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Differentiated Learning by Style Enhances Self-Regulation and Science Achievement in Fourth Grade Students

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ABSTRACT

This study investigates the influence of differentiated instruction, tailored to students' learning styles, on self-regulation and science learning outcomes among fourth-grade elementary students. Utilizing a quasi-experimental design, the research involved an experimental group that received differentiated instruction based on students' learning styles through Project-based Learning (PjBL) model, and a control group taught through Problem-based Learning (PBL) model. Data were collected using validated instruments and analyzed using normality and homogeneity tests, as well as independent and paired sample t-tests, through SPSS version 30. Findings indicate that differentiated instruction significantly improved students' science learning outcomes, as evidenced by a higher posttest mean score in the experimental group compared to the control group. Although the independent t-test showed a significant difference in self-regulation between the groups, the paired sample t-test did not reveal a significant increase in self-regulation within the experimental group itself. These results suggest that while differentiated instruction effectively enhances academic achievement in science, its impact on self-regulation is less pronounced. The study underscores the value of learner-centered instructional approaches that address individual learning differences to optimize educational outcomes in primary science education.

Keywords
Differentiated Learning
Learning outcomes
Learning Styles
Self-Regulation

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Introduction

Education is a vital pillar of national development, with the curriculum functioning as a strategic framework for shaping effective learning experiences. In Indonesia, the introduction of the Merdeka Curriculum in 2022 signifies a paradigm shift toward more flexible, student-centered instruction, aiming to foster holistic competencies such as creativity, autonomy, and critical thinking. Within the domain of Natural and Social Sciences, this curriculum promotes contextualized, inquiry-driven approaches to enhance scientific literacy from an early age. However, the effective realization of these goals remains challenged by the persistence of teacher-centered pedagogies, lack of personalized instructional practices, and the low self-regulation capacities of elementary students—factors that significantly constrain learning engagement and outcomes [1].

Despite the recognition of individual learner differences in theory, in practice, many classrooms still adopt a one-size-fits-all instructional design. This lack of attention to students' learning styles—visual, auditory, or kinesthetic—has been associated with disengagement and suboptimal academic performance [2]. While differentiated instruction has been widely advocated as a pedagogical response to learner diversity, empirical studies that rigorously examine its impact on self-regulation and learning achievement in Indonesian primary schools remain limited [3]. This gap is particularly relevant in light of the Merdeka Curriculum, which mandates adaptive teaching tailored to student characteristics.

Furthermore, the integration of differentiated instruction with constructivist models such as PjBL offers promising potential. PjBL encourages active knowledge construction through authentic tasks, potentially fostering both cognitive achievement and metacognitive skills such as self-regulation [4]. However, few studies have investigated the combined application of learning style-based differentiation and PjBL in elementary science education.

Given these gaps, this study seeks to examine the effectiveness of differentiated instruction based on students' learning styles, implemented through the PjBL model, in enhancing self-regulation and science learning outcomes among fourth-grade students. The findings are expected to inform instructional design and curriculum implementation strategies that align with the goals of inclusive, student-responsive education as envisioned in the Merdeka Curriculum.

Literature Review

A. Differentiated Learning

Differentiated learning is a learning strategy that adjusts materials, processes, and learning environments based on the individual needs of students [5]. This strategy aims to ensure that each student gets an optimal learning experience according to their readiness, interests, and

learning profiles [3], [6]. In its implementation, teachers need to conduct diagnostic assessments to identify students' learning needs and design appropriate strategies [2], [7].

In the context of the Independent Curriculum, differentiated learning is a very relevant approach. This curriculum provides flexibility for teachers to adjust teaching according to the conditions of students, allowing them to develop their potential to the maximum. By implementing differentiated learning, students can be more active in learning, increase engagement, and achieve better learning outcomes. To implement it effectively, educators need to follow a series of structured steps. The key stages in implementing differentiated learning [8] are as follows:

- Identification of educational needs utilizing analyzing students' test answers, assessing daily work, observing students during math lessons, and (if necessary) conducting diagnostic conversations;
- Setting differentiated goals depending on students' achievement level, that is, challenging goals for high-achieving students, well-considered minimum goals for low-achieving students;
- Providing differentiated instruction by adapting the level of abstraction, the modality, the pace, and the amount of instruction to students' needs, or asking questions at various levels during whole-class instruction;
- Differentiation of tasks by providing different types of tasks (e.g., individual or group work, written or drawn responses, on paper or computer) and adjusting the amount and complexity of the task;
- Evaluation of progress and process by analyzing students' work to identify whether the students have met the lesson goals, and whether the instruction and tasks as applied were effective for the specific groups of students.

Steps 1 and 2 are part of the preparation phases (term and lesson); Steps 3 and 4 are part of the enactment of the lesson; and Step 5 is similar to the evaluation phase [9].

So overall, differentiated learning requires a systematic and planned approach. Steps such as setting clear learning objectives, evaluating individual learners' abilities, adjusting learning strategies, and providing a variety of learning alternatives are key to ensuring that each learner can reach their maximum potential. Differentiated learning can be divided into three main aspects: tailored learning content, meaningful processes or activities that support conceptual understanding, assessment through the creation of end products, and the learning environment [10]. This allows teachers to adjust teaching according to the individual needs of learners in terms of materials, teaching methods, and assessments.

1. Differentiated Learning Based on Learning Styles

Differentiated learning based on learning styles is an approach that allows teachers to personalize their teaching according to each student's learning preferences. This approach can increase the effectiveness of learning by accommodating different learning styles, thus meeting the individual needs of students more effectively. Differentiated learning based on learning styles has steps in its implementation which include:

- Identifying each student's learning style through questionnaires or observations.
- Designing learning that suits students' learning styles, such as providing visual materials for students with visual learning styles.
- Carry out learning that has been designed, by adjusting learning methods and media according to students' learning styles.
- Evaluate learning outcomes and reflect to improve learning strategies in the future.

These steps are important to ensure that learning style-based differentiated learning can run effectively and meet the learning needs of each student [10]. Learning style-based differentiated learning has the potential to increase student motivation, engagement, and learning outcomes [11], [12]. Thus, learning style-based differentiated learning not only accommodates the individual needs of students but also increases the effectiveness of teaching and learning as a whole by utilizing each student's strengths and learning preferences.

2. Implementation using Project-Based Learning

PjBL model is a learning method that places students in situations relevant to real life, which positively supports the development of creative thinking [13], [14]. In this model, students actively explore knowledge, ask questions, find problems, design, and implement projects [15], [16]. In the context of science learning, PjBL can be used to help students apply science and social concepts in real life. The application of PjBL in science learning can improve students' understanding of concepts, critical thinking, and scientific thinking skills [17]–[19]. This model is effective in improving students' self-regulation, especially in managing their time and learning strategies [20]–[22].

In line with research conducted by Guven and Baldan Babayıgıt [23], this study uses the help of PjBL syntax in implementing differentiated learning based on learning styles. The syntax used in this study consists of 6 steps: Problem recognition, Design a plan for the project, Create a schedule of activities, Monitor the students and the progress of the project, Assessment of the products, and Evaluation.

B. Self-Regulation

Self-regulation in learning refers to the ability of learners to manage their learning process independently [24], [25]. This includes the ability to set learning goals, monitor progress, and adjust the strategies used according to needs. Good self-regulation is very important in

differentiation-based learning because it allows learners to be more responsible for their learning development [26]. This study is conceptually grounded in Zimmerman's model of self-regulated learning, which outlines a cyclical process involving forethought (goal setting, strategic planning), performance (self-monitoring), and self-reflection (self-evaluation). This aligns with the study's use of self-regulation indicators, such as goal setting, time management, and motivation [27]. In addition, Gardner's theory of multiple intelligences and Vygotsky's sociocultural theory support the rationale for differentiated instruction. Gardner posits that individuals possess distinct forms of intelligence, such as linguistic, spatial, and bodily-kinesthetic, that correspond with varied learning preferences. Meanwhile, Vygotsky's theory emphasizes social interaction and cultural tools in learning, which are operationalized in this study through collaborative PjBL activities and contextualized content.

Self-regulation indicators include several aspects [28], including: goal setting, self-monitoring, task strategies, motivation, time management, and self-reflection. In this study, the self-regulation indicators used include goal setting, self-monitoring, time management, self-reflection, task strategy, and motivation. The selection of these indicators includes cognitive, affective, and behavioral aspects that are important in students' self-regulation. This can provide a comprehensive picture of how they manage and direct their learning process. To measure students' self-regulation using tests or simulation tasks. This method is a direct observation of students' ability to regulate themselves in controlled situations that are close to real conditions. The selection of test methods or simulation tasks is also based on their ability to provide realistic and relevant data, because students are faced with tasks that simulate real challenges. Thus, it can gain accurate insight into how students manage emotions, motivation, and behavior in dealing with certain situations.

C. Learning Outcomes

Learning outcomes serve as key indicators of educational success, encompassing cognitive, affective, and psychomotor domains. In this study, the cognitive domain is emphasized, as it directly reflects students' understanding, retention, and application of subject matter. Research by Rahayu and Maryani [23] highlights that differentiated instruction, when aligned with students' individual needs, positively influences learning outcomes by enhancing engagement, motivation, and comprehension. The cognitive aspect includes six hierarchical levels: knowledge (C1), understanding (C2), application (C3), analysis (C4), evaluation (C5), and creation (C6). These levels measure students' ability to recall facts, interpret information, apply concepts to real-world problems, and engage in higher-order thinking. However, considering the developmental stage of 4th-grade students, typically aged 9–10 years and in Piaget's concrete operational phase, the most relevant cognitive levels are knowledge,

understanding, and application. At this stage, children can reason logically about concrete situations and begin to classify and organize information, although abstract reasoning remains limited. Nonetheless, with appropriate instructional support, students may begin to develop skills in analysis and evaluation.

To assess cognitive learning outcomes, this study employed multiple-choice objective tests. This method was chosen for its efficiency, objectivity, and ability to evaluate a broad range of content reliably. Multiple-choice tests minimize assessor bias and are especially practical for large-scale classroom implementation. As such, they provide an accurate representation of student achievement and conceptual mastery, aligning well with the goals of differentiated instruction at the elementary level.

Materials and Methods

This study employed a quantitative approach using a quasi-experimental design, specifically the nonequivalent control group design. The design involved two groups. An experimental group received differentiated instruction based on students' learning styles through the PjBL model. A control group received instruction using the Problem-based Learning (PBL) model. The research was conducted at Muhammadiyah Bausasran Elementary School (a private school). The participants consisted of 39 fourth-grade students selected through random sampling. Class 4.1 (n = 20) was designated as the experimental group, while Class 4.2 (n = 19) served as the control group.

To begin the intervention, students' learning styles were identified using a structured questionnaire, categorizing them as visual, auditory, or kinesthetic learners. Instructional strategies in the experimental group were adapted accordingly: visual learners were guided to create diagrams or infographics, auditory learners engaged in oral presentations or audio recordings, and kinesthetic learners conducted hands-on experiments. All activities were designed within the PjBL framework, which includes stages such as orientation, project planning, scheduling, project monitoring, result presentation, and evaluation. Learning activities focused on scientific topics such as changes in the states of matter, with students conducting simple experiments (e.g., melting ice, evaporating water) and presenting their findings.

The research instruments consisted of observation sheets, questionnaires, and objective tests. Observation sheets assessed students' engagement in PjBL activities. Questionnaires served two purposes: identifying students' learning styles for instructional grouping, and measuring their level of self-regulation. The self-regulation questionnaire included indicators such as goal setting, self-monitoring, time management, self-reflection, task strategies, and motivation. Responses were scored using the Guttman scale, which employs dichotomous (Yes/No) answers [28]. Pre-tests and post-tests, each comprising 10

multiple-choice questions, were administered to both groups to measure learning outcomes in science. The items assessed various cognitive domains (C1–C5) aligned with the curriculum objectives. Data analysis was carried out using inferential statistics. Preliminary analyses included normality and homogeneity tests to verify the assumptions of parametric testing. Subsequently, independent sample t-tests and paired sample t-tests were conducted to examine significant differences between the experimental and control groups in terms of self-regulation and science learning outcomes.

Before the main analysis, instrument validity and reliability tests were conducted. Validity, which refers to the extent to which an instrument accurately measures the intended construct, was examined using content and empirical approaches. For empirical validity, the Point Biserial formula was applied using SPSS version 30 to assess item-level correlations for the self-regulation and learning outcomes instruments. Reliability, referring to the consistency of measurement results over time or across raters, was also verified to ensure instrument stability and accuracy.

Before the main analysis, instrument validity and reliability tests were conducted. Validity, which refers to the extent to which an instrument accurately measures the intended construct, was assessed using both content and empirical approaches. For empirical validation, the Point Biserial formula was applied to evaluate item-level correlations for the self-regulation and learning outcomes instruments. Reliability, which refers to the consistency of measurement results over time or across raters, was also examined to ensure the stability and precision of the instruments.

As shown in Table 1, all items from the self-regulation and learning outcomes instruments—both pretest and posttest—exhibit correlation coefficients (r-count) exceeding the critical value of 0.388. Specifically, all 12 items in the self-regulation instrument (pretest and posttest) and all 10 items in the learning outcomes instrument (pretest and posttest) are classified as valid. This indicates that each item has a statistically significant relationship with the construct being measured, confirming the construct validity of the instruments.

In terms of reliability, the pretest and posttest analysis for the self-regulation instrument yielded a Cronbach's Alpha value of 0.991, while the learning outcomes instrument produced a Cronbach's Alpha value of 0.997, both at a significance level of 0.01. These results reflect exceptionally high levels of internal consistency, indicating that the instruments are reliable and suitable for use in the subsequent stages of the study.

The validity test results for the learning outcomes instrument indicate that all items (Items 1 to 10) have correlation coefficients (r-count) exceeding the critical value of 0.388,

confirming that each item meets the required validity criteria and demonstrates a significant relationship with the construct being measured.

Table 1. Validation Results for Self-Regulation and Learning Outcomes Instruments

No	Self-Regulation Pretest (r-count)	Self-Regulation Posttest (r-count)	Learning Outcomes Pretest (r-count)	Learning Outcomes Posttest (r-count)	r-table	Information
1.	0.965	0.972	0.986	0.995	0.388	Valid
2.	0.949	0.977	0.992	0.990	0.388	Valid
3.	0.966	0.955	0.990	0.992	0.388	Valid
4.	0.979	0.965	0.991	0.991	0.388	Valid
5.	0.960	0.979	0.991	0.991	0.388	Valid
6.	0.975	0.960	0.995	0.986	0.388	Valid
7.	0.974	0.961	0.997	0.991	0.388	Valid
8.	0.980	0.975	0.992	0.997	0.388	Valid
9.	0.982	0.944	0.991	0.992	0.388	Valid
10.	0.957	0.972	0.991	0.991	0.388	Valid
11.	0.971	0.981	–	–	0.388	Valid
12.	0.963	0.972	–	–	0.388	Valid

Thus, the instrument can be considered valid and appropriate for use in further research. In addition, reliability testing was conducted for both the self-regulation and learning outcomes instruments. The analysis yielded Cronbach's Alpha values of 0.991 for the self-regulation questionnaire and 0.997 for the learning outcomes test, both at the 0.01 significance level. These results indicate exceptionally high internal consistency, confirming that the instruments are not only valid but also highly reliable. Therefore, both instruments are suitable for use as standardized measurement tools in this study and for potential application in similar future research contexts.

Results

This study aims to analyze the effect of differentiated learning based on learning styles on self-regulation and learning outcomes of students in learning Natural and Social Sciences in 4th-grade students. Differentiated learning applied is based on students' learning style preferences, namely visual, auditory, and kinesthetic, in order to increase learning effectiveness. After conducting observations in the control class and the experimental class, the results of the implementation of the learning model in each class were 100%. So that both models are implemented very well by the syntax that has been designed. This indicates that the implementation proceeded effectively.

Differentiated learning based on learning styles in the experimental group. Activities include distributing learning style questionnaires, pretest, and post-test of self-regulation and science learning outcomes. Learning using PjBL syntax with differentiation of content, process, and product. Students are grouped based on learning styles (visual, audio, kinesthetic). Content differentiation is presented through images, audio, and text, while process

differentiation is done with concept maps, material recordings, and experiment summaries. Learning outcomes are presented as product-based differentiation.

A. Differentiated Learning Using PjBL

In the differentiated learning steps based on learning styles with the PjBL model, it begins with orientation activities opening the learning with greetings, asking for news, and then praying to learn together. Continued by checking student attendance, providing motivation for learning enthusiasm, conveying learning objectives, and students are asked to prepare books and stationery. The first syntax in PjBL is to determine the basic question, where the teacher and students discuss through a question and answer session related to the material to be studied by asking questions such as, " Observe your environment". Mention one example of an object that is solid, liquid, and gas?" After that, the material is presented through learning media, followed by practical activities in Fig. 1.

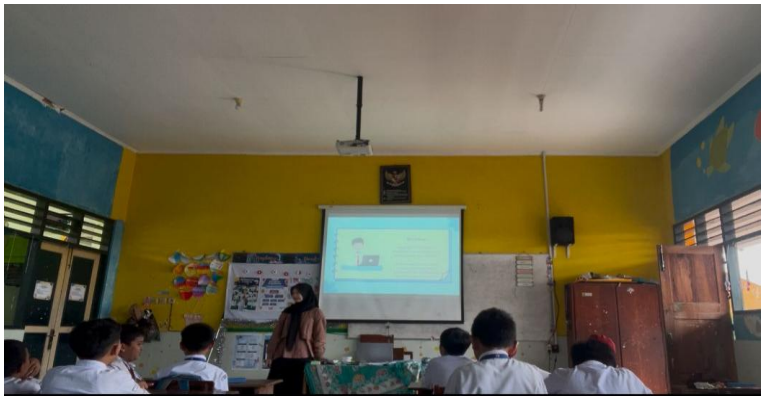


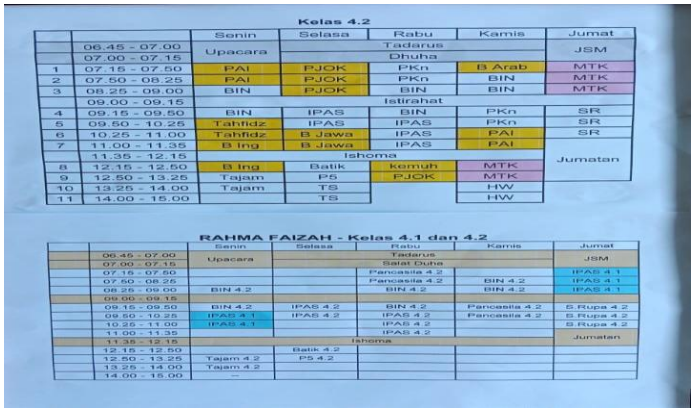
Fig 1. Teachers and Students Determine Basic Questions

In the project planning stage in PjBL syntax, students are divided into three groups based on the results of their learning style assessment. Each group is given a Student Worksheet consisting of two types, namely a general worksheet with the same questions for all groups and a special worksheet that is adjusted to each learning style. Students with a visual learning style work on the worksheet in the form of a concept map that describes the material on changes in form. Meanwhile, the group with an auditory learning style is given the task of making an explanatory recording of changes in form. The group with a kinesthetic learning style compiles a summary of the material based on the results of the practice that has been carried out. This approach aims to optimize student understanding according to the characteristics of their respective learning styles.



Fig 2. Teachers and Students Planning a Project

The third syntax, namely scheduling, teachers and students together determine the duration required to complete the Student Worksheet in each group. See Fig. 3.



Kelas 4.2

		Senin	Selasa	Rabu	Kamis	Jumat
	06.45 - 07.00	Upacara	Tadarus			JSM
	07.00 - 07.15		Dhuha			
1	07.15 - 07.50	PAI	PJOK	PKn	B Arab	MTK
2	07.50 - 08.25	PAI	PJOK	PKn	BIN	MTK
3	08.25 - 09.00	BIN	PJOK	BIN	BIN	MTK
	09.00 - 09.15	Istirahat				
4	09.15 - 09.50	BIN	IPAS	BIN	PKn	SR
5	09.50 - 10.25	Tahfidz	IPAS	IPAS	PKn	SR
6	10.25 - 11.00	Tahfidz	B Jawa	IPAS	PAI	SR
7	11.00 - 11.35	B Ing	B Jawa	IPAS	PAI	
	11.35 - 12.15	Ishoma				Jumatan
8	12.15 - 12.50	B Ing	Batik	kemuh	MTK	
9	12.50 - 13.25	Tajam	P5	PJOK	MTK	
10	13.25 - 14.00	Tajam	TS		HW	
11	14.00 - 15.00		TS		HW	

RAHMA FAIZAH - Kelas 4.1 dan 4.2

	Senin	Selasa	Rabu	Kamis	Jumat
06.45 - 07.00	Upacara		Tadarus		JSM
07.00 - 07.15			Salat Duha		
07.15 - 07.50			Pancasila 4.2		IPAS 4.1
07.50 - 08.25			Pancasila 4.2	BIN 4.2	IPAS 4.1
08.25 - 09.00	BIN 4.2		BIN 4.2	BIN 4.2	IPAS 4.1
09.00 - 09.15					
09.15 - 09.50	BIN 4.2	IPAS 4.2	BIN 4.2	Pancasila 4.2	B.Rupa 4.2
09.50 - 10.25	IPAS 4.1	IPAS 4.2	IPAS 4.2	Pancasila 4.2	B.Rupa 4.2
10.25 - 11.00	IPAS 4.1		IPAS 4.2		B.Rupa 4.2
11.00 - 11.35			IPAS 4.2		
11.35 - 12.15	Ishoma				Jumatan
12.15 - 12.50		Batik 4.2			
12.50 - 13.25	Tajam 4.2	P5 4.2			
13.25 - 14.00	Tajam 4.2				
14.00 - 15.00	--				

Fig 3. Determining the Schedule

Next, in the fourth stage, namely monitoring the progress of the project, the teacher is responsible for supervising the process of working on the worksheet by the students. In addition, the teacher also encourages students to ask questions if they encounter difficulties. In this stage, students work together in their groups to develop ideas and concepts collaboratively in completing the worksheet (Fig. 4).

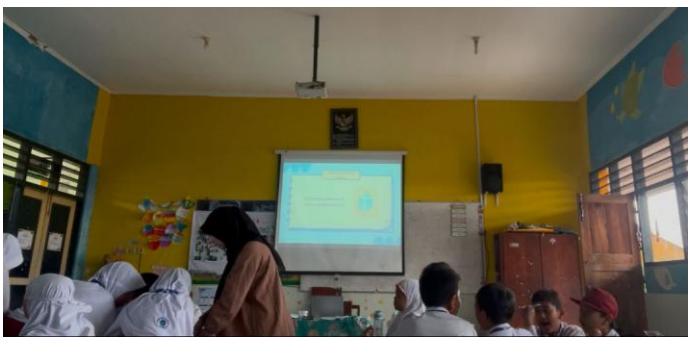


Fig 4. Teacher Monitors Project Progress

The fifth syntax is presenting and evaluating results, each group is responsible for presenting their work in front of the class. Other groups are required to respond to the form of questions, with a maximum limit of two questions. However, there are still some groups who

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are reluctant to ask questions, so that the interaction and discussion in the presentation session are less than optimal. See Fig. 5.

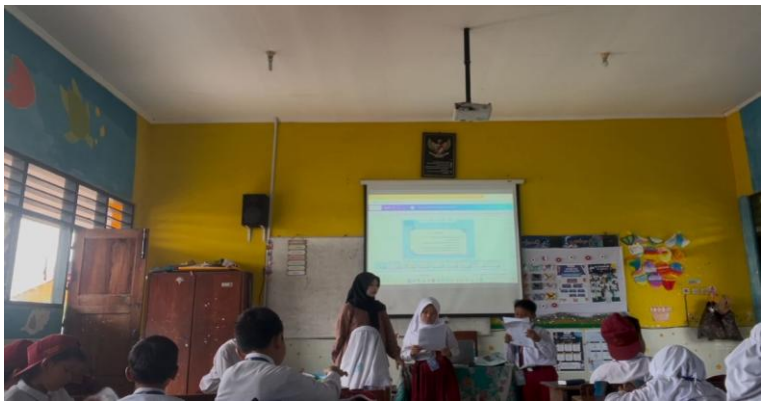


Fig 5. Students Present and Assess Results

The sixth step and the last step are evaluating the project results. At this stage, the teacher and students conduct a question-and-answer session related to the material that has been studied. Some students ask questions, while others respond to the concept of energy transformation. After that, the teacher and students summarize the core of the learning that has been done. In closing, the teacher ensures whether there are still things that are not understood or questions that need to be discussed further.



Fig 6. Teachers and Students Evaluate Project Results

Differentiated learning based on learning styles in the PjBL model has proven effective in improving self-regulation and learning outcomes of students. Through the analysis of learning styles, students are grouped based on their choices (visual, auditory, or kinesthetic) so that the method of delivering the material can be more appropriate to the needs of each individual. With this approach, each student can understand the material more optimally according to their learning characteristics. Although there are still challenges in encouraging active participation in discussion sessions, the results of this study indicate that a more personal and flexible learning method can increase the effectiveness of learning. Therefore, the application

of this model can be a reference for educators in developing more inclusive and adaptive teaching strategies to meet the needs of diverse students.

B. Learning Styles

Each student has a different learning style, which can be categorized into three main types: visual, auditory, and kinesthetic. These learning styles affect how students receive, understand, and process information in the learning process. To find out the distribution of students' learning styles, the following data is presented regarding the number of students based on their learning styles.

Table 2. Number of students based on learning style

Types of Learning Styles	Freq.	% student
Visual Learners	8	40
Audio Learners	7	35
Kinesthetic Learners	5	25
Total	20	100

Table 2 shows the number of students based on learning styles. It can be seen that the number of students who have a visual learning style is eight students, an audio learning style is seven students, and a kinesthetic learning style is five students.

C. Self-Regulation

Self-regulation in education refers to a student's ability to independently manage, monitor, and direct their learning processes to achieve academic goals. It includes cognitive, motivational, and behavioral aspects that enable learners to set goals, stay motivated, apply effective strategies, and evaluate their progress. Students with strong self-regulation tend to be more independent, resilient, and engaged in their learning. Fig. 7 presents a comparative analysis of self-regulation levels in both experimental and control groups before and after the intervention. The figure categorizes self-regulation into three levels: low, moderate, and high.

In the experimental group, there was a notable improvement. The percentage of students in the moderate category increased from 70% (pretest) to 80% (posttest), while those in the low category decreased from 25% to 10%. The proportion of students in the high category also rose from 5% to 10%. These changes suggest a positive shift in self-regulation levels following the implementation of differentiated instruction based on learning styles. In contrast, the control group showed a decline in the high self-regulation category—from 11% at pretest to only 5% at posttest. Meanwhile, the moderate category increased significantly from 37% to 84%, and the low category decreased from 52% to 11%.

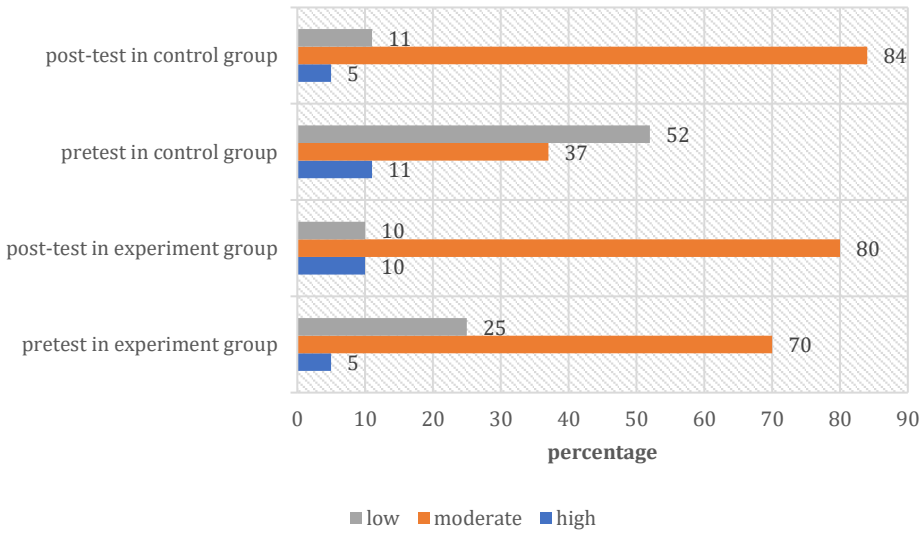


Fig 7. Self-Regulation Levels in Experimental and Control Groups

Although a shift away from low self-regulation is apparent, the decrease in high self-regulation suggests that PBL may not sufficiently support advanced self-regulatory development. The data illustrate that differentiated instruction implemented through the PjBL model provides more meaningful support for enhancing students' self-regulatory skills, especially by reducing low-performing learners and promoting moderate-to-high self-regulation.

D. Science Learning Outcomes

Learning outcomes serve as a key indicator in evaluating the effectiveness of instructional practices, reflecting the extent to which educational objectives are achieved through interactions between students, teachers, and the learning environment. Achieving optimal learning outcomes is influenced by several factors, particularly the instructional models used. In elementary education, scientific and student-centered approaches are crucial to foster active engagement and promote deeper understanding. Differentiated instruction—especially when tailored to individual learning styles—can significantly improve motivation and academic performance in science learning. To examine this impact, this study compared pretest and posttest data between experimental and control groups.

As shown in Fig. 8, the experimental group maintained a consistent level of performance in the moderate category, with 70% of students falling into this range in both the pretest and posttest. Importantly, the high category improved from 10% to 15%, while the low category decreased from 20% to 15%. These changes indicate a positive shift in learning outcomes among students receiving learning style-based differentiated instruction using the PjBL model.

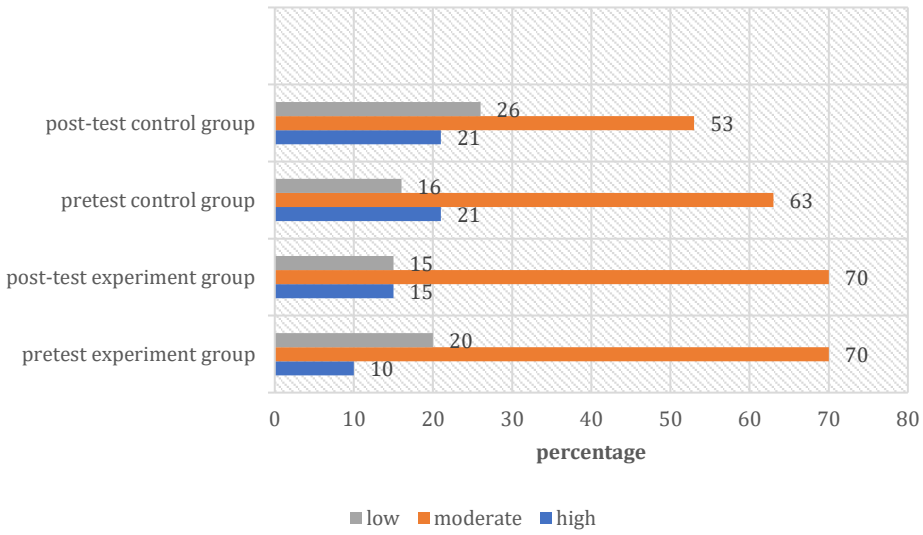


Fig 8. Distribution of Learning Outcomes

In contrast, the control group, which received conventional instruction using the Problem-Based Learning model, experienced less favorable progress. The percentage of students in the moderate category decreased from 63% to 53%, while the low category increased from 16% to 26%. The proportion of students in the high category improved slightly from 21% to 21% (no change), indicating that while some improvement occurred, the control group showed less consistent gains overall. These findings support the conclusion that differentiated instruction based on learning styles, when integrated with the PjBL model, has a more substantial and favorable impact on improving students' science learning outcomes compared to conventional approaches. This further affirms the value of tailoring instruction to accommodate individual differences in learning preferences in elementary classrooms.

E. Hypothesis Testing

The hypothesis testing in this study began with assumption tests, including normality and homogeneity. The Shapiro–Wilk normality test results (Table 3) show that all variables—self-regulation and learning outcomes, for both experimental and control groups—have significance values greater than 0.05. This indicates that the data are normally distributed and meet the assumption required for parametric analysis.

Table 3. Normality Test

Variables	Group	Shaphito-Wilk			Trust Level	Caption
		Statistics	df	Sig		
Self Regulation	Pretest-Experiment	.934	20	.187	α = 0.05	Normal
	Posttest-Experiment	.929	20	.150		Normal
	Pretest-Control	.969	19	.749		Normal
	Posttest-Control	.950	19	.389		Normal
Learning outcomes	Pretest-Experiment	.919	20	.094	α = 0.05	Normal
	Posttest-Experiment	.918	20	.091		Normal
	Pretest-Control	.956	19	.488		Normal
	Posttest-Control	.955	19	.485		Normal

The Levene's Test for Equality of Variances (Table 4) further confirmed that all significance values were above 0.05, demonstrating that variances across groups are homogeneous. This supports the use of parametric tests, specifically the Independent Sample t-Test and Paired Sample t-Test.

Table 4. Homogeneity Test

		Levene Statistics	df1	df2	Sig
Pretest Self-Regulation	Based on the Mean	.739	1	37	.396
Posttest Self Regulation	Based on Mean	1.884	1	37	.178
Pretest Learning Outcomes	Based on Mean	1.442	1	37	.238
Posttest Learning Outcomes	Based on Mean	1.465	1	37	.234

Based on these assumption tests, an Independent Sample t-Test was conducted (Table 5). The results indicate a significant difference between the experimental and control groups for both self-regulation ($p = 0.017$) and learning outcomes ($p < 0.001$). These findings confirm that differentiated instruction based on students' learning styles had a statistically significant positive effect on both variables.

Table 5. Independent Sample t-Test Results

Levene's Test for Equality of Variances	Significance							95% Confidence Interval of the Difference	
	f	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Self-Regulation	1.994	0.166	-2.495	37	0.017	<.001	0.548	-2.48	-0.257
Learning outcomes	6.136	0.018	4.886	37	<0.001	21.553	4.430	12.577	30.528

These findings are consistent with previous studies that emphasize the effectiveness of learning style-based differentiation in enhancing metacognitive abilities and academic achievement. Differentiated instruction helps align teaching strategies with individual learning preferences, thereby increasing student motivation and engagement [14]. To examine within-group effects, a Paired Sample t-Test was conducted on the experimental group (Table 6). The results showed no statistically significant difference between pretest and posttest scores for both self-regulation ($p = 0.230$) and learning outcomes ($p = 0.235$), despite a visible increase in average scores.

This contrast between inter-group and intra-group results suggests that while the intervention had a comparative advantage, its short duration or limited scope may not have been sufficient to generate statistically significant gains within the experimental group alone. This pattern aligns with findings by Erina et al. [29] and Kooken et al. [30], who noted that sustained and structured implementation is necessary for differentiated strategies to impact internal student factors like self-regulation.

Table 6. Paired Sample t-Test Results (Pre-test and Post-test)

	Paired Difference			95% Confidence Interval of the Difference				Sign.
	Mean.	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Self-Regulation	0.316	1.108	0.254	-0.85	0.218	-1.242	18	**0.23**
Learning Outcomes	-2.632	9.335	2,142	-7.131	1.868	-1.229	18	**0.235**

Discussion

The findings of this study indicate that differentiated instruction based on students' learning styles has a significant influence on both self-regulation and science learning outcomes among fourth-grade elementary school students. This approach, which integrates principles of learning style theory with PjBL, fosters more personalized and engaging learning experiences. The three core variables explored in this study—learning style differentiation, self-regulation, and learning outcomes—are interrelated in ways that reinforce each other within the instructional context.

Self-regulation is a metacognitive skill that enables students to plan, monitor, and evaluate their learning processes [31]. In this study, the implementation of differentiated instruction based on visual, auditory, and kinesthetic learning preferences allowed students to engage with content through methods that align with their strengths. This alignment is particularly relevant to the development of self-regulatory capacities, such as goal setting, self-monitoring, task strategies, time management, motivation, and self-reflection. As illustrated in Fig. 7, students in the experimental group exhibited a noticeable increase in the high self-regulation category, with a corresponding decrease in the low self-regulation group. These outcomes support the cyclical model of self-regulated learning, which emphasizes the role of strategic forethought, performance control, and self-reflection in effective learning [27] . Thus, differentiated learning experiences appear to cultivate metacognitive awareness and behavioral regulation among students.

Science education in the primary grades requires more than rote memorization; it demands conceptual understanding and the ability to apply knowledge in authentic contexts [32]. Differentiated instruction enables students to access content in ways that are cognitively and experientially appropriate for them. For example, visual learners may benefit from diagrams to understand changes in states of matter, while kinesthetic learners may engage more effectively through hands-on experiments. Fig. 8 presents comparative data that reveals a greater increase in posttest scores within the experimental group, as opposed to modest gains in the control group. Although the paired sample t-test did not detect statistically significant differences within the experimental group ($p > 0.05$), the independent sample t-test showed statistically significant differences between groups for both self-regulation ($p = 0.017$) and learning outcomes ($p < 0.001$). These findings suggest that, while the internal growth may

not have been large enough to reach significance within the limited time frame, differentiated instruction remains superior to conventional problem-based learning in comparative terms.

The study further confirms that self-regulation and academic achievement are mutually reinforcing constructs. Students with strong self-regulatory abilities are more likely to maintain focus, manage their time effectively, and reflect on their learning processes. In project-based learning contexts, these skills are essential for goal planning, group collaboration, and task execution. Although the within-group analysis did not show significant improvements in learning outcomes, the increase in self-regulation scores may have contributed indirectly to higher posttest performance in the experimental group. This aligns with prior research [33], [34], which demonstrates that self-regulated learners tend to achieve better academic outcomes due to their heightened autonomy and adaptive learning strategies.

Implications and Further Considerations

The findings support earlier research [35], on the effectiveness of differentiated instruction in enhancing academic performance and metacognitive development. Although the within-group changes were not statistically significant, the positive trends observed underscore the importance of sustained implementation and contextual adaptation. It is recommended that educators systematically assess student learning styles and design instruction that accommodates these differences. Furthermore, integrating differentiated instruction into broader curricular initiatives, such as Indonesia's Merdeka Curriculum, requires institutional support and targeted teacher training. Future studies with larger sample sizes and extended intervention periods may offer clearer insights into the longitudinal impact of learning style-based differentiation on student achievement and self-regulation.

Conclusion

The findings of this study highlight the differential effects of learning style-based differentiated instruction on students' self-regulation and science learning outcomes. The independent sample t-test results show a significant improvement in the experimental group's performance compared to the control group, particularly in science learning outcomes. This finding supports the assertion that aligning instructional methods with students' preferred learning styles can enhance conceptual understanding and academic achievement. The substantial increase in posttest scores in the experimental group indicates that differentiated instruction effectively supports the acquisition of scientific knowledge among elementary students. In contrast, the impact of the intervention on students' self-regulation was less conclusive. While there was a significant difference in self-regulation scores between the experimental and control groups, the within-group analysis using paired sample t-tests did not yield significant results. This suggests that improvements in self-regulatory behavior may

require longer intervention periods or more intensive strategies beyond instructional differentiation. These results are consistent with previous studies highlighting the importance of matching instruction to individual learner profiles to improve cognitive outcomes. However, they also point to the complexity of influencing behavioral and motivational constructs such as self-regulation, which may be shaped by multiple environmental and personal factors. In light of these findings, educators are encouraged to adopt differentiated instructional practices to optimize learning outcomes. Future research should explore extended interventions and integrate metacognitive training to better support the development of students' self-regulation skills.

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