more important than learning science products (Nworgu & Otum, 2013). Science process skills have benefits. For example, the students can realize to participate in the inquiry. Besides, science process skills cannot be separated in the practice of conceptual understanding in learning and science implementation (Karamustafaoğlu, 2010). When the students do an investigation, they can apply the different skills of investigation, such as asking, formulating a hypothesis, planning the experiment to test the hypothesis, accessing and analyzing data, interpreting data, reporting and writing the experiment report (Osman, Hiong, & Vebrianto, 2013). The improvement of students' learning experience is an investigation in the learning (Vartak, Ronad, & Ghanekar, 2013). Koksal and Berberoglu (2014), in their research, found out that the use of inquiry-based learning can improve effectively on the student's achievement and skills.



	High	Moderate	Low
Guided Inquiry	3.00%	90.00%	7.00%
Open Inquiry	83.00%	17.00%	0%

Figure 2. Comparison graph of the percentage of Normalized Gain Score integrated science process skills in each category

Science process skills are classified into two, namely basic skills and integrated skills (Rezba, Sprague, Matkins, Fiel, & Mcdonnough, 2007). According to Barba (Astuti, 2012), Integrated science process skills include formulating a hypothesis, controlling variables, investigating, designing the definition of operational, and investigating. Based on these aspects, this study's integrated science process skills are grouped into four aspects, namely, planning the experiment, analyzing, and communicating. The activity in problem-solving and experiments carried out by teachers and students can be considered their reason for science process skills. In line with Rofiah's study (2013), problem-solving involves skills to connect the knowledge and experience to think creatively in solving the problem that is not only memorizing and recalling the knowledge. When the students' experiment, they will practice their skills and process skills (Abungu et al., 2014).

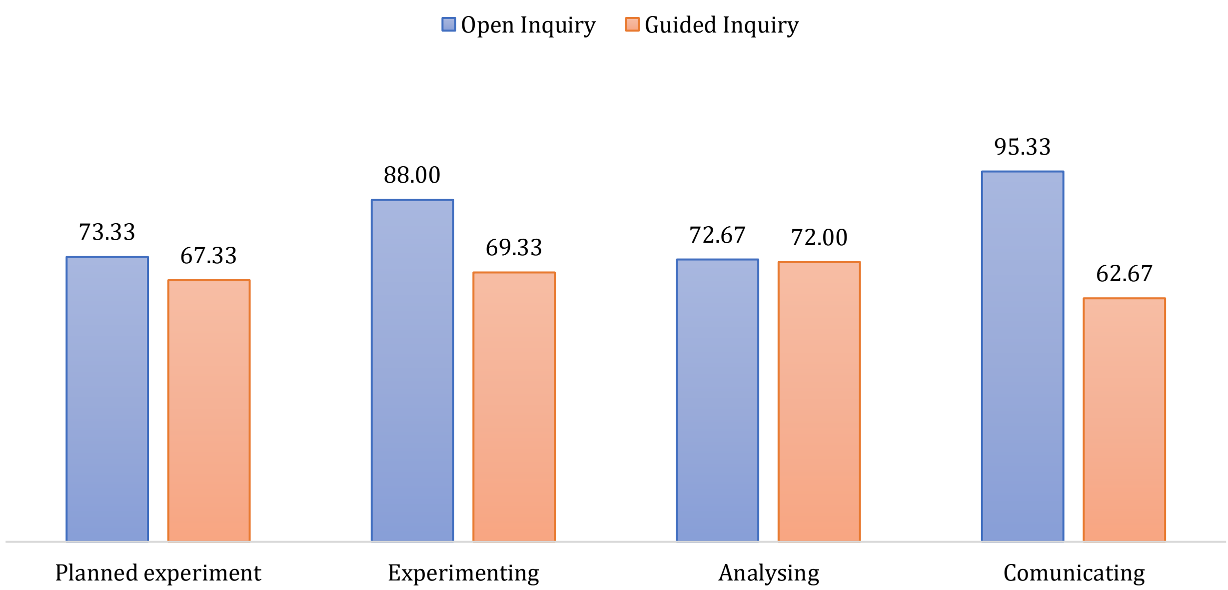


Figure 3. The comparison between the mean scores of integrated science process skills in each aspect

Furthermore, the inquiry learning model will train the students in applying the concept, referring to the formulation of the problem so that interpreting data can be more directed (Roller & Zori, 2017). The mean post-test can be seen in each aspect of the experimental class and control class. The result data can be seen in Figure 3.

Based on Figure 3, the highest post-test means a score of the post-test aspect of communication with a value of 95,33, whereas the aspect of communication has the lowest mean score in the control class with a value of 62,67. These aspects are the development of basic science process skills. Several aspects need the students' skills to synergize skills of analyzing the theory with the investigation that is then communicated in written, such as report and verbal, such as presenting in the classroom.

Communication is the highest of the post-test result of students' integrated science process skills in the experimental class. It happens because the students who learn with the open inquiry model get the freedom to think and search for information independently. Searching without the teacher's instruction will broaden the information that they obtain. When communicating the investigation results, the students who learn with the open inquiry model will do better than learning with the guided inquiry model. The students in the guided inquiry class only focused on the teacher's instruction so that the information they get is limited to what the teacher leads them to do. This situation will cause the students not to enrich the information to support them in processing the words when they communicate the investigation. Social skills emerged when the students interact and communicate with each other, for example, when discussing observation (Rustaman, 2007). Another study (Brata & Cicik, 2020) indicated that the skills of classifying and communicating in learning with guided inquiry learning are significantly higher than structured inquiry learning. However, this study had a different dependent variable, namely comparing the guided inquiry learning model to the structured inquiry learning model where the guided inquiry learning model is more independent than the structured inquiry learning model. Hence, this study's results determined that the open inquiry learning model gives more independence for students to investigate. The aspect of communication is higher in the pretest and post-test scores rather than the guided inquiry learning model. The learning that requires them to directly observe the sequence of collecting data activity through observation with prioritizing scientific method based on proof from the objects which are observed, empirical, and measurable using principles of reasoning will make them enthusiastic in learning (Gillies & Rafter, 2020; Jerrim et al., 2019; Yudarwati, 2019).

CONCLUSION

This study showed a significant difference in the mean scores of the post-test of the 10th-grade students' integrated science process skills between experimental class and control class in the material of plants (Plantae). The N-gain score indicated that the open inquiry class was categorized as high, whereas the N-gain score in the guided inquiry class was moderate. The most influential aspect of science process skills in the experimental class is the aspect of communication. To sum up, based on the result of the test, the open inquiry learning model is effective on the 10th-grade students' integrated science process skills, particularly in communication in the material of plants (Plantae). This study needs to develop as the results of this study can be an alternative biology learning model suitable to improve science process skills in other aspects.

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