PROJECT-BASED LEARNING IN CREATING EDIBLE STRAWS FROM RED DRAGON FRUIT PEEL TO DEVELOP SCIENCE PROCESS SKILLS

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Abstract

This study aims to analyze the implementation of project-based worksheets utilizing red dragon fruit peel waste (*Hyolocereus polyrhizus*) to develop students' science process skills (SPS). The method used was pre-experimental with a one-shot case study design, conducted at a vocational high school in Cimahi City involving 31 students from class XI Industrial Chemistry-C. The research instruments included student activity observation sheets, project-based worksheets, and SPS performance sheets. The results showed an average student activity score of 95%, cognitive SPS score of 90%, and psychomotor SPS score of 96%, all categorized as very good. The project-based worksheet on making edible straws from red dragon fruit peel waste proved to be highly feasible and effective in developing students' SPS.

Keywords: project-based worksheet; science process skills; edible straw; red dragon fruit peel

Abstrak

Penelitian ini bertujuan menganalisis penerapan lembar kerja (LK) berbasis proyek dengan memanfaatkan limbah kulit buah naga merah (*Hyolocereus polyrhizus*) untuk mengembangkan keterampilan proses sains (KPS) peserta didik. Metode yang digunakan adalah pre-eksperimental dengan desain *one-shot case study*, dilaksanakan di salah satu SMK di Kota Cimahi dengan 31 peserta didik kelas XI Kimia Industri-C. Instrumen penelitian meliputi lembar observasi aktivitas peserta didik, LK berbasis proyek, dan lembar kinerja KPS. Hasil menunjukkan rata-rata aktivitas peserta didik sebesar 95%, nilai kognitif KPS 90%, dan psikomotorik KPS 96%, yang termasuk kategori sangat baik. LK berbasis proyek dalam pembuatan *edible straw* dari limbah buah naga merah terbukti sangat layak dan efektif untuk mengembangkan KPS peserta didik.

Kata kunci: LK berbasis proyek; keterampilan proses sains; *edible straw*; kulit buah naga merah

Introduction

Science education plays a crucial role in preparing the younger generation to face the increasingly complex challenges of a continuously evolving modern society. It is founded on practice and interpretation and is designed to engage students in scientific inquiry (Behera, 2023). In this context, chemistry is one of the branches of science acquired through observation and the analysis of substances and their transformations (Raymond, 2022). Students in science classes, especially chemistry, are expected to develop science process skills in the acquisition of knowledge and skills scientifically (Beichumila et al., 2022). Therefore, chemistry is a discipline grounded in up-to-date research. Nevertheless, science learning is not solely focused on memorizing facts and concepts but also involves the development of skills essential for understanding and exploring the scientific world (Sunarya et al., 2022). One of the key elements in science learning is the development of science process skills (SPS).

SPS are skills that focus students on learning processes aimed at developing their abilities to understand concepts, as well as to cultivate facts and values relevant to everyday life (Widdina et al., 2018). These skills encompass both cognitive abilities, such as information processing, critical thinking, and problem solving and group psychomotor skills, including interpersonal communication, teamwork, and management (Sunarya et al., 2023). They represent essential learning goals, as these competencies are required in the workplace and are expected to be possessed by members of the scientific community (Reynders et al., 2019).

In reality, students still demonstrate low levels of science process skills. This deficiency is primarily due to their limited understanding of scientific concepts in learning (Af'idayani et al., 2018). This issue arises from instructional practices that prioritize cognitive aspects over other domains for instance, assigning excessive homework and relying on one-way, content-centered teaching (Subarkah et al., 2016). In secondary schools, chemistry instruction is often dominated by lecture-based methods, which result in low student creativity in problem-solving, minimal participation, inefficient learning activities, and poor academic outcomes (Nnoli, 2024). The study showed that learning the science process skills approach resulted in higher learning achievement than the conventional lecture method on reduction and oxidation materials. Based on the paired t test, the average score of the experimental group's posttest was 15.0 (SD = 3.09), while the control group was only 9.09 (SD = 2.31), with a significance value of $p = 0.00$ ($p < 0.05$) (Majeed et al., 2023)

This condition is further complicated by the abstract nature of chemistry content and the tendency of educators to deliver instruction in a one-way manner, which results in students being less active during the learning process. Therefore, it is essential to implement instructional models that encourage students to be more active, critical, and capable of designing and solving problems through direct experience with a series of scientific processes. Student-centered learning activities can foster critical thinking, investigation, communication, and interaction during experimentation (Farida et al., 2017).

Given these challenges, there is a clear need for a new instructional approach that promotes student engagement and scientific skills development. One of the learning approaches considered effective in addressing these needs is the Project-Based Learning (PjBL) model. Project-based learning provides students with opportunities to engage in concrete learning activities, develop solutions, and practice real-world decision-making (Lou et al., 2017). PjBL is also specifically designed to equip students with both content understanding and problem-solving skills (Budner & Simpson, 2018).

The syntax of project-based learning can guide students toward solving real-world problems (Almulla, 2020). Problem-solving skills are a crucial aspect to be developed throughout the educational journey, with particular significance in the field of chemistry education (Sunarya et al., 2024). In this context, student worksheets play an essential role in facilitating PjBL by embedding SPS indicators directly into project tasks, allowing students to engage in observation, classification, experimentation, and interpretation throughout the learning process. Thus, PjBL, supported by well-structured worksheets, becomes an effective means of developing SPS.

SPS encompass both cognitive and psychomotor aspects, which can expand prior understanding or generate new ideas, principles, and innovations (Winandika, 2020). There are ten indicators that can be developed within science process skills, including identifying problems, posing questions, formulating hypotheses, designing experiments, making observations, interpreting observation results, applying concepts, classifying, communicating, and drawing conclusions (McLaughlin et al., 2024).

PjBL for developing SPS in students can be implemented using project-based worksheets that assist students in planning and designing projects during learning activities (Ruder & Stanford, 2020). The use of project-based worksheets can enhance students' science process skills. This aligns with findings that the implementation of project-based learning increases student engagement in the learning process and is capable of developing their SPS (Fatnah et al., 2021).

PjBL model can be linked to real-life issues, such as plastic waste, particularly single-use plastic straws (Baran et al., 2018). According to data from the Ministry of Environment and Forestry, Indonesia generates 64 million tons of waste annually, of which 14% is plastic waste. Most of the plastic waste in Indonesia consists of straws, totaling 93.2 million units per day (Purwaningrum, 2016). Recycling plastic waste is more challenging for conventional plastic straws, which are difficult to separate and process due to the widespread disposal after use (Guo et al., 2023). An effective way to reduce plastic straw waste is through the production of edible straws.

Edible straw is made from a mixture of polysaccharides, lipids, and proteins(Liu et al., 2024). Edible straw is the right choice because it is food grade and zero waste. (Petchimuthu, 2021). The peel of red dragon fruit (*Hylocereus polyrhizus*) has potential as a raw material for the production of edible straws, as it constitutes 30–35% of the fruit and contains approximately 19.39% pectin, which can serve as a natural binding agent (Riyamol et al., 2023). This innovation aligns with Sustainable Development Goal 12: Responsible Consumption and Production, which emphasizes reducing food loss and waste throughout production and consumption chains. Utilizing fruit peel waste, such as dragon fruit skin, contributes to a circular economy approach by converting agricultural by-products into value-added products, thus minimizing environmental impact and promoting sustainable resource use (United Nations, 2015).

Based on the background described above, this study aims to analyze the implementation of project-based worksheets utilizing red dragon fruit peel waste to develop students' science process skills. While the theme of edible straw production has been previously applied in green chemistry topics, this research innovatively integrates waste valorization of red dragon fruit peel within project-based learning to enhance both practical skills and environmental awareness. This novel approach addresses the gap in combining hands-on scientific inquiry with sustainable waste management in chemistry education.

Method

This study focuses on student activities and PjBL to develop students' science process skills (SPS). A pre-experimental method with a one-shot case study design was employed. This research design was chosen because it does not involve a control group; thus, the treatment is applied to a single group, followed by observation of the outcomes (Sugiyono, 2021).

This study aims to develop a product in the form of a worksheet, referred to as a student worksheet. The worksheet developed in this research is based on PjBL and is oriented toward the application and processing of organic waste, incorporating green chemistry concepts.

The subjects of this study were students of Grade XI Industrial Chemistry-C at a vocational high school (SMK) in Cimahi City during the 2024/2025 academic year. The focus was on the application and processing of organic waste. The students were divided into five groups, each consisting of 6–7 members, and were given a treatment involving the implementation of project-based worksheets. Subsequently, observations were conducted to assess their SPS, which served as the main focus for analysis and data collection in evaluating the impact of the applied method or treatment during the study.

The data collection techniques in this study included: (1) observation sheets to monitor student activities during project-based learning; (2) student worksheets as evidence of project implementation and outcomes; and (3) performance assessment sheets (assessment rubrics) to evaluate the SPS demonstrated by students throughout the learning process. The data were analyzed using a descriptive quantitative approach, which involved calculating the average scores and percentages from the observation sheets and SPS performance rubrics.

Instrument validation was conducted prior to data collection to ensure the reliability and feasibility of the observation sheets, performance rubrics, and project-based worksheets. The validation process is described in the Preparation Phase subsection. The research was carried out in three phases: (1) the Preparation Phase, which involved instrument development and validation; (2) the Implementation Phase, where PjBL activities were carried out and data were collected; and (3) the Conclusion Phase, where data were analyzed and findings were interpreted.

The preparation phase included key activities to ensure instrument validity and the effective implementation of the PjBL model. It began with designing observation sheets, student worksheets containing SPS indicators, and performance assessment rubrics to evaluate SPS during the project. Validation was carried out prior to the research by three validators who are experts in their fields. The validation assessed three aspects: presentation, construct, and content. The results are presented in Figure 1.

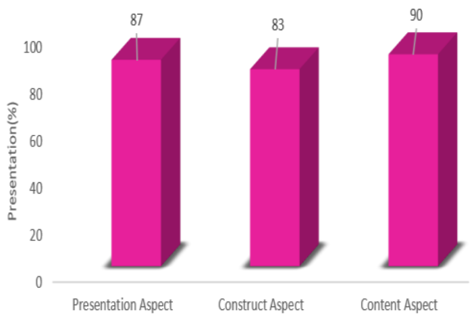

Figure 1. Graph of Expert Validation Scores for the Worksheet

The average score shown in Figure 1 is 88, which can be interpreted as a high feasibility rating. (Puspitasari & Febrinita, 2021). The instrument used in this study was deemed valid.

The implementation phase began with an explanation to students regarding the description and objectives of using project-based worksheets to create edible straws from dragon fruit peel waste. Students were divided into small groups and conducted experiments, which were assessed by observers. They were guided to complete the worksheets, reflect on the experimental results in relation to the theories previously studied, and discuss any challenges encountered during the process.

The final phase involved analyzing the collected data to evaluate student performance and the outcomes of the practicum. The results of the analysis were presented and described to provide an overview of the research findings. Conclusions were drawn based on the data analysis as a response to the research questions identified.

Result and Discussion

This section presents the results of implementing project-based worksheets to enhance students' science process skills in the context of green chemistry. Student activity data during the learning process were collected through observation by three observers. The overall average activity score was 95, indicating a "very good" level of student engagement. The highest scores 100 were observed in the indicators of *problem identification*, *conducting experiments*, and *closing*. The lowest score 87 was found in the *product rating* activity, which still falls under the "very good" category. These results suggest that students actively participated across all stages of PjBL. A detailed breakdown of scores for each activity is presented in Table 1.

Table 1. Average Scores of Student Activities at Each Stage of PjBL

No.	Student Activities	Average	interpretation
1	Introduction	89	Very good
2	Identifying the problem	100	Very good
3	Designing the project	94	Very good
4	Conducting an experiment	100	Very good
5	Drafting/prototype of product	98	Very good
6	Product Rating	87	Very good
7	Finalization and publication of the product	92	Very good
8	Closing	100	Very good

The observation sheet was used solely to assess student activity during the learning process. Therefore, in addition to measuring student activity, this study also focused on the development of students' science process skills using project-based worksheets and was supported by performance sheets. The performance sheet was specifically designed to assess students' performance during the experimental activities. These supporting instruments the worksheet and performance sheet were used to observe both the cognitive and psychomotor development of science process skills. The project-based worksheet served as a learning medium that embedded indicators of science process skills, aiming to stimulate students to think critically and to design and solve scientific problems.

In the problem identification stage, there were two indicators. The first indicator of science process skills was observing. The researcher divided the students into five groups consisting of 6–7 members each to facilitate discussion. The students were then given a reading passage to help them identify a problem that they needed to discuss and resolve collaboratively. In the observation aspect, students were able to answer the questions provided after reading the passage. This outcome was supported by the group seating arrangement, which allowed them to engage in discussion and collaborate effectively during the learning process (Candia et al., 2022).

The identified problems were then directed to the next indicator, which is formulating questions. At this stage, the students were able to develop problem statements based on the issues presented in the passage. The average score obtained was 86, which is interpreted as very good. This outcome is attributed to the students' strong curiosity about edible straws that can be made by utilizing red dragon fruit peel (*Hylocereus polyrhizus*). The indicator of formulating questions requires higher-order thinking skills (Jais et al., 2021).

The next stage was the project design, which included the science process skills indicator of designing an experiment. This involved formulating the objectives of the experiment, identifying the principles behind it, selecting the tools and materials, and outlining the experimental procedures in the form of a flowchart. In this indicator, students analyzed information based on a given context and a series of experimental images provided in the worksheet. The average score obtained by the students was 81, which falls into the "very good" category.

The next stage was conducting the experiment, which included the science process skills indicator of making observations. Students carried out the experiment and recorded the process and observations both in terms of treatments applied and the outcomes observed using the worksheet and the science process skills performance sheet. At this stage, the students achieved an average score of 100, which is categorized as "very good." The resulting edible straw products made from red dragon fruit peel can be seen in Figure 2.

Figure 2. Edible Straw Products from Red Dragon Fruit Peel: (a) dried using a dehydrator, (b) dried using an oven

In Figure 2, (a) shows the edible straw dried using a dehydrator at 60°C, while (b) shows the edible straw dried using an oven at the same temperature. However, the drying methods resulted in different colors of the edible straws. This difference is attributed to the stability of anthocyanin pigments, which is influenced by factors such as pH, light, and temperature (Nassour et al., 2020).

Degradation of anthocyanin pigments occurs in the oven due to higher temperature and oxidation, which cause the anthocyanins to break down more rapidly, resulting in a faded, brownish, or dull color. In contrast, the dehydrator maintains a more stable and controlled temperature, with hot air circulating effectively. The drying process is slower and more uniform, preserving the structure and color of the anthocyanin pigments. The slow-moving dry air reduces oxidation and overcooking, thus maintaining the reddish-purple color of the peel (Mattioli et al., 2020).

This was followed by the stage of drafting/prototyping the product, which included the indicator of interpreting observation results by applying theoretical concepts to the observed outcomes. In this stage, students were required to organize their observation data into paragraphs and relate their findings to relevant theoretical concepts. However, students encountered difficulties in finding coherent theoretical references from academic journals, as they were not accustomed to searching for information in such sources (Aziz et al., 2024). The average score achieved by the students for this indicator interpreting observation results using theoretical concepts was 74, which falls into the "good" category.

In the product evaluation stage, the science process skills indicator involved was classifying. Students compared and assessed the characteristics of the edible straw products they had made with those produced by other groups. The evaluation was based on the results of organoleptic tests (color, aroma, taste), swelling tests (absorption capacity), and solubility tests. These tests were conducted by the students, as shown in Figure 3.

Figure 3. Students' Activities During Product Testing

Good characterization was determined based on the organoleptic test results, where the product exhibited no taste, no strong odor, and displayed a reddish-purple color (the natural color of dragon fruit peel). This is important to ensure that the edible straw made from red dragon fruit peel does not alter the taste of beverages consumed. Furthermore, in the absorption test, the swelling did not exceed 150%, and the solubility test showed complete dissolution, indicating that the edible straw easily decomposes when immersed in water (Deswinta et al., 2024). At this stage, students produced products with varying characteristics; however, they were able to compare the differences, analyze the distinguishing factors, and classify which product was the best. The highest quality product was the edible straw made with 35 grams and 40 grams of red dragon fruit peel. Students achieved an average score of 100, which is interpreted as "very good."

The final stage was finalization and publication, which included the indicators of drawing conclusions and communicating research results. Students prepared experimental reports in the form of scientific posters, which were then presented. The session concluded with a question-and-answer discussion and the reading of the conclusions. In this stage, the researcher assessed the students' presentations and scientific posters, as detailed in Table 2 and Table 3.

Table 2. Average Score of Presentation Assessment

No.	Observed Aspects	Average	Interpretation
1	Title	100	Very Good
2	Purpose of the Experiment	100	Very Good
3	Theoretical Framework	87	Very Good
4	Results and Discussion	93	Very Good
5	Conclusion	87	Very Good
6	References	80	Very Good

Table 3. Average Poster Rating Score

No.	Observed Aspects	Average	Interpretation
1	Introduction	95	Very Good
2	Main Discussion	100	Very Good
3	closing	95	Very Good
4	Systematics of Presentation	100	Very Good
5	Use of language	80	Very Good
6	Effectiveness of material delivery	95	Very Good

The average score obtained for the indicators of drawing conclusions and communicating research results was 85, which falls into the "very good" category. This was supported by the high scores achieved by students in their presentations and scientific posters, which were also classified as "very good." Based on the analysis of each science process skills aspect in the worksheet, it was evident that all students demonstrated science process skills at a "very good" level. The overall average score across all aspects of the worksheet was 90, also categorized as "very good." These outcomes reflect the significant positive impact of using the Project-Based Learning (PjBL) model in the learning process.

The science process skills performance sheet was also used to assess students' psychomotor abilities in applying science process skills. This performance sheet focused on two stages of the PjBL model the project design stage, aligned with the science process skills indicator of designing experiments, and the experiment implementation stage, aligned with the indicator of making observations. During the experiment design phase, students demonstrated a high level of caution and accuracy in selecting the prepared tools and materials. They reported any tools or materials that were in poor condition. Students' sense of responsibility was evident in the careful manner in which they handled laboratory equipment.

In the implementation stage of the experiment, under the science process skills indicator of making observations, three aspects were assessed: sample weighing, solution measurement, and the overall product-making process. During the sample weighing process, some students tended to overlook decimal values, indicating a lack of precision in measurement. However, in measuring solutions such as glycerol and distilled water which are both colorless students were able to measure accurately by ensuring the reading was taken at the bottom of the meniscus. In the overall product-making process, students followed the series of procedural diagrams provided in the worksheet, which helped train their analytical thinking skills.

The achievement of students' science process skills, as assessed through the performance sheet, is illustrated in greater detail in Figure 4.

Figure 4. Graph of Average Value of Science Process Skills Aspects

M1: observe
M2: ask questions
M3: plan experiments
M4: make observations

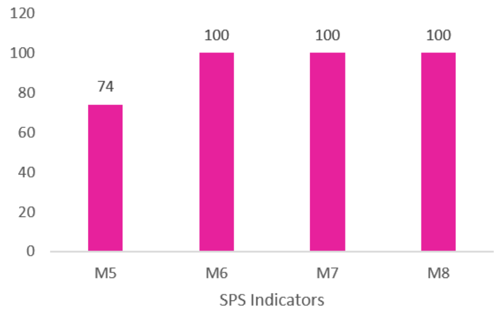

Figure 5. Graph of Average Value of Science Process Skills Aspects (M5-M6)

M5: interprets the observation results by applying theoretical concepts
M6: classifies the products,
M7: draws conclusions,
M8: communicates the findings.

The average score for each aspect indicates a value within the 'very good' interpretation category, with an overall average score of 96.

Based on the analysis of the performance assessment sheets and student worksheets containing SPS indicators, the findings demonstrate a high level of student competence in SPS. The average performance score reached 96%, which falls into the "very good" category. This result indicates that the implementation of project-based learning not only engages students actively in the learning process but also enhances their previously acquired science process skills. Qualitative observations noted students' ability to observe, hypothesize, conduct experiments, and interpret data with minimal guidance, reinforcing the quantitative outcomes (Fatnah et al., 2021).

Conclusion

The findings of this study highlight the effectiveness of the Project-Based Learning (PjBL) model in enhancing students' science process skills (SPS) through environmentally oriented projects. Learning activities ran smoothly, as reflected by an average student engagement score of 95. The students also demonstrated strong SPS development, achieving an average score of 90 on the project-based worksheets. In terms of performance, students reached an outstanding score of 96. These results underscore the success of integrating PjBL with project-based worksheets in addressing real-world issues—specifically plastic straw waste—through the innovative use of red dragon fruit peel (*Hylocereus polyrhizus*) to create edible straws. This approach not only supports green chemistry education but also proves to be a practical and impactful instructional strategy for high school students.

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