Research Article

Learning Bryophyta: **Improving students' scientific** literacy through problem-based learning

Vitri Anugrah Nainggolan [a,1], Risya Pramana Situmorang [a,2,*] , Susanti Pudji Hastuti [a,3]

[a] Biology Education Study Program, Faculty of Biology, Universitas Kristen Satya Wacana, Jl. Diponegoro 52-60 Salatiga 50711 Indonesia
[1] vitri.anugrah.nainggolan@gmail.com; [2] risya.situmorang@uksw.edu*; [3] susanti.hastuti@uksw.edu
* corresponding author

ARTICLE INFO

ABSTRACT

Regarding 21st-century learning, scientific literacy is an important competency which must be owned by students. Nevertheless, scientific literacy of Indonesian students has been recognized in low **level. This study aimed to describe students' scientific literacy in** Bryophyta topic using problem-based learning. This Classroom Action Research (CAR) used the Kemis & Mc.Taggart research design. This study involved 30 students of X graders in Kristen Satya Wacana Senior High School. Students' scientific literacy was measured using a test which comprised of 15 MCQs and 5 essay questions. The data obtained was analyzed using N-gain score. The results indicated that students' scientific literacy was improved from cycle 1 (45.20) to cycle 2 (65.59) as they learnt about Bryophyta. The use of PBL in learning Bryophyta accommodates students' activities to promote their scientific literacy. Scientific activities in PBL strongly support the development of students' scientific literacy.

INTRODUCTION

Science represents the knowledge that leads to the process of collecting data through experimental methods, observations, and deductive ways of thinking. Validation of valid natural phenomena is valid. Biology is one branch of science that is closely related to life processes and the interaction of collecting life with its environment (Ariana et al., 2020). The learning process in a field requires a concept that can question the concept of science and associate the concept with other concepts (Kurniati, 2015). Indeed, how to apply the concepts of science in everyday life becomes an important part of learning science (Allchin, 2014). The development of science and technology in the era of globalization has greatly influenced human life. This causes many problems that appeared in daily life to require scientific handling. The reason states scientific literacy is very important for everyone to be able to support life's challenges (Lederman et al., 2013; Rusilowati et al., 2016). The 21st-century shows the development of information moving very fast. All people must be able to understand the aspects of science and its problems in the modern era. Everyone must be able to understand the scientific aspects and problems in this modern era. Scientific literacy can be applied by recognizing the meaning and urgency to put all of the scientific literacy aspects as an application needed to develop student potential.

Science literacy is defined as the ability to use scientific knowledge to identify questions, obtain new knowledge, explain scientific phenomena, and infer based on scientific evidence (OECD, 2013). The gain process of scientific literacy has a prominent position because it could give some contribution to improve making decision skills at the community level even personal competence (Lederman et al., 2013). Students need meaningful activities to develop their full potential (McCrae, 2011). Holbrook's research results state that learning science is still not in great demand by many students. This is due to the practice of learning more to place the material as a subject but not relate to problems in daily life (Holbrook & Rannikmae, 2016). Because contextual learning can build student awareness of the importance of science, especially in the field of science (Lederman et al., 2013).

Learning on achieving scientific literacy is following the hardship of learning science and learning is not only oriented to knowledge but also the process and formation of attitudes. Therefore, the assessment of scientific literacy is not only oriented to the mastery of science material but can lead to the mastery of life skills, thinking abilities, and abilities in the science process. Scientific literacy can be implemented by using students' science knowledge to integrated values and competence in other to use the scientific method to solve a problem (Kaya et al., 2012; Oliver & Adkins, 2020). Priyambodo and Situmorang (2017) said the development of a process skills approach was one of the important efforts to obtain optimal learning success.

Program for International Student Assessment (PISA) has researched students' scientific literacy in many developing countries because it was considered a key success in learning science. The result of PISA in 2018 had indicated that the achievement of Indonesian students' scientific literacy was still not satisfactory because it just reached a lower level was around 500, not far from the score before in the year 2015 (OECD, 2019). Compared with the OECD average, Indonesian students still lower. This condition should reflect our quality in science education still needs improvement in all aspects, especially the science learning process. Science teachers should change their habits not only to transfer knowledge but also to empower scientific literacy. The strategy for developing scientific literacy is a challenge for teachers, especially in senior high schools.

The survey results at Kristen Satya Wacana Senior High School students in class X[th] grade in the odd semester of the 2019-2020 school year showed that students' scientific literacy skills needed improvement in the learning process in class. Preliminary research conducted on 30 students from three different classes showed that 7% of students could identify issues scientifically, and 10% were tired of explaining a phenomenon. Furthermore, students also stated that biology material was oriented to remember. For example, 26% of students commented that biological material was memorized and sometimes confusing. These were indicated that an educator had some difficulties gained a learning process based on the scientific process. The scientific process is planning (information acquisition), implementation (data collection), data analysis and interpretation, and decision making.

Based on the explanation from the biology teacher that the students' literacy skills are classified as low due to several conditions, namely: 1) the lack of learning activities that lead to a scientific process to support the development of scientific literacy skills; 2) limited opportunities for teachers to construct evaluation tools that lead to scientific literacy; 3) teachers are still minimal in assisting students to train students' scientific literacy skills; and, 4) the lack of student assistance in science learning. The application of the scientific model by the teacher has been carried out in Biology learning, both in the classroom and in the laboratory. It's just that the scientific learning model used by the teacher only facilitates students to identify problems given by the teacher in the form of answering basic questions but has not led to scientific explanations and uses various facts or data for problem-solving. Therefore, the application of problem-oriented models to improve students' scientific literacy. One alternative that can be applied is to use it which can improve students' scientific attitudes. Some studies find that the teacher should apply the Problem-Based Learning (PBL) model continuously in biology learning as a solution (Günter, 2020; Moutinho et al., 2015; Prastika et al., 2019; Suwono et al., 2017).

Innovative learning models are needed that can move students' understanding of creativity in problem-solving Improving scientific literacy requires a comprehensive understanding to be able to teach biology by using appropriate models and by learning objectives (Glaze, 2018). PBL is a learning model that develops students' ability to solve problems based on scientific phenomena in everyday life (Parno et al., 2020). Bryophyta is one of the biological materials related to the realm. Students can find Bryophyta groups in their circumstances. The implementation of PBL can help students to improve science process skills to gain meaningful learning through students' scientific literacy skills (Kaya et al., 2012). Research from Ardianto and Rubini (2016) explained that PBL could improve students' scientific literacy skills in the aspect of explaining scientific issues, explaining the events of everyday scientific phenomena, and utilizing data based on scientific phenomena. Students who are given a comprehensive understanding of the scientific learning model of each class meeting will interpret biology as a related science in daily life. In line with the finding from some studies that the problems arranged in PBL can be in the form of authentic problems related to everyday life (Bledsoe & Flick, 2012; Elder, 2015; Ismiani et al., 2017; Lokitaswara et al., 2019; Mustofa et al., 2016; Ünal & Özdemir, 2013; Wang et al., 2012).

Scientific activities through PBL are expected to help students strengthen science knowledge and gain interaction with their environment (Foyle et al., 2018). If students have interacted with their environment,

students will get an opportunity to learn contextually. Learning activities with scientific methods will train and familiarize students with investigations based on valid information (Sivamoorthy et al., 2013). Furthermore, support from the teacher is also an important element to engage students as learners. One of the biology contents that can be created to be the process of investigation is Bryophyta. Based on an interview with 60 students, 66% of students have difficulties identifying and classifying this topic. The PBL model facilitated students to implement in contextual learning (Baran & Sozbilir, 2018; Bate, et al., 2014). The construction of knowledge through PBL is a reason to engage student's ability. Students will be involved in observing the types of Bryophyta and their classification based on students' findings in the environment.

It is important to develop scientific literacy skills for students to provide critical solutions from the information obtained. This research is important because it is suspected that the students 'problem-solving skills gradually have a positive impact on students' scientific literacy skills. According to Gurses et al. (2015) problem-solving which is related to everyday life can empower students' critical thinking skills to gain meaningful learning. Some previous studies exhibited that the PBL model can increase the ability of scientific literacy, nevertheless, the research has not focused on empowering students about using scientific evidence and phenomena scientifically (Husna et al., 2017; Prastika et al., 2019). When students' thinking abilities are empowered, it will provide a strong stimulus for increasing scientific literacy. This means that when the student's ability to increase the problem will also increase the student's scientific literacy ability (Parno et al., 2020; Rosa et al., 2018). However, previous research on scientific literacy on Bryophyta topic was still limited. This research is very important to be studied more deeply for the empirical investigation that PBL can improve students' scientific literacy skills in Bryophyta learning.

METHOD

This Classroom Action Research (CAR) study was conducted at Kristen Satya Wacana Senior High School, Salatiga City in February-March 2020. The CAR design used was the research design model of Kemis & Mc. Taggart consists of steps, namely 1) planning: consisting of activities to design learning devices, 2) actions: implementation of learning on Bryophyta topic based on the PBL model, 3) observation (observing) is an observation activity towards the action process in research, 4) reflection is an activity to evaluate the implementation and achievement of students' scientific literacy (described in Figure 1).
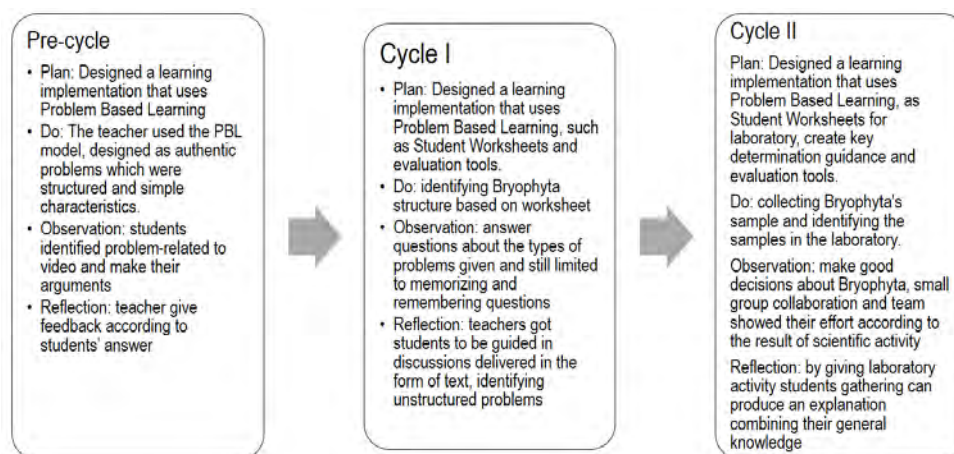

Figure 1. Diagram of the implementation of learning from pre-cycle, cycle I, and cycle II

The subjects of this study were 30 students of X graders at Kristen Satya Wacana Senior High School of the academic year 2019/2020. The sample was purposive sampling and consist of 1 group which is learning through PBL The scientific literacy assessment instrument consisted of 3 indicator items with 15 multiple choice questions and 5 essay items. The instrument is an adaptation from Gormally et al. (2012) as presented in Table 1.

Table 1. Scientific literacy indicator

Indicator of scientific literacy	Question number
Identifying scientific problems	1, 4, 5, 6, 16 (essay), 17 (essay)
Explain phenomena scientifically	2, 3, 7, 8, 10, 11, 18 (essay), 19 (essay)
Using scientific evidence	9, 12, 13, 14, 15, 20 (essay)

Data were collected using a written test and analyzed based on the N-Gain score from cycle one to cycle two. The test is carried out using a pretest and posttest regarding Bryophyta topic. Based on its construct, the test instrument was declared valid by content experts (biology lecturer). Empirical validation was done towards

the scientific literacy ability test instrument. The test validation is the test with three indicators which consisted of 15 multiple choices and 5 essays. Implementation of test items involved 25 students of XI graders at same school who had learned the topic of a Bryophyta in the previous semester. The result of the validation was that 20 test items were declared as valid with **Cronbach's alpha reliabilit**y of 0.84. The distribution of test items according to scientific literacy indicators is presented in Table 1. The stages of PBL that implement in this study are shown in Table 2. PBL implementation was conducted for two cycles and each cycle has consisted of two meetings. In the first up to the second meeting, it was the first cycle and the third to fourth where the second cycle. The research was carried out through stages of 2 cycles is the first cycle students were taught using conventional methods, while the second cycle uses PBL.

Table 2. Syntax of PBL

Syntax of PBL	Student activity
1. Orientation problems	Students tried to understand the description of the problem given by the teacher regarding Bryophyta in the student activity sheet. Problem starts from collecting activities to Bryophyta's sample and students carrying them into a laboratory to identifying the structure of a sample. Problem starts from collecting activities to Bryophyta's sample and students carrying them into a laboratory to identifying the structure of a sample. By determination instruction, students determined the sample and grouping them into the classification concept. The problem is, how students could identify all of the samples accurately and made them into the right group. The teacher's role was to ensure all of the students' group members gave a scientific argument above the identification result. So, they tried to solve it through the discussion in the group.
2. Organizing students into research	Students in groups formulate problems related to the Bryophyta concept in the problem description, to find ways of solving through observation and experimental activities to provide solutions to the problems given.
3. Independent investigation in a group	Students collect data (sample from a group of Bryophyta) for finding the concept of grouping characteristics. These purposes were stimulated students to solve a problem about classification, ecological characteristics, and cycle reproduction.
4. Preparation of summary concept of Bryophyta for development (discussion) related to observation data	Students, guided by the teacher, identify forming a group of Bryophyta. Students could be connecting a key determination of Bryophyta and put them into an appropriate group. Based on the ecological characteristics, students should define how Bryophyta could sustain in that area. They must be related to the reproduction cycle of Bryophyta. The summary results of Bryophyta according to the data collected, all of the group members listening and discussing to the summary results. If there are errors in the results, they can give some suggestions to correct the answer.
5. Presentation	Pairs of students from all of the group in class, present their results for the whole class, and students from other couples respond to the presentation of the result.
6. Conclusion	Pairs of students who do presentations conclude for all of students' suggestion in the classroom, assisted by another member of the group, they can maximize their report about solving problems.

The test instrument was used to measure scientific literacy skills. The tests were given before as a pretest and after the learning process as a posttest (the treatments). Item of the test was the same even though it spread randomly. Improvement of students' scientific literacy skills through the implementation of PBL models is analyzed through the calculation of average scores using N-Gain. The N-Gain formula is used according to Hake (2014), presented in Formula (1). The criteria for calculating the N-Gain score data are needed as a reference for changing the score using Formula (2). Furthermore, interpretation of students' scientific literacy (by using N-Gain score) is described in Table 3.

$$g = \frac{Sf(\%) - Si(\%)}{100 - Sf(\%)}$$

(1)

Information:
Sf = posttest score average
Si = pretest score average

$$P = \frac{f}{N} \times 100$$

(2)

Information:
P = value expressed as a percentage
F = the frequency that is being sought for the percentage
N = number of frequencies

Implementation of the PBL model contains scores of four scale marks for each phase indicator. Finally, the data were analyzed by descriptive analysis through the calculation of the percentage of the results of the implementation PBL model. The instruments used were the forms of observation sheet. The observation sheet was used to obtain information about the implementation of the PBL model. The criteria for the results of the

research instrument data are carried out then the initial data in the form of scores are converted into qualitative data (interval data) with a scale of four presented in Table 4 (Nuryadi et al., 2017). Indicators of success in this study are based on (1) An increase in the scientific literacy of students who scored above minimal completeness criteria by 65, (2) The implementation of the PBL model by 90% in learning following the lesson plan that has been prepared and implemented.

Table 3. Interpretation of scientific literacy (gain score)

Score interval	Interpretation
> 0.7	High
0.7 ≥ X ≥ 0.3	Medium
<0.3	Low

Table 4. Convert scores of four scale

Score interval	Category
3.33 < score ≤ 4.00	Very good
2.33 < score ≤ 3.33	Good
1.33 < score ≤ 2,33	Enough
≤1.33	Deficient

RESULTS AND DISCUSSION

Pre-Cycle

The implementation of the pre-cycle was done by the teacher through scientific-based learning. The teacher used the PBL model, learning activities were designed as authentic problems which were structured and simple characteristics. The PBL phases in the pre-cycle were problem identification, collaborative problem solution, presentation, and evaluation. Based on the observations, teachers have not implemented the PBL model optimally. Even though several points around the school environment could be used as learning resources related to environmental knowledge but the achievement of students' cognitive learning outcomes becomes less optimal in several aspects. This is shown from the results of tests with the attainment of students completing 13% with a minimum score of 75. The result of the pre-cycle is obtained as in Table 5.

Table 5. Descriptive statistics results in pre-cycle observation

Criteria	Result of pre-cycle
Number of students	20
Average	46.01
Standard deviation	12.22
Max. score	70
Min. score	20
Percentage of completeness	13%
Percentage of incompleteness	87%

Cycle I

The implementation of the first cycle started from the planning stage which consists: 1) Designed a learning implementation plan that uses PBL as well as each of the other supporting devices such as student worksheets and evaluation tools; 2) Prepared test instruments to measure the increase in students' scientific literacy and observation sheet of the implementation of learning. The acquisition of students' scientific literacy in the first cycle is described in Table 6.

Table 6. Achievement **of students' scientific literacy** in cycle I

Indicator of scientific literacy	Value description		N-Gain	Category
	Pre-test	Post-test		
Identifying scientific problems	40.5	65.5	42.01	Medium
Explain phenomena scientifically	34.6	61.3	40.81	Medium
Using scientific evidence	41.37	72.3	52.80	Medium
Average	49.02	67.2	45.20	Not complete

Based on Table 6, the result showed that the indicator of identifying scientific problems is 65.5 (moderate category), explaining the phenomenon scientifically 61.3 (moderate category), and using scientific evidence 72.3 (high category). The N-Gain score of students' scientific literacy abilities shows that the indicators of identifying scientific problems and explaining scientific phenomena have almost the same average value, but the indicators using scientific evidence show a gap value. The achievement of indicators identifying scientific problems and explain phenomena scientifically was still less able to answer questions about the types of

problems given and still limited to memorizing and remembering questions. Bybee, R., and McCrae (2011) explain that if students could identify problems related to fact issues factors and everyday lives, they can improve scientific literacy skills comprehensively.

The results of the students' scientific literacy abilities show that the indicators of identifying scientific problems and explaining scientific phenomena have almost the same average value. It showed a gap in the N-Gain score on the indicators using scientific evidence. Hestiana and Rosana (2020) explain that factors that can improve scientific literacy skills are fact-oriented issues and place problems as a starting point for learning. Reflection activities with biology teachers got students to be guided in discussions delivered in the form of text. Students' understanding of problems is still limited to thinking processes systematically. Therefore, the teacher's role in facilitating students to think about problems should be to formulate problems then linked them to the specific solution. Questioning facts and explain scientific phenomena prove scientific truth through accurate verification. Students need to verify data so that the analysis process became more precise.

Description of the implementation of PBL could be known based on observations of teacher's activity. Observations were made based on the steps of the PBL model which had five core activities with the following phases: observing, asking questions, collecting data, associating, and communicating. Observations were made by two observers using the observation sheet. The analysis of the percentage of the PBL model learning implementation is presented in Table 7.

Table 7. Implementation of PBL in cycle I

Class meeting	Score	Category
First	2.66	Good
Second	3	Good
Average	2.83	Good

The implementation of PBL in learning Biology on Bryophyta as a whole result is 2.83 (good category). This means that every phase of PBL on Bryophyta learning has been carried out almost entirely. If we would see from each observation result, each meeting stated that almost all activities were carried out in the PBL model with a score of 2.66 each at the first meeting and 3 at the second. The implementation of the PBL model in the first cycle showed that student participation is still not optimal. This is due to students have some trouble identifying unstructured problems. Students still had not adapted to each phase of the PBL model. For example, when given problems, students still need to be repeated explanations to provide understanding. Frequent problems that teachers often face in implementing the PBL model related to characteristics of the PBL model. Bledsoe and Flick (2012) argue that implementation of PBL takes time so that students get used to problem solving activities. The PBL model requires students to have adequate information in identifying the problems given, especially in unstructured problems (Redhana, 2013; Supiandi, M. & Julung, 2016).

Cycle II

The implementation of the second cycle was carried out two times meeting through teaching activities. Based on reflection in cycle I, learning is done by presenting materials that are not fully mastered by students. The implementation of learning in cycle II teachers and collaborators (researchers) have applied the PBL model. The teacher gives apperception in the form of questions related to the classification of Bryophyta. Next, the teacher explains the steps of the PBL model that will be used in the learning. Students are also given motivation and explained the benefits in daily life when learning about the classification of Bryophyta.

Learning activities starting with collecting Bryophyta's sample and identifying the samples in the laboratory. Students determined the sample using the key of determination and grouping them into the classification concept. The teacher gave a step identification as a problem to the students, and they tried to solve it through the discussion in the group. The teacher also accompanies students in formulating problems and determining hypotheses. The teacher facilitated all the groups by monitoring the students' discussion process in groups. For testing hypotheses, teachers also guide all of the groups to determine the point of the hypotheses. The purposes are they could have the ability to predictions and found the appropriate solutions. After that, each group presented the results of their discussion to the class.

Furthermore, provide a rationale for students' decisions including prioritization of problems about structure identification of Bryophyta. For example, a general characteristic of Bryophyta has not a specific vascular system to bring water and mineral. Indeed, group members in the independent investigation phase should be addressed the proper characteristic according to the problems or issues. Besides, they identify what information is missing and needed to make good care decisions about Bryophyta. In this phase, students engage in using scientific evidence (Figure 2). To strengthen their answer, every student could be identified what resources will help them gather the missing identification. In the presentation phase, small group collaboration and team showed their effort according to the result of scientific activity. In this phase, all of the group done feedback and validation. Other small group gave their feedback and explain phenomena scientifically. This activity engages the students to find information from the discussion.

Figure 2. Students' activities to get Bryophyta sample as scientific evidence

Student learning activities (Figure 2) showed that students are invited to link contextual learning to Bryophyta's subject. This activity affected increasing scientific literacy. Increased scientific literacy indicates that students have a curiosity about science issues and practice science directly. When students pay attention to their learning behavior, it can be empowering their experiences and form scientific expertise from various sources using scientific methods. Dragoş and Mih (2015) explained students could achieve their learn best if they could employ a variety of data collection methods. Moreover, setting up an outdoor class as a learning activity will allow students to observe the phenomena by themselves and empower their scientific abilities to be more optimal (Feille, 2017; Fettahlıoğlu & Aydoğdu, 2020).

The results of the scientific literacy score can be analyzed in every aspect to analyze their skills. Based on the recapitulation of scientific literacy (Table 8), the data obtained with the highest average using scientific evidence, while the lowest value is in explaining the problem of phenomena scientifically. Based on observations on the learning process, students have sufficient theoretical or scientific concept skills, can identify or determine a problem but still have difficulty explaining the phenomenon or problem properly. This can be seen in the implementation of the learning process when students are given a problem, they can identify the basics of theoretical, but they still have difficulty in the analysis of complex cases by linking various concepts or viewed from other conceptual perspectives. This is because they are not used to solving problems, such as the statement from McCrumz (2017) that the habit of thinking to find problem-solving needs to be practiced continuously.

Table 8. Achievement of **students' scientific liter**acy in cycle II

Indicator of scientific literacy	Value description		N-Gain	Category
	Pre-test	Post-test		
Identifying scientific problems	48.33	80.66	62.58	Medium
Explain phenomena scientifically	38	76.83	62.63	Medium
Using scientific evidence	43.12	83.62	71.58	High
Average	49.02	44.81	75.44	Complete

Learning in the second cycle showed an increase in student enthusiasm for learning. The educator promoted literacy practices by finding information using textbooks and stimulated students to be connected to the dynamic scientific inquiry. This is in line with Sørvik et al. (2015) explanation that investigating the variation of texts and present in these science lessons the context from texts were being used. Presenting graphics and pictures in-depth will indicate that students have emphasized their concepts. It also exercised students' involvement to understand literacy as further emphasis. Students communicate and provide their respective analyses of the information based on the reference. Furthermore, the teacher verifies the student's opinion.

Increasing students' literacy skills is carried out by utilizing the school environment as a form of problem finding and increasing students' ability to solve these problems (Heard, 2016; Wirdianti et al., 2019). Other efforts were also made through strengthening the content of Bryophyta in teaching materials. Some of the Bryophyta sample search activities are activities that lead students to be able to map the types of Bryophyta and provide a classification of the sample findings. Problems found in the context of classification, Bryophyta body structure, and reproductive methods can train student activities to identify, analyze problems, explain phenomena based on observations, and use facts empirically.

Table 9 showed the result of the implementation of PBL models in learning Bryophyta as a whole is 3.49. The stage of experimental activities is guiding students to collect data as a sample of Bryophyta from the surrounding area. Many activities carried out by students in this stage, begin the learning process by observing objects following the Bryophyta characteristic. Then students brought the sample to identify in the laboratory. They were also guided by a key determination to identify a group of Bryophyta. Besides, they have been answered questions from a worksheet, they have to answer them scientifically. For example, when students are faced with several specimens of Bryophyta, character observations are made about the state of the vaginula, seta, apophysis, archegonium, speculum, and peristome. This means that every phase of PBL on Bryophyta topic had been carried out almost entirely. In connection with this activity, students learn how to answer questions scientifically, analyze them by connecting to the concept. Exploration activity was carried out in the context of collecting data based on experimental results. Some research showed that these activities help students to improve their science literacy skills (J. Kang, 2020; Murphy et al., 2019).

Table 9. Implementation of PBL in cycle II

Class meeting	Score	Category
First	3.33	Good
Second	3.66	Very good
Average	3.49	Very Good

Based on each observation result, each meeting stated that almost all activities were carried out in the PBL model with a score of 80% each at the first meeting and 76.47% at the second. **Results of students' activity** showed that the dominant activity during the learning process with the PBL model was the experiment activities **and teacher's explanation.** When investigation phase, students were using the key determination, this was identified as a functional level of scientific literacy because most of the student was able connected characteristic member group of Bryophyta. Besides, even though they struggled to interpret information from key determination, the teacher also facilitates each group by giving an example data analysis. When the teacher displayed the procedure, it stimulated their power of conceptual. They provided multiple ideas and linked some concepts about the morphology of Bryophyta. As stated by Putri et al. (2018) that authentic problems as a starting point gain multiple students' ideas by relating problems that closely into everyday life.

By giving questions on the worksheet, students gathering the data and produce an explanation combining their general knowledge. It was predicted that students who were able to provide a multidimensional level of using data to solve a problem (Cheng et al., 2018). They were also able to link several ideas together to form a comprehensive response. This means that the identified object conducted by found the characteristics by students contributed p**ositively to students' understanding** (Moutinho et al., 2015). Indeed, students were allowed to discover the concept of reproduction of Bryophyta. After the experimental activity was completed, the teacher also gave reinforcement in the concept of the reproduction cycle in Bryophyta through the video. Strengthening students in experimental activities is one way to exercise students' scientific reasoning in the context of science (Wulandari, 2017).

Moreover, the data comparison of students' scientific literacy in cycles I and II can be seen in Table 10. It shows the results of students' scientific literacy in cycle II have completed because appropriate with the expected target (more than 60 points). Increased completeness of scientific literacy through the implementation of PBL models on Bryophyta topic shows that there has been a change in students' scientific literacy in the aspects of problem identification, the ability to explain scientifically, and use scientific evidence. Achieving higher levels of scientific literacy and the ability to apply scientific knowledge in life situations depend on how the student could be applied that knowledge in their life situations (Garthwaite et al., 2014; Zhu, 2019). Implementation of the PBL can stimulate students to be actively solving problems in learning and construct their knowledge. The activity of students will give a positive chance to change their mindset find out and provide solutions. Students who are trained to be sensitive to problems will influence how they can think positively and solve problems appropriately (Rahayuni, 2016; Ristanto et al, 2017).

Table 10. Completeness of **students' scien**tific literacy in cycle I and cycle II

Cycle I Achievement (>65)	Criteria	Cycle II Achievement (>65)	Criteria
45.20	Incomplete	75.44	Complete

The high level of scientific literacy skills of students after implementing the PBL model is in line with several previous research that has also implemented this learning model. Some of these studies examine the increase of students' scientific literacy by implementing a PBL (N.-H. Kang et al., 2012; Mun et al., 2015). Several researchers from Indonesia also reported similar cases (Hestiana & Rosana, 2020; Parno et al., 2020; Prastika et al., 2019). Improvements in scientific literacy could have occurred if biological learning was designed with integrated scientific literacy and scientific activity. This proven support from some activities consisted of

stimulated students in biological activity, for example, the classification of Bryophyta and connecting their knowledge. The engagement of students can prove some ability in scientific literacy, for example, student explore their knowledge in experimental activity, they can be involved in getting data and connect to theory. This is in line with Sharon and Baram-Tsabari (2020), who explains that science literacy must be taught in the science classroom for students to identify misinformation. This implies that the ability of content knowledge provides a chance to gain scientific literacy through PBL.

However, there are some limitations of the implementation of the PBL model for instance need time extended to facilitate student for doing the experimental activity. It needs supporting equipment to analyze in detail according to identify the life cycle of Bryophyta in real-time. The teacher should have an alternative way to illustrate some parts of Bryophyta to explain the concept comprehensively. Some research shows that unreachable activity in the laboratory can be designed with a virtual laboratory, it's effective to use a blended approach to present the abstract concept (Darrah et al., 2014; Kapici et al., 2019; Pyatt & Sims, 2012).

CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the implementation of the Problem-Based Learning model can increase students' scientific literacy in the X graders of Kristen Satya Wacana Senior High School in Academic Year 2019/2020. It was found that the PBL model was able to support students to learn Bryophyta so that it affected improving their scientific literacy. The achievement of students' scientific literacy in the first cycle reached 45.20 and increased in the second cycle to 75.44. Meanwhile, the learning implementation aspect was completed in the first cycle with an achievement of 2.83 (good category) and in the second cycle reach 3.49 (very good category). The results of this study have implications in the learning process which can be used as a reference for developing students' scientific literacy through problem-based learning in scientific activities. Scientific activities strongly support the development of scientific literacy at the high school level and can be used in the learning process by teachers to support increased scientific literacy with relevant material.

REFERENCES

Allchin, D. (2014). From science studies to scientific literacy: A view from the classroom. *Science and Education, 23*(9), 1911–1932. https://doi.org/10.1007/s11191-013-9672-8

Ardianto, D., & Rubini, B. (2016). Comparison of students' scientific literacy in integrated science learning through model of guided discovery and problem based learning. *Jurnal Pendidikan IPA Indonesia, 5*(1), 31–37. https://doi.org/10.15294/jpii.v5i1.5786

Ariana, D., Situmorang, Risya, P., & Krave, Agna, S. (2020). Pengembangan modul berbasis discovery learning pada materi jaringan tumbuhan untuk meningkatkan kemampuan literasi sains siswa kelas XI IPA SMA. *Jurnal Pendidikan Matermatika dan IPA, 11*(1), 34–46. https://doi.org/10.26418/jpmipa.v10i2.27630

Baran, M., & Sozbilir, M. (2018). An application of context- and problem-based learning (C-PBL) into teaching thermodynamics. *Research in Science Education, 48*(4), 663–689. https://doi.org/10.1007/s11165-016-9583-1

Bate, E., Hommes, J., Duvivier, R., & Taylor, D. C. M. (2014). Problem-based learning (PBL): Getting the most out of your students-Their roles and responsibilities. *Medical Teacher, 36*(1), 1–12. https://doi.org/10.3109/0142159X.2014.848269

Bledsoe, K. E., & Flick, L. (2012). Concept development and meaningful learning among electrical engineering students engaged in a problem-based laboratory experience. *Journal of Science Education and Technology, 21*(2), 226–245. https://doi.org/10.1007/s10956-011-9303-6

Bybee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7–26. https://doi.org/10.1080/09500693.2011.518644

Cheng, S. C., She, H. C., & Huang, L. Y. (2018). The impact of problem-solving instruction on middle school students' physical science learning: Interplays of knowledge, reasoning, and problem solving. *Eurasia Journal of Mathematics, Science and Technology Education, 14*(3), 731–743. https://doi.org/10.12973/ejmste/80902

Darrah, M., Humbert, R., Finstein, J., Simon, M., & Hopkins, J. (2014). Are Virtual labs as effective as hands-on labs for undergraduate physics? A comparative study at two major universities. *Journal of Science Education and Technology, 23*(6), 803–814. https://doi.org/10.1007/s10956-014-9513-9

Dragoş, V., & Mih, V. (2015). Scientific literacy in school. *Procedia-Social and Behavioral Sciences, 209*, 167–172. https://doi.org/10.1016/j.sbspro.2015.11.273

Elder, A. D. (2015). Using a brief form of Problem-Based Learning in a research methods class: Perspectives of instructor and students. *Journal of University Teaching and Learning Practice*, *12*(1), 13. https://ro.uow.edu.au/cgi/viewcontent.cgi?article=1491&context=jutlp

Feille, K. K. (2017). Teaching in the field: What teacher professional life histories tell about how they learn to teach in the outdoor learning environment. *Research in Science Education*, *47*(3), 603–620. https://doi.org/10.1007/s11165-016-9519-9

Fettahlıoǧlu, P., & Aydoǧdu, M. (2020). Developing environmentally responsible behaviours through the implementation of argumentation and problem-based learning models. *Research in Science Education*, *50*(3), 987–1025. https://doi.org/10.1007/s11165-018-9720-0

Foyle, L., Hostad, J., & Fisher, J. (2018). Problem-based learning: Not such a problem. In *Innovations in Cancer and Palliative Care Education* (pp. 24–36). https://doi.org/10.1201/9781315379913-3

Garthwaite, K., France, B., & Ward, G. (2014). The complexity of scientific literacy: The development and use of a data analysis matrix. *International Journal of Science Education*, *36*(10), 1568–1587. https://doi.org/10.1080/09500693.2013.870363

Glaze, A. (2018). Teaching and learning science in the 21st century: Challenging critical assumptions in post-secondary science. *Education Sciences*, *8*(1), 12. https://doi.org/10.3390/educsci8010012

Gormally, C., Brickman, P., & Lutz, M. (2012). Developing a test of scientific literacy skills (TOSLS): Measuring undergraduates' evaluation of scientific information and arguments. *CBE Life Sciences Education*, *11*(4), 364–377. https://doi.org/10.1187/cbe.12-03-0026

Günter, T. (2020). Effectiveness of a Problem-Based Learning (PBL) scenario for enhancing academic achievement of energy metabolism. *Research in Science Education*, *50*(5), 1713–1737. https://doi.org/10.1007/s11165-018-9750-7

Gurses, A., Dogar, C., & Geyik, E. (2015). Teaching of the concept of enthalpy using problem based learning approach. *Procedia-Social and Behavioral Sciences*, 2390–2394. https://doi.org/10.1016/j.sbspro.2015.07.298

Hake, R. R. (2014). *Design-based research in physics education: A review.* Routledge. https://doi.org/10.4324/9781315759593-42

Heard, M. J. (2016). Using a problem-based learning approach to teach students about biodiversity, species distributions & the impact of habitat loss. *The American Biology Teacher*, *78*(9), 733–738. https://doi.org/10.1525/abt.2016.78.9.733

Hestiana, H., & Rosana, D. (2020). The effect of problem based learning based sosio-scientific issues on scientific literacy and problem-solving skills of junior high school students. *Journal of Science Education Research*, *4*(1), 15–21. https://doi.org/10.21831/jser.v4i1.34234

Holbrook, J., & Rannikmae, M. (2016). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, *29*(11), 1347–1362. https://doi.org/10.1080/09500690601007549

Husna, F. R., Sukaesih, S., & Setiati, N. (2017). The influences of problem based learning accompanying analyze case study toward scientific literacy of students. *Journal of Biology Education*, *6*(3), 357–367. https://doi.org/10.15294/jbe.v6i3.21091

Ismiani, S., Syukri, S., & Wahyudiati, D. (2017). Pengaruh penerapan metode problem based learning terhadap sikap ilmiah dan hasil belajar biologi siswa Kelas VII MTs NW 01 Kembang Kerang. *Biota*, *10*(1), 104–113. https://doi.org/10.20414/jb.v10i1.27

Kang, J. (2020). Interrelationship between inquiry-based learning and instructional quality in predicting science literacy. *Research in Science Education.* https://doi.org/10.1007/s11165-020-09946-6

Kang, N.-H., DeChenne, S. E., & Smith, G. (2012). Inquiry learning of high school students through a problem-based environmental health science curriculum. *School Science and Mathematics*, *112*(3), 147–158. https://doi.org/10.1111/j.1949-8594.2011.00128.x

Kapici, H. O., Akcay, H., & de Jong, T. (2019). Using hands-on and virtual laboratories alone or **together—which works better for acquiring knowledge and skills**? *Journal of Science Education and Technology*, *28*(3), 231–250. https://doi.org/10.1007/s10956-018-9762-0

Kaya, V. H., Bahceci, D., & Altuk, Y. G. (2012). The **relationship between primary school students' scientific** literacy levels and scientific process skills. *Procedia - Social and Behavioral Sciences*, *47*, 495–500. https://doi.org/10.1016/j.sbspro.2012.06.687

Kurniati, T. (2015). Penerapan model belajar siklus 5E terhadap pemahaman konsep biologi umum dan kemampuan aplikasi sains mahasiswa pendidikan biologi. *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam*, *20*(1), 60. https://doi.org/10.18269/jpmipa.v20i1.564

Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in*

Mathematics Science and Technology (IJEMST), *1*(3), 138–147. https://doi.org/10.18404/ijemst.19784

Lokitaswara, E., Hidayat, S., & Shahri, I. (2019). Upaya meningkatkan penguasaan konsep melalui model problem based learning pada materi protista Kelas X di SMA Muhammadiyah Sekayu. *BIODIK*, *5*(1), 59–67. https://doi.org/https://doi.org/10.22437/bio.v5i1.6392

McCrae, N. (2011). Nurturing critical thinking and academic freedom in the 21st century university. *International Journal of Teaching and Learning in Higher Education*, *23*(1), 128–134. https://eric.ed.gov/?id=EJ938588

McCrum, D. P. (2017). Evaluation of creative problem-solving abilities in undergraduate structural engineers through interdisciplinary problem-based learning. *European Journal of Engineering Education*, *42*(6), 684–700. https://doi.org/10.1080/03043797.2016.1216089

Moutinho, S., Torres, J., Fernandes, I., & Vasconcelos, C. (2015). Problem-based learning and nature of science: A study with science teachers. *Procedia - Social and Behavioral Sciences*, 1871–1875. https://doi.org/10.1016/j.sbspro.2015.04.324

Mun, K., Shin, N., Lee, H., Kim, S. W., Choi, K., Choi, S. Y., & Krajcik, J. S. (2015). Korean secondary **students' perception of scientific literacy as global citizens**: Using global scientific literacy questionnaire. *International Journal of Science Education*, *37*(11), 1739–1766. https://doi.org/10.1080/09500693.2015.1045956

Murphy, C., Smith, G., & Broderick, N. (2019). A starting point: Provide children opportunities to engage with scientific inquiry and nature of science. *Research in Science Education*. https://doi.org/10.1007/s11165-019-9825-0

Mustofa, Z., Khoiriyah, A. J., Sulistiyawati, I., Harmawati, D., & Muhdhar, M. H. I. Al. (2016). Penerapan strategi pembelajaran problem based learning melalui lesson study untuk meningkatkan keterampilan memecahkan. *Jurnal Pendidikan Biologi*, *8*(1), 32–37. https://doi.org/10.17977/um052v8i1p32-37

Nuryadi, Astuti, T. D., Utami, E. S., & Budiantara, M. (2017). *Dasar-Dasar Statistika Penelitian.* Universitas Mercu Buana Yogyakarta. http://eprints.mercubuana-yogya.ac.id/6667/1/Buku-Ajar_Dasar-Dasar-Statistik-Penelitian.pdf

OECD. (2013). *PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy.* https://doi.org/10.1787/9789264190511-en

OECD. (2019). PISA 2018 results. In *OECD Publishing* (Vol. 3). https://www.oecd.org/pisa/publications/pisa-2018-results.htm

Oliver, M. C., & Adkins, M. J. (2020). "Hot-headed" students? Scientific literacy, perceptions and awareness of climate change in 15-year olds across 54 countries. *Energy Research and Social Science*, *70*, 1-9. https://doi.org/10.1016/j.erss.2020.101641

Parno, Yuliati, L., Hermanto, F. M., & Ali, M. (2020). A case study on comparison of high school students' scientific literacy competencies domain in physics with different methods: PBL-stem education, PBL, and conventional learning. *Jurnal Pendidikan IPA Indonesia*, *9*(2), 159–168. https://doi.org/10.15294/jpii.v9i2.23894

Prastika, M. D., Wati, M., & Suyidno, S. (2019). The effectiveness of problem-based learning in improving students scientific literacy skills and scientific attitudes. *Berkala Ilmiah Pendidikan Fisika*, *7*(3), 185-195. https://doi.org/10.20527/bipf.v7i3.7027

Priyambodo, P., & Situmorang, R. P. (2017). *Antigen antibodi pembelajaran* (R. S. Zuhri (ed.)). Pustaka Pelajar. http://balaiyanpus.jogjaprov.go.id/opac/detail-opac?id=299193

Putri, P.D., Tukiran, & Nasrudin, H. (2018). The effectiveness of Problem-Based Learning (PBL) models based on Socio-Scientific Issues (SSI) to improve the ability of science literacy on climate change materials. *Jurnal Penelitian Pendidikan Sains (JPPS)*, *7*(2), 1519–1524. https://doi.org/10.26740/jpps.v7n2.p1519-1524

Pyatt, K., & Sims, R. (2012). Virtual and physical experimentation in inquiry-based science labs: Attitudes, performance and access. *Journal of Science Education and Technology*, *21*(1), 133–147. https://doi.org/10.1007/s10956-011-9291-6

Rahayuni, G. (2016). Hubungan keterampilan berpikir kritis dan literasi sains pada pembelajaran ipa terpadu dengan model PBM dan STM. *Jurnal Penelitian dan Pembelajaran IPA*, *2*(2), 131–146. https://doi.org/10.30870/jppi.v2i2.926

Redhana, I. . (2013). Model pembelajaran berbasis masalah untuk peningkatan keterampilan pemecahan masalah dan berpikir kritis. *Jurnal Pendidikan dan Pengajaran*, *46*(1), 78–86. https://doi.org/10.23887/jppundiksha.v46i1.1694

Ristanto, R. H., Zubaidah, S., Amin, M., & Rohman, F. (2017). Scientific literacy of students learned through guided inquiry. *International Journal of Research Review*, *4*(5), 23–30. https://www.ijrrjournal.com/IJRR_Vol.4_Issue.5_May2017/IJRR004.pdf

Rosa, G. C., Cari, C., Aminah, N. S., & Handhika J. (2018). Students' understanding level and scientific literacy competencies related to momentum and impulse. *Journal of Physics: Conference Series, 1097,* 1–8. https://doi.org/10.1088/1742-6596/1097/1/012019

Rusilowati, A., Kurniawati, L., Nugroho, S. E., & Widiyatmoko, A. (2016). Developing an instrument of scientific literacy asessment on the cycle theme. *International Journal of Environmental & Science Education, 11*(12), 5718–5727. https://eric.ed.gov/?id=EJ1115684

Sharon, A. J., & Baram-Tsabari, A. (2020). Can science literacy help individuals identify misinformation in everyday life? *Science Education, 104*(5), 873–894. https://doi.org/10.1002/sce.21581

Sivamoorthy, M., Nalini, R., & Kumar, C. S. (2013). Environmental awareness and practices among college students. *International Journal of Humanities and Social Science Invention, 2*(8), 11–15. https://doi.org/29.7722/0283011015

Sørvik, G. O., Blikstad-Balas, M., & Ødegaard, M. (2015). "Do books like these have authors?" New roles for text and new demands on students in integrated science-literacy instruction. *Science Education, 99*(1), 39–69. https://doi.org/10.1002/sce.21143

Supiandi, M., I., & Julung, H. (2016). Pengaruh model Problem Based Learning (PBL) terhadap Kemampuan memecahkan masalah dan hasil belajar kognitif siswa biologi SMA. *Jurnal Pendidikan Sains, 4*(2), 60–64. https://doi.org/10.17977/jps.v4i2.8183

Suwono, H., Pratiwi, H. E., Susanto, H., & Susilo, H. (2017). Enhancement of students' biological literacy and critical thinking of biology through socio-biological case-based learning. *Jurnal Pendidikan IPA Indonesia, 6*(2), 213–222. https://doi.org/10.15294/jpii.v6i2.9622

Ünal, C., & Özdemir, Ö. F. (2013). A physics laboratory course designed using problem-based learning for prospective physics teachers. *European Journal of Science and Mathematics Education, 1*(1), 29–33. http://www.acarindex.com/dosyalar/makale/acarindex-1423880574.pdf

Wang, C., Boukhtiarov, A., DiBiase, W., & Steck, T. R. (2012). The use of open-ended problem-based learning scenarios in an interdisciplinary biotechnology class: Evaluation of a problem-based learning course across three years. *Journal of Microbiology & Biology Education, 13*(1), 2–10. https://doi.org/10.1128/jmbe.v13i1.389

Wirdianti, N., Komala, R., & Miarsyah, M. (2019). Naturalist intelligence and personality: An understanding students' responsible environmental behavior. *JPBI (Jurnal Pendidikan Biologi Indonesia), 5*(2), 229–236. https://doi.org/10.22219/jpbi.v5i2.7193

Wulandari, R. (2017). Berpikir ilmiah siswa dalam pembelajaran IPA untuk meningkatkan literasi sains. *SEJ (Science Education Journal), 1*(1), 29. https://doi.org/10.21070/sej.v1i1.839

Zhu, Y. (2019). How Chinese students' scientific competencies are influenced by their attitudes? *International Journal of Science Education, 41*(15), 2094–2112. https://doi.org/10.1080/09500693.2019.1660926