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phenomenon@walisongo.ac.id

Implementation of a Differentiated Project Based Learning Model to Improve Students' Science Process Skills and Scientific Attitudes

Nadila Qothrun Nada[1], Ani Rusilowati[2], Budi Astuti[3], Arif Widiyatmoko[4], Suharto Linuwih[5]

[1,2,3,4,5] *Universitas Negeri Semarang, Semarang, Indonesia*

Abstract

Science process skills and scientific attitudes are two important components of science education that foster critical thinking, problem-solving, and the development of a scientific mindset in students. However, studies show that both of these skills are relatively low in Indonesia. The purpose of this study is to implement a differentiated project-based learning (PjBL) model to enhance students' science process skills and scientific attitudes. The quasi-experimental method used has a pretest-posttest control group design. The research population consists of 10th grade students at State Senior High School 12 Semarang in the 2024/2025 academic year. The sample consisted of two classes, namely the experimental class that used differentiated PjBL and the control class that used non-differentiated PjBL, each with 36 students. The material used was renewable energy. The instruments used included science process skills tests, observation sheets, and scientific attitude questionnaires that had undergone validity and reliability tests. The data were analyzed using the N-gain test, independent sample t-test, and simple linear regression with the help of SPSS 23. The results showed that the differentiated PjBL model was effective in improving science process skills (N-gain = 0.72) and scientific attitudes (N-gain = 0.57), and there was a significant positive influence between the two ($R^2 = 0.484$). This model is recommended as an alternative to contextual learning in the Merdeka Curriculum.

Keywords: *Project Based Learning, Science Process Skills, Scientific Attitude*

Implementasi Model Pembelajaran *Project Based Learning* Berdiferensiasi untuk Meningkatkan Keterampilan Proses Sains dan Sikap Ilmiah Peserta Didik

Abstrak

Keterampilan proses sains dan sikap ilmiah merupakan dua komponen penting dalam pembelajaran sains yang mendukung pengembangan kemampuan berpikir kritis, pemecahan masalah, serta pembentukan karakter ilmiah peserta didik. Namun, hasil studi menunjukkan bahwa kedua keterampilan tersebut masih tergolong rendah di Indonesia. Penelitian ini bertujuan untuk mengimplementasikan model *Project Based Learning* (PjBL) berdiferensiasi guna meningkatkan keterampilan proses sains dan sikap ilmiah peserta didik. Metode yang digunakan adalah quasi experimental dengan desain *pretest-posttest control group*. Populasi penelitian adalah peserta didik kelas X SMA Negeri 12 Semarang tahun ajaran 2024/2025.

Universitas Negeri Semarang
Email: nadilaqothrunnada07@students.unnes.ac.id

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Sampel terdiri dari dua kelas, yaitu kelas eksperimen yang menggunakan PjBL berdiferensiasi dan kelas kontrol yang menggunakan PjBL non-diferensiasi, masing-masing berjumlah 36 peserta didik. Materi yang digunakan adalah energi terbarukan. Instrumen yang digunakan meliputi tes keterampilan proses sains, lembar observasi, dan angket sikap ilmiah yang telah melalui uji validitas dan reliabilitas. Data dianalisis menggunakan uji N-gain, *independent sample t-test*, dan regresi linier sederhana dengan bantuan SPSS 23. Hasil menunjukkan bahwa model PjBL berdiferensiasi efektif meningkatkan keterampilan proses sains (N-gain = 0,72) dan sikap ilmiah (N-gain = 0,57), serta terdapat pengaruh positif yang signifikan antara keduanya (R^2 = 0,484). Model ini direkomendasikan sebagai alternatif pembelajaran kontekstual dalam Kurikulum Merdeka.

Kata kunci: *Project Based Learning, Keterampilan Proses Sains, Sikap Ilmiah.*

INTRODUCTION

Education is an important foundation for individual and community development. In Indonesia, the education system continues to evolve and change to be more adaptive to the demands of the times, including in terms of curriculum change. The current curriculum is the Merdeka Curriculum, which began to be implemented in the 2021/2022 academic year. The Merdeka Curriculum focuses on essential content and the development of competencies aligned with the developmental stages of students (I. D. L. Usman et al., 2022) . These stages refer to learning outcomes that must be achieved, taking into account the characteristics, potential, and needs of students (Rahmadayanti & Hartoyo, 2022) . Meanwhile, learning outcomes are the minimum competencies that students must master in each subject (I. D. L. Usman et al., 2022).

In the Ministry of Education and Culture Decree No. 008/H/KR/2022, it is stated that physics learning outcomes are divided into two elements, namely physics understanding and process skills. In the process skills element, students are required to have the ability to observe, question, and predict; plan and conduct investigations; process and analyze data or information; create, evaluate, and reflect; and communicate results. These abilities are part of scientific process skills (Hamidah & Citra, 2021) . Therefore, it can be said that physics learning outcomes in the process skills element refer to science process skills.

Science process skills are essentially basic learning tools, which are abilities that serve as a foundation for each individual to develop themselves (Cain & Evans, 2010). Science process skills are defined as the competence of students to seek and discover a

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Email: nadilaqothrunnada07@students.unnes.ac.id

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law or science through scientific methods or steps independently (Mardianti et al., 2020). Science process skills are very important for students because they can help students understand and discover concepts in learning materials (Suryanti et al., 2020) . In addition, through the scientific process, students can identify and solve problems logically (Lestari & Diana, 2018), which can have implications for students' readiness to face the challenges of life today and in the future.

Scientific process skills not only encompass technical abilities in discovering scientific laws or knowledge, but also require the development of a comprehensive scientific attitude (Tawil, 2024) . Scientific attitudes such as curiosity, objectivity, perseverance, and openness to facts play a crucial role in supporting science process skills (Dyan Wulan Sari Hs & Agus Kistian, 2020; Simatupang, 2019). Rahman et al. (2017) emphasize that in science learning, both scientific process skills and scientific attitudes play equally important roles in building deep conceptual understanding. Thus, scientific conceptual understanding does not only focus on the final outcome but also on the process involved in achieving that understanding. This process plays a crucial role in building sustainable knowledge among learners.

According to Toharudin (2011), scientific attitudes are an individual's tendency to act or behave in solving problems systematically through scientific steps. Scientific attitudes need to be nurtured and developed in students because they cannot be formed in a short time. The process of nurturing and developing scientific attitudes requires a series of continuous activities. Therefore, scientific attitudes should be developed alongside the improvement of scientific process skills. If scientific attitudes are well-established, it is hoped that these attitudes will remain ingrained and reflected in daily life. Scientific attitudes play an important role in shaping the adaptive and innovative character of students in the ever-evolving information age (Fatonah et al., 2024).

Based on international survey results, students' scientific process skills in Indonesia are still relatively low. The 2015 TIMSS (Trends in Mathematics and Science Study) survey ranked Indonesia 44th out of 49 countries with a score of 397. Meanwhile, in the 2022 PISA (Program for International Student Assessment) participation, Indonesia ranked 69th out of 80 countries with a score of 383 on the science proficiency test. Indonesia's scores in the TIMSS and PISA surveys are still far below the overall average, even though both surveys present questions that emphasize science process

Universitas Negeri Semarang
Email: nadilaqothrunnada07@students.unnes.ac.id

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skills (Rosyida & Nurita, 2018) . This indicates that Indonesia faces significant challenges in achieving science skills at the international level, so it can be stated that the science process skills of Indonesian students are still very low. This is also revealed in the research by Jumaniar et al. (2024), Subkhi et al. (2024), Aidarahmi et al. (2024), which states that science process skills in Indonesia are still relatively low.

One factor contributing to the low level of scientific process skills is the lack of activities that involve in-depth scientific processes (Purnamasari et al., 2021) . Observations at SMA Negeri 12 Semarang show that physics learning processes are not sufficiently oriented toward the development of scientific process skills. Although practical activities have been implemented, complete scientific work steps have not been fully incorporated. Some indicators of scientific process skills that have not been applied include the skills of predicting, interpreting, and designing investigations. Additionally, physics learning activities are more focused on cognitive aspects using non-differentiated PjBL methods. According to Wicaksono & Widiyaningrum (2020), non-differentiated PjBL methods do not actively involve students in the learning process, making them less effective in developing scientific process skills in students.

Scientific attitudes are one of the fundamental elements in science and are a focus of Natural Sciences (IPA) learning, including physics (Azhari et al., 2020) . However, despite years of science education with the nature of science as one of the topics discussed, the expected outcomes regarding students' scientific attitudes have not been optimally achieved (Siski Fitriani & Lasdi Irmansyah, 2021). This gap is evident in various studies. Kusherawati et al. (2020) reported that students' scientific attitudes were low, with an average score of only 26.41%. Additionally, research by Rahman et al. (2017) showed that students' scientific attitudes ranged from 40-44%, which is also considered low. Another study by Rusni et al. (2020) noted that the average percentage of scientific attitude scores among students ranged from 62-63.5%, indicating the need for further development.

Interviews with physics teachers at SMAN 12 Semarang revealed that there are still students who have not demonstrated good scientific attitudes. During the learning process, students tend to be passive, accept information without critical analysis, and give up easily when faced with difficulties. This low level of scientific attitude is attributed to a teacher-centered teaching approach that has not fully incorporated

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experiments aligned with scientific steps or other teaching methods that could enhance students' scientific attitudes. Additionally, assessments have primarily focused on cognitive aspects (mastering the material), while evaluations of affective aspects (scientific attitude) have been overlooked. The development of scientific attitudes through appropriate learning models will significantly influence the cultivation of positive attitudes toward the concepts or topics being studied (Gunada et al., 2023)

The lack of development of scientific process skills and scientific attitudes can hinder the achievement of science learning objectives (Rahman et al., 2017; Rapi et al., 2025). Students who do not have good scientific process skills will find it difficult to understand abstract concepts (Rahmadani & Albeta, 2020a), while weak scientific attitudes can hinder the application of knowledge in daily life (Safitri et al., 2024). This is consistent with research findings which show that low scientific process skills limit students' ability to interpret scientific information and construct conceptual understanding, and that weak scientific attitudes reduce curiosity, persistence, and openness to evidence, thereby inhibiting the transfer of knowledge into real-life contexts. Therefore, learning innovations are needed that can optimally improve students' scientific process skills and scientific attitudes.

One interesting learning innovation is the Project-Based Learning (PjBL) model. This model gives students the freedom to plan learning activities, carry out projects, and produce products (Nababan et al., 2023). PjBL actively involves students in investigation, data collection, information analysis, and drawing conclusions. This process not only has the potential to enhance conceptual understanding but also fosters scientific attitudes such as curiosity, precision, and objectivity (Trinaini et al., 2024). According to Syamsuriwal et al. (2024), Ginting et al. (2024), Surayya et al. (2024), PjBL influences the science process skills of high school students. Meanwhile, Safitri et al. (2024) revealed that PjBL also has a significant impact on students' scientific attitudes.

PjBL has the potential to develop students' skills, knowledge, and attitudes. This model enhances scientific process skills by involving students in various activities, such as observing, identifying problems, planning projects, applying concepts, interpreting data, and communicating results (Rahmadani & Albeta, 2020a). These activities align with the indicators of scientific process skills, so PjBL is expected to be an appropriate

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Email: nadilaqothrunnada07@students.unnes.ac.id

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learning model for developing these skills.

Additionally, PjBL also plays a role in improving students' scientific attitudes (Indriawati et al., 2019; Syahrial, 2024) . This model has advantages in fostering independence, increasing responsibility, developing problem-solving skills, and expanding learning access (Setiawan et al., 2021) . Its implementation can encourage positive behavioral changes in students, such as increasing curiosity, valuing evidence, thinking flexibly and critically, and having sensitivity in investigating the surrounding environment (Utomo et al., 2020) . PjBL also helps students build understanding individually according to their respective capacities (Pratama et al., 2020) . In project work, a scientific attitude is an important factor in achieving optimal results.

The Merdeka Curriculum emphasizes a differentiated approach to learning. A learning model that integrates a differentiated approach has been proven to enhance students' scientific process skills (Krisnanto et al., 2024). Differentiated learning allows educators to tailor teaching strategies based on students' needs, interests, and learning styles, enabling students to develop scientific process skills and scientific attitudes more effectively (Tomlinson, 2017). Through this approach, each student receives a learning experience tailored to their level of understanding and ability, thereby not only enhancing conceptual understanding but also sharpening critical thinking and problem-solving skills (Astutik et al., 2024)

Although the Merdeka Curriculum explicitly encourages the application of a differentiated approach, its underlying principles are universal and not limited to a specific curriculum. Differentiated learning can also be applied to previous curricula, such as the 2013 Curriculum, or even to future curricula. The 2013 Curriculum has even recommended the use of project-based learning as a means to strengthen the application of knowledge, character building, and the development of 21st-century skills such as creativity, collaboration, and communication. Thus, the differentiated PjBL model has high flexibility and adaptability to be applied in various curriculum contexts with the aim of improving the overall quality of learning.

The implementation of PjBL in differentiated learning is expected to create an effective and adaptive learning environment. This model not only improves students' scientific process skills but also accommodates the diversity of students' learning styles, making learning more inclusive and meaningful. The collaboration between PjBL and

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differentiated learning provides space for students to explore their potential to the fullest. With this approach, students will be better prepared to face real-world challenges and able to apply scientific concepts in their daily lives through contextual and meaningful learning experiences.

In addition to considering students' needs, the learning model applied must also be adapted to the learning materials and objectives (Angga et al., 2022) . Observation results indicate that physics learning at SMA Negeri 12 Semarang focuses more on mastering theory and is less contextual. However, some physics materials are concrete, such as renewable energy. Renewable energy material covers several real-world environmental issues that need to be addressed. Additionally, the existing learning outcomes require students to develop the ability to create solutions to problems based on local, national, or global issues related to environmental change understanding (Ministry of Education and Culture, 2022). The PjBL model is considered suitable for the characteristics and learning outcomes of renewable energy material, as the PjBL learning model can guide students in solving environmental problems in their surroundings (Lette & Kuntjoro, 2019a)

Based on the issues outlined above, this study aims to apply a differentiated PjBL model to enhance students' scientific process skills and scientific attitudes. Unlike previous studies, this study specifically integrates differentiated learning as one of the main approaches in the Merdeka Curriculum. Differentiated learning was chosen because observations showed that the learning activities designed by teachers did not fully accommodate the different needs, interests, and learning profiles of students. Teachers still tend to use uniform content and learning processes in one class. Therefore, this differentiated PjBL model is expected to assist or serve as a reference for teachers in implementing innovative physics learning and to improve scientific process skills and scientific attitudes.

Although Project-Based Learning (PjBL) has repeatedly been shown to improve learning outcomes, most applications of this model still adopt uniform learning designs that do not consider learner diversity. Previous studies have demonstrated the contributions of PjBL in strengthening science process skills and conceptual understanding (Ellianawati et al., 2024; Guo et al., 2020; Lette & Kuntjoro, 2019b; Rahmadani & Albeta, 2020b) , enhancing scientific attitudes and entrepreneurial

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interests (Safitri et al., 2024) , and describing the profile of students’ science process skills and scientific attitudes (Rahman et al., 2017; Wahdi Ginting et al., 2023). Other studies also confirmed that PjBL facilitates higher-order thinking and active scientific investigation (Eliyasni et al., 2019; Guo et al., 2020; Loyens et al., 2023) and supports the development of scientific attitudes through inquiry-based project activities (Ergül et al., 2011; Ma, 2023). However, findings from these studies generally apply PjBL in a uniform format where the same learning content, learning process, and project output are assigned to all students, regardless of differences in readiness, interest, or learning profiles. Meanwhile, differentiated instruction has been shown to influence pedagogical practices and improve student learning engagement (Astutik et al., 2024) , yet differentiation has not been explicitly embedded within the PjBL framework. This gap underlines the need to explore whether a differentiated PjBL model can more effectively strengthen science process skills and scientific attitudes in heterogeneous classroom contexts.

This research then addresses the following objectives: (1) to describe the implementation of differentiated PjBL in improving students' science process skills and scientific attitudes; (2) to compare the outcomes of differentiated PjBL versus traditional lecture methods; and (3) to investigate the relationship between science process skills and scientific attitudes. Through those objectives of research, I aim to contribute theoretically to the discussion of physics learning by combining the PjBL and practical approaches, this research aims to give practical significance as guidance for teachers to modernize their teaching approach and method.

RESEARCH METHODS

This research is a quasi-experimental study with a pretest-posttest control group design, which compares two groups without random assignment (Sugiyono, 2020:112). The independent variable in this study is the differentiated PjBL model, while science process skills and scientific attitudes are the dependent variables. The research design can be seen in Table 1.

Table 1. Research Design

Group	Before	Treatment	After
Experiment	O_1	X	O_2
Control	O_1	Y	O_2

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Description:

O_1 : pretest results for science process skills/scientific attitudes

O_2 : posttest results for science process skills/scientific attitudes

X : learning with differentiated PjBL model

Y : learning with non-differentiated PjBL method

The research was conducted at SMAN 12 Semarang. The research population consisted of all tenth-grade students at SMAN 12 Semarang in the 2024/2025 academic year. The sample was selected using purposive sampling based on the criterion that the students had previously been taught by the same physics teacher. The sample consisted of 72 students divided into two classes, each consisting of 36 students. Class X.E 6 was designated as the experimental class that applied the differentiated PjBL model, while class X.E1 was designated as the control class that applied the non-differentiated PjBL model.

Data collection procedures were conducted using several instruments. The first instrument was a science process skills test consisting of four essay questions developed based on four indicators of science process skills, namely observing, questioning and predicting, planning and conducting investigations, and processing and analyzing data and information. The second instrument was an observation sheet used to assess students' science process skills directly during the learning process, covering the indicators of creating; evaluating and reflecting; and communicating results. All six indicators, whether measured through the test or observation, constitute the learning outcomes specified in the Merdeka Curriculum for Grade 10 students (Phase E). The test was administered during the pretest and posttest to measure improvements in students' science process skills, while the observation sheet was used to evaluate students' actual performance during learning activities.

The third instrument was a scientific attitude questionnaire used to measure changes in students' scientific attitudes before and after the treatment. The questionnaire consisted of 20 statements with a Likert scale developed based on scientific attitude indicators according to Anwar (2009), namely curiosity, critical thinking, persistence, creativity and inventiveness, respect for data/facts, and cooperation.

The content validity of the instruments was tested by seeking expert opinions from physics lecturers and teachers. The content validity was analyzed using Microsoft

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Excel. The analysis results showed that the science process skills instrument obtained a validity score of 0.90, while the scientific attitude instrument obtained a score of 0.89, both of which indicated that the instruments were valid. Reliability was tested through instrument trials on students and analyzed using Cronbach's Alpha formula. The analysis results obtained a value of 0.73, which means it falls into the reliable category (Arikunto, 2010) . This means that the instrument can be used to measure students' science process skills and scientific attitudes.

Differentiated learning in this study was based on students' learning styles. Therefore, the study began with a diagnostic learning style test to group students based on their learning styles in the experimental class. Following this, a pretest of scientific process skills and scientific attitudes was conducted, followed by the implementation of differentiated PjBL in the experimental class and non-differentiated PjBL in the control class. The material used in the learning process was Renewable Energy. After the learning process was completed, a post-test was conducted for both groups.

The pre-test and post-test data were analyzed using the N-gain test to measure the improvement in students' science process skills and scientific attitudes. The comparison between the experimental and control groups was conducted using an independent sample t-test to determine the significance of the differences in results. This procedure is commonly used in quasi-experimental research to assess the effectiveness of different instructional interventions (Harlen, 2001; Rogers & Revesz, 2019) . The results of the observation of science process skills were analyzed descriptively and quantitatively using percentages to provide an in-depth description of the science process skills demonstrated by the students during the learning process. In addition, the pretest and posttest scores were also used for simple linear regression analysis to determine the effect of science process skills on students' scientific attitudes (Yuniar et al., 2024). The entire data analysis process was conducted using IBM SPSS Windows 23.

RESULTS AND DISCUSSION

The implementation of the differentiated PjBL model was carried out at SMAN 12 Semarang in the 2024/2025 academic year with the research subjects being 10th grade science students and the learning topic being renewable energy. The study employed a quasi-experimental design with two classes: an experimental class

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implementing differentiated PjBL and a control class using PjBL without differentiation, each comprising 36 students. The differentiated PjBL model was implemented over four sessions, each lasting three class periods. In the first session, the teacher conducted a diagnostic assessment to identify students' learning styles through an online test. The test results were used to group students based on their learning styles (visual, auditory, or kinesthetic), which served as the basis for differentiating content and process. This strategy distinguished the experimental class from the control class, which did not apply learning style grouping and used a uniform learning approach. The implementation of diagnostic tests is a form of content differentiation, as it allows teachers to tailor the delivery of material to the learning preferences of students (Marlina et al., 2020).

The learning stages were designed following the PjBL syntax from the George Lucas Educational Foundation, including: asking fundamental questions, designing projects, scheduling, monitoring project progress, assessing results, and evaluating learning experiences. In the initial stage, students select learning content (videos or articles) according to their learning styles to address the issue of dwindling fossil fuel reserves. This reflects the implementation of content differentiation, which provides learning access tailored to individual preferences (Wardani et al., 2025).

In the second session, students present their observations on the potential of renewable energy sources in their surroundings, such as hydroelectric power plants, solar power plants, wind energy, and biomass. This discussion reinforces scientific process skills and scientific attitudes, particularly in observing, analyzing, and communicating results. Next, they design simple alternative energy products based on their observations, such as posters, educational videos, or demonstration tools. This adaptation of product form is an application of product differentiation (Wardani et al., 2025).

The third meeting focused on the prototype creation process. Teachers monitored students' activities and scientific attitudes, provided guidance, and evaluated project progress. This process trained responsibility, creativity, and teamwork skills (Arini et al., 2024) . The fourth meeting was used to test and present project results. Teachers guided the analysis of the prototype's strengths and weaknesses and evaluated the overall learning experience.

Although the PjBL syntax in both classes is similar, the fundamental difference

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lies in the adaptation to the individual characteristics of the students (Zhang & Ma, 2023) . Differentiated PjBL provides space for visual learning styles (products in the form of posters), auditory learning styles (videos or recordings), and kinesthetic learning styles (teaching aids), while the control class produces uniform products in the form of written works. This demonstrates that the differentiated approach is more adaptive and inclusive (Saputra et al., 2025).

The implementation of this model promotes contextual, constructive learning that aligns with the demands of the Merdeka Curriculum. Students not only understand concepts theoretically but are also able to connect them to real-world experiences (Agustin & Kurniawaty, 2025). Additionally, science process skills such as observing, designing investigations, analyzing data, and communicating results develop significantly (Ekici & Erdem, 2020). Scientific attitudes such as curiosity, responsibility, and collaboration also grow naturally during project work. Thus, differentiated PjBL becomes a relevant, meaningful, and diverse learning solution that values students' learning styles.

Science process skills are measured through tests and observations. Test data is analyzed to determine improvements in students' skills and compare the effectiveness of two different learning models. Improvements are analyzed using the N-gain test, while comparisons between classes use the independent sample t-test. Observation results are analyzed descriptively and quantitatively in the form of percentages. Improvements in science process skills were analyzed using the N-gain test with pretest and posttest data. The N-gain value indicates the extent of skill improvement after learning and is classified into categories of improvement levels. The analysis results are presented in Table 2.

Table 2. Results of The Analysis of The N-Gain Test of Science Process Skills

Group	Average Score		N-gain Score	Criteria
	Pretest	Posttest		
Experiment	48,96	85,76	0,72	High
Control	43,92	57,64	0,24	Low

Based on Table 2, the science process skills of students in the experimental class who participated in differentiated PjBL learning experienced a significant increase, with an N-gain score of 0.72 (high category). In contrast, the control class that participated in

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non-differentiated PjBL obtained an N-gain score of 0.24 (low category). This shows that the application of differentiation in PjBL contributes more to the improvement of science process skills than PjBL without differentiation. These findings are in line with Sánchez-García & Reyes-de-Cózar (2025) , who state that PjBL strengthens investigative activities through the process of designing and evaluating scientific projects. Sunartri (2025) also emphasizes that differentiation allows students to learn according to their readiness and interests, thereby increasing the effectiveness of PjBL. This is reinforced by Firda et al. (2024) who state that PjBL consistently improves science process skills in various learning contexts. In addition, Sari & Utami (2023) show that PjBL can improve learning outcomes because it provides space for active student involvement.

These results are also relevant to the findings of Rahmadani & Albeta (2020a), which show that PjBL improves investigative skills and conceptual understanding through project activities. Vaithianathan et al. (2024) add that the integration of projects and practice-based skills significantly increases engagement and learning success. On the other hand, Safitri et al. (2024) reveal that PjBL can build scientific attitudes and learning responsibility through meaningful project experiences.

The observation data in this study showed that students in the experimental class were more active in observing, questioning, predicting, and analyzing data than those in the control class. Thus, the improvement in science process skills in the experimental class was a logical consequence of a more focused learning experience, tailored to individual needs, and supported by a project structure that reinforced the scientific process. A more detailed analysis of science process skill indicators is presented in table 3.

Tabel 3. Achievement of Science Process Skills

No	Science Process Skills Indicators	Percentage of achievement (%)			
		PjBL Berdiferensiasi		PjBL	
		Pretest	Posttest	Pretest	Posttest
1.	Observation	49	90	53	70
2.	Questioning and predicting	47	90	51	66
3.	Planning and conducting investigations	51	81	28	42
4.	Processing and Analyzing Data and Information	49	83	44	53

All indicators show improvement, especially in the experimental class. Differentiated

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Email: nadilaqothrunnada07@students.unnes.ac.id

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learning has a positive impact by adjusting to the needs, interests, and learning styles of students, thereby increasing motivation and engagement. This finding is consistent with previous studies showing that instruction tailored to learners' characteristics enhances participation and strengthens scientific reasoning (Sari & Utami, 2023; Vaithianathan et al., 2024).

The observation method assesses scientific process skills through activities such as creating, evaluating, reflecting, and communicating results. The observation scores for the experimental group are higher, supporting the test results (Figure 1).

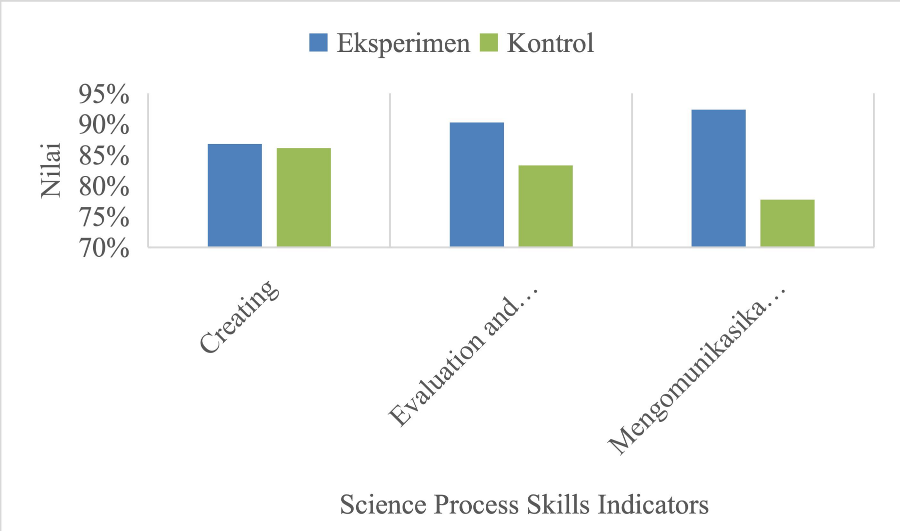

Figure 1. Results of Science Process Skills Analysis for Each Indicator

Figure 1 shows the achievement of each science process skill indicator based on the observation sheet. Based on the figure, the indicators of creating, evaluating and reflecting, and communicating results show consistent improvement throughout the learning process. These three indicators, along with four other indicators measured through tests, are part of the learning outcomes of the Merdeka Curriculum for 10th grade students (Phase E). This confirms that differentiated PjBL not only improves science process skills through written tests, but also improves authentic scientific performance during learning activities.

The improvement in the indicators of creating and reflecting is supported by the characteristics of PjBL, which provides an exploratory and flexible space so that students can develop original ideas, make independent improvements, and convey their findings in a more structured manner. These findings are consistent with the research by Safitri et al. (2024), which states that project activities encourage students' analytical,

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synthesis, and scientific communication skills through real-world problem-based experiences. The test results are presented in Table 4.

Table 4. Results of Independent Sample t-test for Science Process Skills

Group	n	*Mean*	df	t_{hitung}	sig. (2−tailed)
Experiment	36	85,76	70	8,310	0,000
Control	36	57,63			

A significance value of 0.000 (<0.05) indicates a statistically significant difference in science process skill scores between differentiated and undifferentiated PjBL groups. These results prove that the differentiated PjBL model is more effective because it tailors project tasks to students' interests, learning styles, and readiness, thereby increasing motivation, engagement, and investigative (Lette & Kuntjoro, 2019a; Rahmadani & Albeta, 2020a) . Conversely, the non-differentiated PjBL model offers a uniform learning experience that does not meet individual needs, resulting in lower participation and less than optimal scientific reasoning (Setiawan et al., 2021) . These findings are consistent with the principles of constructivism, which emphasize active and meaningful learning, and are in line with previous studies showing that differentiated instruction improves students' scientific inquiry skills (Firda et al., 2024; Safitri et al., 2024; Sari & Utami, 2023; Vaithianathan et al., 2024) . Overall, previous evidence and the results in Table 4 reinforce the conclusion that differentiated PjBL provides a more supportive environment for developing scientific process skills compared to undifferentiated models.

Students' scientific attitudes were measured using a questionnaire instrument. Questionnaire data were analyzed to determine improvements in scientific attitudes and compare the effectiveness of learning. Improvements were analyzed using the N-gain test, while comparisons between differentiated and non-differentiated PjBL classes were analyzed using an independent sample t-test. The analysis of improvements in scientific attitudes was conducted using the N-gain test based on pretest and posttest questionnaire scores measuring indicators such as curiosity, perseverance, creativity, respect for data, and cooperation (Toharudin, 2011; Tomlinson, 2017) . The instrument has been tested for validity and reliability, ensuring that each indicator reflects the true state of students' scientific attitudes (Tariq, 2025) . The results of the N-gain test are presented in Table 5.

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Table 5. Results of the N-gain Scientific Attitude Test

Group	Average Score		N-Gain Score	Criteria
	Pretest	Posttest		
Experiment	66,50	85,72	0,57	Moderate
Control	60,69	77,88	0,43	Moderate

Based on Table 5, both groups experienced an increase in scientific attitudes; however, the increase in the class that applied the differentiated PjBL model was higher than in the non-differentiated class. These findings indicate that differentiation strategies have a stronger positive influence on the formation of scientific attitudes because learning activities are tailored to the interests, learning styles, and readiness of students. These adjustments made students more willing to actively engage in the learning process. This is in line with the research by Lestari & Diana (2018) , which found that learning tailored to student characteristics can significantly increase motivation and participation. This finding is also supported by Azhar & Wahyudi (2024) who reported that students who learn with a differentiated approach show deeper cognitive involvement, so their scientific attitudes develop more optimally than students who learn in a uniform learning environment.

Scientific attitudes play a central role in science learning because they include curiosity, perseverance, critical thinking skills, creativity, appreciation of data, and the ability to work together. These attitudes do not arise automatically but develop through active, reflective, structured, and contextual learning experiences. This is in line with the research by Baartman & de Bruijn (2011), which states that scientific attitudes are formed when students have the opportunity to engage in authentic inquiry activities. In this learning process, students are consistently trained to formulate questions, solve problems, test ideas, evaluate evidence, and communicate results. This finding is in line with the research by Virmayanti et al. (2023) , which confirms that repeated investigative activities can gradually strengthen students' scientific attitudes.

The differentiated PjBL model integrates student involvement in authentic projects with learning adjustments based on individual needs. Through this model, students are given the freedom to choose topics, methods, and product forms according to their interests and learning styles (Tomlinson, 2017). This freedom increases students'

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cognitive and emotional engagement, fostering curiosity, perseverance, and responsibility during the project process. In addition, relevant and meaningful tasks also encourage creativity and reinforce an attitude of valuing facts when students process and analyze data. This is supported by research by Virmayanti et al. (2023) , which shows that authentic project-based learning can optimize the development of scientific attitudes. A more detailed analysis of scientific attitude indicators is presented in Table 6.

Table 6. Achievement of Scientific Attitude

No	Indicators of Scientific Attitude	Percentage of Achievement (%)			
		PjBL Berdiferensiasi		PjBL	
		Pretest	*Posttest*	*Pretest*	Postest
1.	Curiosity	60	85	60	79
2.	Critical Thinking	67	85	60	76
3.	Persistence	67	86	61	80
4.	Creativity and Inventiveness	65	85	54	77
5.	Respect for Evidence/Fact	66	86	60	76
6.	Cooperation with Others	71	87	69	80

Based on Table 6, all scientific attitude indicators showed a higher increase in classes that used the differentiated PjBL model compared to the control classes. Learning that gives students the freedom to choose topics and lines of inquiry has been proven to trigger curiosity and encourage deeper exploration; this is in line with research conducted by Nafa et al. (2025), which confirms that relevance and freedom in learning strengthen students' intrinsic motivation. In addition, the complex decision-making process in differentiated projects has been shown to improve critical thinking, perseverance, and creativity; this is in line with the findings of Alkhatib (2019) , who states that challenging tasks have a significant impact on the development of scientific disposition. The direct involvement of students in data collection and analysis also strengthens their attitude of appreciating facts, while group work during the project contributes to improving students' collaborative skills.

Overall, these results are supported by previous studies showing that differentiated PjBL provides a more meaningful and contextual learning experience, thereby directly impacting the strengthening of all aspects of scientific attitudes. These findings are also in line with the results of the independent sample t-test in Table 7, which shows a significant difference in the increase in scientific attitudes between the

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experimental and control classes.

Table 7. Results of Independent Sample t-test Scientific Attitude

Group	n	$Mean$	df	t_{hitung}	sig. (2−tailed)
Experiment	36	85,72	70	4,878	0,000
Control	36	77,89			

A significance value of 0.000 (<0.05) indicates that the differentiated PjBL model is statistically more effective in improving scientific attitudes. This learning approach strengthens students' scientific character through active engagement in projects that are adapted to their abilities, interests, and needs. Differentiated learning encourages students to take responsibility for their learning choices, increases persistence during investigations, and enhances emotional engagement when solving real world problems factors that directly contribute to the development of scientific (Amalia & Ratnaningrum, 2025).

This finding is in line with the Merdeka Curriculum policy, which promotes contextual, inclusive, and character-building learning oriented toward 21st-century skills (Lestari & Diana, 2018). The differentiated PjBL model also supports the growth of independence, critical thinking, and collaboration as elements of the Pancasila Student Profile (Ni Luh Made Mita Oktaviani et al., 2023; U. Usman et al., 2023). This study aims to analyze the effect of science process skills on students' scientific attitudes using simple linear regression with IBM SPSS Statistics 28. The test was conducted on two classes, namely the experimental class that applied the differentiated PjBL model and the control class with the non-differentiated PjBL model. The test of the influence of science process skills on scientific attitudes using simple linear regression is a hypothesis test. The research hypothesis is as follows.

H_0 : Science process skills do not influence students' scientific attitudes.

H_a : Science process skills influence students' scientific attitudes.

If the significance value is greater than 0.05, then H_0 is accepted and H_a is rejected. Conversely, if the significance value is less than 0.05, then H_0 is rejected and H_a is accepted. The test results can be seen in Table 8.

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Table 8. Simple Linear Regression Test Results

Group	R	R^2	a	b	t_{hitung}	$sig.$
Experiment	0,695	0,484	46,227	0,444	8,096	0,000
Control	0,388	0,151	57,590	0,230	3,524	0,000

Based on the results of the simple linear regression test shown in Table 8, it is known that the significance value (Sig.) is 0.000, which is smaller than the significance level of 0.05. Thus, the alternative hypothesis (H_a) is accepted, which means that there is a significant effect between science process skills and students' scientific attitudes. This result is also supported by the calculated t-value of 8.096, which is greater than the table t-value of 1.977 (at $\alpha = 0.05$; df = 142), further confirming that the effect is statistically significant. The coefficient of determination (R^2) of 0.484 indicates that 48.4% of the variation in students' scientific attitudes can be explained by science process skills, while the remaining 51.6% is influenced by factors outside the model. The simple linear regression equation for the experimental class is:

$$\text{Scientific Attitude} = 46.227 + 0.444 \times \text{Science Process Skills}$$

This equation shows that every one-unit increase in science process skills will increase students' scientific attitude scores by 0.444 points. This positive regression coefficient indicates a direct relationship between science process skills and scientific attitude. The higher the science process skills possessed by students, the higher their scientific attitude. This finding is very logical because science process skills are the main foundation in science learning that stimulates scientific thinking skills and shapes scientific attitudes, such as curiosity, perseverance, critical thinking skills, respect for facts, and cooperation (Carin & Sund, 1989; Toharudin, 2011) . This is in line with Talavera-Mendoza et al. (2024) opinion that science activities involving observation, question formulation, and investigation can foster scientific attitudes from an early age.

The stages of scientific process skills also play an important role in shaping various aspects of scientific attitudes. For example, the activities of observing and asking questions foster curiosity Harlen (2001) , while the stages of questioning, predicting, and evaluating train students' critical thinking skills Ennis (1996) . The stages of planning and conducting investigations encourage perseverance in carrying out experiments, while processing and analyzing data helps build an attitude of respecting facts. Furthermore, activities such as creating and reflecting support creativity and the

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development of scientific attitudes related to finding solutions Ramadhani & Supriyadi (2024) , whereas communicating results strengthens cooperation and students' social skills.

These findings are also supported by research by Aktamis & Ergin (2008) and Juhji & Nuangchalerm (2020) , which shows that science process skills have a significant influence on students' scientific attitudes. This is in line with constructivist theory, which emphasizes that scientific knowledge and attitudes are formed through direct experience and meaningful investigative activities (Nuryati & Fauziati, 2021) . Furthermore, the results of this study are relevant to the differentiated Project Based Learning approach, as this model provides ample room for exploration through the adjustment of content, processes, and products according to students' needs (Fajrina et al., 2024). This is also reinforced by the Merdeka Curriculum policy, which emphasizes contextual, adaptive learning oriented toward character development and 21st-century skills (Kemdikbudristek, 2022). Thus, the differentiated PjBL model not only improves science process skills and scientific attitudes but also creates meaningful learning experiences that align with the characteristics of 21st-century learners.

CONCLUSION

This study confirms that the differentiated project-based learning (PjBL) model is effective in improving students' science process skills and scientific attitudes. Adapting project activities to students' interests, readiness, and learning styles promotes active participation in scientific inquiry, which in turn strengthens both cognitive and affective learning outcomes. Empirical results show that students in the experimental class achieved higher gains than those in the control class, with N-gain scores of 0.72 for science process skills and 0.57 for scientific attitudes, compared to 0.24 and 0.43 in the control class. The presence of a positive correlation between science process skills and scientific attitudes indicates that the development of scientific skills contributes meaningfully to the enhancement of students' scientific attitudes. Therefore, differentiated PjBL can be recommended as an effective and contextual learning approach that aligns with the principles of the Merdeka Curriculum and supports the development of 21st-century competencies and the Pancasila Student Profile.

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