

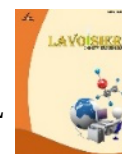


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Analysis of Students' Science Process Skills in Project-Based Chemistry Learning Integrated with Education for Sustainable Development

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Abstract: This study aims to analyze the profile of science process skills through the implementations of project-based learning integrated education for sustainable development on acid-base material. The aim of the project is to create a natural acid-base indicator that can determine the pH range of various solutions and the concentration of a solution using the titration method. This study uses a qualitative research method, the interpretive paradigm with the research subjects of XI IPA students in Jakarta totaling 29 people. Data collection techniques are carried out by class observation, reflective journals of student, interviews, and tests of science process skills. The results showed that science process skills arises during learning and were classified as very good with an average value of 86.99% according to observations and classified as good with an average value of 72.26% in the test of science process skills. Students apply the education for sustainable development (ESD) concept during the project by choosing safe solvents and conducting small-scale experiments to reduce the waste produced. The application of this project is expected to make students have the skills of a researcher by paying attention to sustainable development in every decision they make during learning.



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1. Introduction

The concept of education for sustainable development (ESD) has three pillars namely environmental, economic and social (Svanström, M., Lozano-García, F. J., & Rowe, 2008; Olsson et al., 2016; Sinakou et al., 2019). The introduction of this concept is expected to make students responsible for the environment in making decisions related to economic and social issues (Jegstad & Sinnes, 2015). This is important because the knowledge instilled in students today will influence the decisions they make in the future. 21st-century competency is also a demand that must be mastered by students in this era, such as critical thinking, creativity, collaboration, and communication. School is one place to develop this competence through the learning process. One learning model that can develop 21st-century competence is project-based learning (PjBL). (Amaral et al., 2015; Kızıkan & Bektaş, 2017; Sumarni, 2015).

Every stage of PjBL conditions students to be actively involved in solving problems by producing products. Through investigation, the use of tools and learning media this learning is able to improve skills in investigating or process science skills such as formulating problems, designing experiments, making products, testing products through experiments and then communicating project work (Septiani, A., & Rustaman, 2017; Yalçın et al., 2009; Yam & Rossini,

2010). Increasing these skills also helps build knowledge that involves the ability to think skills, creative thinking skills and problem-solving skills (Özgelen, 2012; Temiz, B. K., Taşar, M. F., & Tan, 2006).

PjBL learning is right to be integrated with the ESD concept to train students to make decisions. Like Kricsfalusy et al. (2018) said that provide students with opportunities to acquire knowledge and skills to better address sustainability challenges. One application of ESD in chemistry education is carried out by presenting four ESD strategies, namely: Adopting green chemistry, incorporating ESD content in learning, incorporating socioscientific issues, utilizing chemical learning as part of developing ESD-based school culture (Burmeister et al., 2012).

Acid-base material that has wide applications such as using chemical compounds in households and the chemical industry impacts the environment (Cigdemoglu, C., Arslan, H. O., & Cam, 2017). The characteristics also require an experimental method and are proven to be able to train students to produce products (Addiin, Redjeki, 2014). Duda, H. J., Susilo, H., & Newcombe (2018) said that he stage of project carried out by the experimental method gave rise to science process skills. Based on these characteristics, the application of an integrated ESD chemical content is carried out through a project to produce natural acid-base indicators that adopt the principle of green chemistry. This research is expected to make students trained in making projects by applying the concept of ESD to practice science process skills.

2. Research Methodology

Qualitative methods with interpretive paradigms have applied the descriptions, views, and explanations regarding the profile of science process skills. Interpretative research allows researchers to collect data from various sources, as long as the data collected is still in the context of the research conducted (A. S. Thomas, 1998). The research subjects in this study were 29 students of XI Science class in Jakarta, who was accustomed to experimenting with work procedures, tools and materials available at the student's desk. The steps of student's project can be seen in Figure 1. Learning begins with giving a discourse on chemical content related to environmental issues related to acid-base material such as acid rain, detergent waste and the use of synthetic indicators in schools.

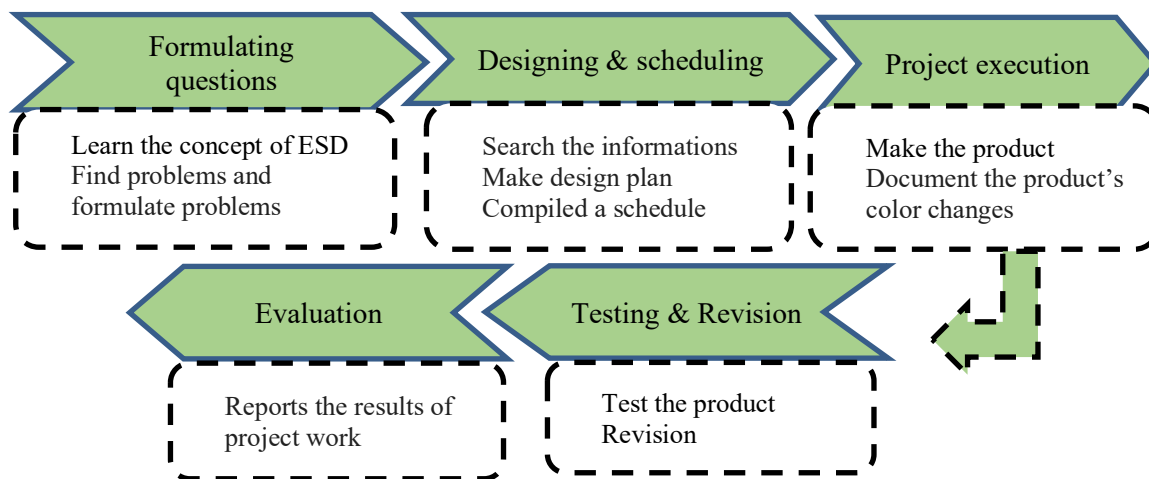


Figure 1. Project Learning Syntax

Learning is done following the syntax of PjBL for 6 meetings. Learning begins with giving a discourse on chemical content related to environmental issues related to acid-base material such as acid rain, detergent waste and the use of synthetic indicators in schools. Next, the teacher explained the concept of ESD. ESD integration in learning is carried out by incorporating ESD content into learning and applying the principles of green chemistry in the laboratory in the form of prevention of waste generation, safe chemical product design, use of renewable raw materials, safe use of solvents, and design of easily degraded chemicals. Through the discourse, students are directed to find problems and formulate problems to replace synthetic indicators with natural indicators in groups with members of 3-4 people.

At the second meeting, each group planned the making of natural indicators and compiled a schedule and reported it to the teacher. Project planning is done by searching for information through Google and YouTube. At the end of the lesson the teacher notifies students that at the next meeting, the natural indicators made by students will be reacted with various pH

solutions to determine the change in indicator color at various pH so that at the front meeting each group carries a camera. At the third meeting, students bring plants that will become natural indicators and work in groups. The tools needed by all groups have been prepared based on the previous meeting report so students must take the necessary tools themselves. After that students react natural indicators with a solution of pH 1-14 to obtain a standard color from natural acid-base indicators at each pH. The color change that occurs is documented to be a pH scale that will be used for the next meeting.

At the fourth meeting, the products made by each group were tested to determine the pH range of several solutions such as soap solution, lime juice, rainwater, NaOH, HCl, NH₃ and CH₃COOH solutions of 0.1 M. After obtaining the data, the teacher guiding students to calculate the pH of a solution known for their concentration and compare with the results of the experiment. At the fifth meeting, students test natural indicators to determine the concentration of acid or base through the titration method. The experiment was carried out like 2-3 times using the natural indicator of jambolan fruit skin as much as 6 drops at 10 mL titrant as a comparison. At the sixth meeting, each group reports the results of the project work to the entire class. Some groups present reports in the form of powerpoints and some in the form of videos. In this presentation, each group presents work methods to conclusions regarding the ability of natural indicators to determine the pH range of the solution and the titration method. Other students are given the opportunity to give the question to each other and the teacher help the group to answer questions that cannot be answered.

In this research, test questions, observation sheets, interviews, and reflective journals used to collect data profile on students' science process skills in the form of formulating hypothesis, asking questions, designing experiments, using tools and materials, experiments conducting, observing, classifying, applying concepts, interpreting and communicating. Test questions are used to analyze science process skills through students' understanding of acid-base material. The observation sheet was used by two observers to assess students during learning, reflective journals to find out what was felt at the end of each lesson and interview to find out in depth the reasons for each activity by students during learning.

Interviews were carried out in two ways, first carried out using a mobile messenger when the research subjects were unable to conduct direct interviews and second interviews conducted in groups with the help of a voice recorder to prevent data loss and facilitate researchers to capture the connection answers between group members. Interviews were conducted to explore the reasons students answer questions in tests and reflective journals. Group interviews take 30-45 minutes.

After the data is collected, the data is analyzed by data reduction, presentation, and conclusion drawing. Data obtained through test and observation questions are processed to produce presentations of students' science process skills while reflective journals and interviews are reduced to selecting data that is suitable for research purposes. The results of the reduction are presented in descriptive and diagrams.

3. Result and Discussion

Based on observations by observers, students' science process skills are classified as very good with 86.99% presentation while based on the results of process skills tests are classified as good with a presentation of 72.26%. The detailed results of observations and tests of science process skills are found in Figure 2.

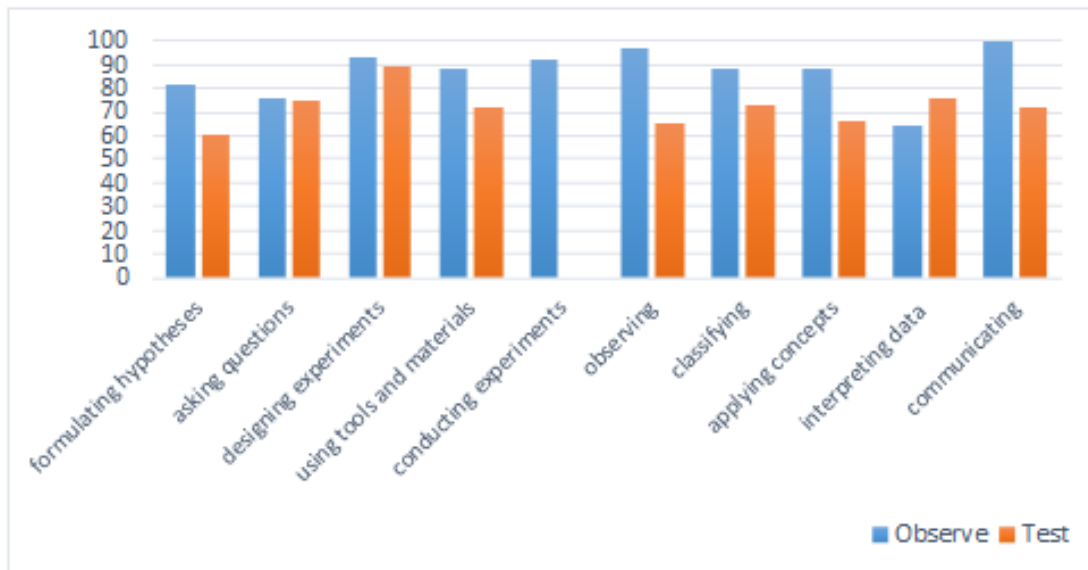


Figure 2. Profile of Science Process Skills of Students

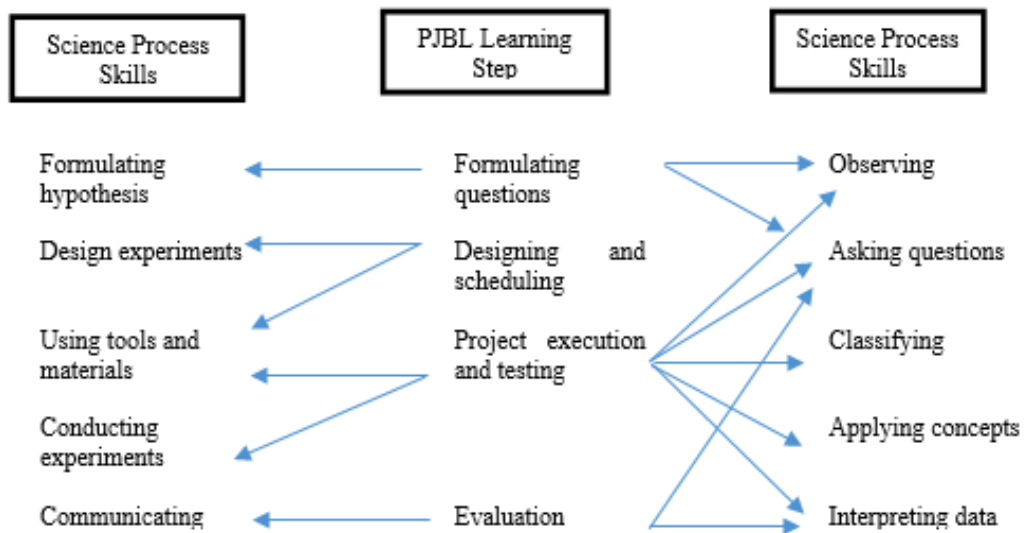


Figure 3. Profile of Science Process Skills in Project Based Learning

The results indicate that the skills of interpreting data, observing, composing hypothesis and applying concepts are relatively low compared to other skills. The profile of science process skills observed during learning with the PjBL model is shown in Figure 3 with the following details:

Formulating hypothesis. This skill is observed at the formulating questions stage. This skill arises in 81.67% based on observations and 60.83% based on test questions. At the beginning of learning it was observed that some students had difficulty in making hypotheses and need teacher guidance. while some students make the hypothesis well by paying attention to the ESD concept in making the project. Making hypotheses is a skill they have learned in Bahasa Indonesian lessons but it is observed that some students have difficulty using good sentence structures. This is in line with (Akinbobola & Afolabi, 2010) that the difficulty of making a hypothesis occurs because it is not used to being trained in learning. Some results of observation, interview and reflection journals on formulating hypothesis can be seen in Table 1.

Table 1. Results of observation, interview and reflection journals on formulating hypothesis

Source	Statement
Observation sheet	<i>"The skill of composing hypothesis for some students is not yet good. Students are able to make a hypothesis as answers to the formulation problem but the sentence structure is incorrect." (Observer 2, January 28, 2019)</i>
Reflective Journal	<i>"The hypothesis is clear and directed, namely about natural acid-base indicators that can determine pH by reducing waste use, especially synthetic chemical waste, so the principle of ESD here is to protect the environment from being polluted and to be able to measure the pH of the solution can also be with natural, more environmentally friendly and cheaper." (Student 14, 8 January 2019).</i>
Interview	<i>"Making a hypothesis is quite difficult because I am not too able to choose every word and arrange it into a hypothesis. However, with group discussions and the help of friends, we can hypothesize the given discourse." (Student 9, 10 February 2019).</i>

Although based on the answers to the test questions it was observed that the hypothesis-making skills were lower than the results of the observation, but students who at the beginning of the study did not really understand the hypothesis were now able to make hypothesis better. This is in accordance with the research by Maghfiroh et al. (2016) that formulating hypotheses is well trained through PjBL learning.

After making a hypothesis, students can then continue the process of making the product. As said by Septiani, A., & Rustaman (2017) that hypothesis skills at the beginning of the project are carried out by understanding the problem in the discourse and knowing the variables to be studied. Through discussion, students communicate by explaining opinions to answer questions (Rauf et al., 2013).

Designing experiments. This skill arises in 93.33% based on observations and 89.33% based on test questions. This activity is not easy to do because the topic and project design of natural indicators are new. This makes students try and think about what designs might be appropriate. Applying concepts is also applied by students when modifying the designs they get from e-search activities. Some results of interview on designing experiments can be seen in Table 2.

Table 2. Results of the interview on designing experiments

Source	Statement
Interview	<i>"We are having trouble because it was the first time we found out about acid-base indicators so I had to find out about any plants, tools, and materials so that I could get an idea of how to make them. In fact, I also find out various kinds of variables that can be used to be able to compare which ones are easier and faster so that in making indicators can save time." (Students 27, 1 February 2019).</i>
	<i>"We crushed turmeric so that more turmeric extract because it is in accordance with the material of the reaction rate, namely the surface area, the finer the particles, the greater the surface area so the faster the reaction and a lot of turmeric to make it more concentrated." (Student 10, February 15, 2019).</i>

The hypothesis made by students is then proven by conducting a planning plan. Technology integration in learning is done through research activities to make students find the information faster like said by Shultz & Zemke (2019) that Information is very much needed in PjBL learning so technology plays an important role. Modification of the project design conducted shows that students become creative when designing experiments by exploring prior knowledge, namely knowledge about the concept of effect of temperature in reaction rates. This is relate by the research by Supasorn (2014) that through the activity of designing experiments students become aware of the application of chemical concepts.

In designing the experiment, students choose the material used. The integration of the ESD concept that appears when students choose to use a drip plate determines that students begin to realize the importance of protecting the environment by reducing waste from laboratory results. This is in accordance with the principles of green chemistry; preventing is better to prevent waste than clean waste (Wardencki et al., 2005).

Using tools and materials. This skill arises in 88.06% based on observations and 71.67% based on test questions. In the usual lab activities, students often forget the names of laboratory equipment so they take the wrong tool. In working on the project, each group determines and selects the tool as needed. In addition to the use of safe solvents such as ethanol. Some results of interview on using tools and materials can be seen in Table 3.

Table 3. Results of interview on using tools and materials.

Source	Statement
Interview	<i>"Our group uses drip plates to make it easier to observe colors because there are many holes. If you use a glass or test tube, you will use many tools to make it more efficient." (Student 22, 4 February).</i>
	<i>"Aside from being white and maybe more obvious, we chose to use a drop plate because the less solution we use, the less waste produced." (Student 10, interview on February 15, 2019).</i>

The titration method in natural indicator testing also increases students' knowledge regarding the use of tools such as burettes and volumetric pipette. Through student test, the student states that burettes are used because the addition of titrants is done every drop with a regulated speed so that the practitioner can focus on changing the indicator color without having to count the number of droplets. This is in accordance with research by (Sumarni, 2015) that said that the PjBL model is a learning experience and practice to provide the tools needed to complete a task.

Conducting experiments

This skill arises in 92.5% learning based on observations. Knowledge of the goals and procedures of project execution allows students to experiment quickly and thoroughly at work. In addition, according to the written steps, even modifying the procedure if their trial is considered unsatisfactory. Modification of the project design conducted shows that students become creative when designing experiments by exploring prior knowledge, namely knowledge about the concept of reaction rates. Through the activity of designing experiments students become aware of the application of chemical concepts (Supasorn, 2014). Some results of interview on conducting experiments can be seen in Table 4.

Table 4. Results of interview on conducting experiments.

Source	Statement
Interview	<i>"I became more careful and cleaner when working on experiments because I didn't want my product to fail." (Student 10, 10 February 2019).</i>
	<i>"When doing this experiment I was trained to get the desired results. We tried using two solvents, apparently using ethanol resulted in an extract that produced more beautiful colors than using heated distilled water solvents." (Student 9, 10 February 2019).</i>

The PjBL model requires students to conduct experiments to test hypotheses. The skill of conducting experiments was considered very good because each group chose tools and materials and carried out experiments according to the steps that had been written. This is in accordance with research by (Maghfiroh et al., 2016) which states that the PjBL model is able to improve the ability to conduct experiments.

Observing

This skill arises in 97.15% based on observations and 65% based on test questions. In this skill there is a fairly large difference in results between observer observations and test results, according to the researcher this is because so far practicum activities have been carried out with practicum books that inform the changes that must be observed so that students are not accustomed to observing each change. This is in accordance with what was expressed by (Feyzioğlu, 2009), that the use of practicum books makes students only focus on observations after the experiment.

In this stage students observe the experiments conducted to determine the best procedure. In testing natural indicators with titration methods, observing skills are seen when students determine the end point of the titration and the measurement of the volume of the titrant needed. Students must focus on the erlenmeyer solution and continue to shake so that the dripping titrant is homogeneous with the solution in Erlenmeyer. Some students have difficulty doing that while others don't. Some results of interview on observing can be seen in Table 5.

Table 5. Results of interview on observing

Source	Statement
Interview	<p><i>"We observed differences in color density when the purple cabbage was not smoothed and smoothed, we observed differences in discoloration when boiled and if the purple cabbage was stirred and not stirred. then we observe the color change of the purple cabbage indicator when it is pH 1-14. from there we observed that the smoothed, boiled and stirred purple was faster and the color after dropping pH 1-14 was clearer then we used the method of work."</i> (Student 4, February 15, 2019).</p> <p><i>"The color change happens very quickly, just adding one drop suddenly the color can change, we must really focus on observing the color change."</i> (Students 14, 9 February 2019).</p> <p><i>"I dripped the titrant slowly, occasionally there was a change in color but when it was shaken the color disappeared again and then I added it again and finally the change changed clearly so that I had no difficulty."</i> (Student 30, February 9, 2019).</p>

Measuring the volume of the titrate is important to determine the concentration of titrant. Through interviews, the way students observe changes in volume is by looking at the meniscus draw in Figure 4

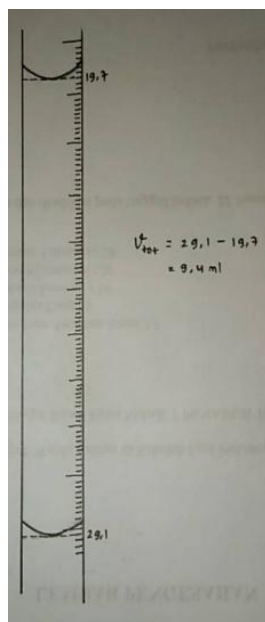


Figure 4. Titrant Measuring

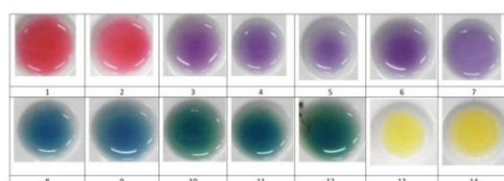


Figure 5. One of student's pH scale

Based on observation, the group uses as many senses as possible to collect data both before and after the experiment. This is different from the laboratory activities using a practical book that has written the changes that must be observed. This requires students to pay attention to the observed aspects. This is in accordance with Abungu et al. (2014) that in observing skills, students must pay attention to the observed aspects because they involve the five senses to understand objects. In the application of the PjBL model this time, most of the activities were carried out by experimentation and through laboratory activities observing the development of students (Hofstein et al., 2004).

Classifying

This skill arises in 87.92% based on observations and 72.66% based on test questions. In this research, the students classify solutions that are classified as acid or base along with the strength of the acid or the base. Student's pH scale (Figure 5) helps students classify solutions according to the color equation observed.

Classifying skills are considered good when distinguishing acidic and basic solutions based on observing the color of the indicator. However, in the classification of the strength of acid-base solutions, it was found that some students experienced misconceptions. The exact classification is observed from several students who classify by applying the concept of ionization. Some results of interview on classifying can be seen in Table 6.

Table 6. Results of interview on classifying

Source	Statement
Interview	<i>"Based on the color we just have to see, if the pH is 7 means neutral, below 7 means acid, above 7 bases. pH 1-3 is strong acids, 4-6 weak acids, 8-11 weak bases, 12-14 strong bases."</i> (Student 14, 8 February 2019).
	<i>"0.1 M HCl has a pH of 1, it means that the acid is strong because it is perfectly ionized if CH₃COOH 0.1 M turns out to use its pH indicators like pH 3 and above, it means that it is only slightly H⁺ so that it is weak".</i> (Student 26, 8 February 2019).

Classification carried out by students depends on students' observations of changes in indicator colors, so that the data collected on project work must be collected and documented properly. The classification of solutions based on the strength of acid-base solutions is detected by misconceptions that occur in acid-base material. Misconceptions occur when students think the higher pH the stronger the base solutions and the lower pH the stronger the acidic solution. This is relate with previous research by Amry & Rahayu (2017). The right concept is captured by students because active learning provides an opportunity to observe directly so that can reduce the possibility of misconceptions in acid-base material (Sesen & Tarhan, 2011). Combining observing skills and applying concepts has helped develop students' classifying skills. This is in accordance with the research of (Rahmasiwi et al., 2015) that science process skills are interconnected with each other.

Asking question

This skill arises in 75.42% based on observation and 75% based on a test question. This skill was seen when students make problem formulation, work on projects and group presentations. students ask questions about things they want to know both to the teacher and search through google. Some results of interview on asking question can be seen in Table 7.

Table 7. Results of reflective journal, interview on asking question

Source	Statement
Reflective journal	<i>"I ask because I don't understand and ask questions better because, in the end I get maximum results."</i> (Student 18, 11 February 2019).
Interview	<i>"We searched Google for some info like the best temperature to heat purple cabbage solvents, whether or not to boil."</i> (Student 22, 11 February 2019).

Through PjBL with an open experimental method, students have the opportunity to discuss an experiment that will be carried out, develop a hypothesis and plan experiments that are characteristic of the research. In addition active learning such as PjBL makes active students ask, even though some students are still embarrassed to express their opinions in public because they

are embarrassed that the question is considered too easy, but in process students ask both to group friends and teachers. This is in accordance with what was conveyed by Wiranto in (Suryaningsih, 2017) that the skill of asking questions arises when students ask questions to ask for an explanation, about what, why, how, or ask the background of the hypothesis. about how, what and why related to the project made, and Hofstein, Shore, & Kipnis (2004) said that experimental activities that provide opportunities for students to be actively involved can improve the ability to ask questions.

Applying concept

This skill arises in 88.61% based on observations and 66.25% based on test questions. According to the observations, the students apply ESD concepts by dispose the waste in the space provided and had washed and dried the practicum equipment before use to avoid contamination from unclean lab equipment. The interview on applying concept can be seen in Table 8.

Table 8. Results of interview on applying concept.

Source	Statement
Interview	<i>"A plant can be used as an acid-base indicator because it has a weak anthocyanin acid compound. Adding acid or base will shift the equilibrium so that the color changes."</i> (Student 26, 8 February 2019).

After observation and classification stage, students apply the concept to explain the working principle of acid-base indicators. Students are directed to apply the equilibrium concept to explain why indicators can change color in acids or base. A plant can be used as an acid-base indicator because it has a weak anthocyanin acid compound. Adding acid or base will shift the equilibrium so that the color changes. The application of other concepts such as the calculation of pH is also needed to answer whether the acid-base indicators they make are successful.

PjBL learning that involves experimentation makes students accustomed to applying concepts to complete projects. (Suhanda & Suryanto, 2016) said that PjBL can improvement of applying skills.

Interpreting

This skill arises in 64.79% based on observation and 76.11% based on test questions. The skill of students to interpret is relatively good, although not as high as other skills. This skill arises because students have made a hypothesis and know the purpose of the project that makes it easy for them to draw conclusions. Some results interview on formulating hypothesis can be seen in Table 9.

Table 9. Results of interview on interpreting

Source	Statement
Interview	<i>"Conclusions are made to answer the practical objectives so it is not difficult to conclude whether our artificial indicators failed/succeeded."</i> (Student 14, 10 February 2019).
	<i>"I think our natural indicators are successful because the concentration of HCl in the trial uses our indicator with the jambolan fruit skin indicator not much different after 2 trials."</i> (Student 11, 10 February 2019).

Collection of all data, classification, and application of concepts helps students to interpret the results of the experiment. This is in accordance with Abungu et al. (2014) that interpreting skills are cognitive abilities that make students think logically to connect the data they get during the experiment.

Communicating

This skill arises in 100% presentation based learning and 72.22% based on test questions in science process skills. Based on observations, each group actively conducts discussions during project planning and work. Some results interview on communicating can be seen in Table 10.

Table 10. Results of interview on communicating

Source	Statement
Interview	<p><i>"I became more communicative because of frequent discussions with group friends about what to do so that the project succeeded."</i> (Student 13, February 15, 2019).</p> <p><i>"Our group uses tables because tables are not long-winded, easy to understand, many people more easily understand the contents of a table than reading long sentences so that it is more practical but it still contains the information that is needed, also easily made."</i> (Student 14, 4 February 2019).</p> <p><i>"When making indicators we do two ways and the results are different. Therefore at the power point, we display both of them so that friends can see and compare the results of our work that the ratio of cabbage to water (2: 1) results in a clearer color change."</i> (Student 19, 11 February 2019).</p>
Observation	<i>"The communication skills of students look good because students can convey what they have done to their friends with an attractive and easy-to-understand appearance."</i> (Observer 2, 11 February 2019)

Experimental data obtained is collected by students and displayed in a form that they easily understand. At presentation, students' skills are assessed based on delivering presentations and presentations. The results of other interviews stated that students did not experience difficulties when communicating the results, even though they felt they were not ready at the presentation.

Evaluation and reflection activities in PjBL are carried out by communicating the results of project work through presentations in class. Through presentation, communication is carried out in various forms including words, actions, graphics, symbols to describe an action or event (Turiman et al., 2012). Questions that arises from other students to groups making presentations should be higher than what is observed if students have high self-confidence (Burrows, 2017). The learning environment affects students' self-confidence, the prominence of active and critical students asking makes students feel ashamed to ask questions.

4. Conclusion

Through the integrated PjBL learning model of education for sustainable development, it can be concluded that the profile of science process skills of students is very good with an average value of 86.99% according to observations and classified as good with an average value of 72.26% on science process skills tests. Students apply the ESD concept during project work by choosing to use safe solvents and conducting small-scale experiments to reduce the waste produced. The application of this project is expected to make students have the skills of a researcher by paying attention to sustainable development in every decision they make during learning.

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