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THE EFFECT OF DIFFERENTIATED SCIENCE INQUIRY LEARNING MODEL BASED ON TEACHING AT THE RIGHT LEVEL ON STUDENTS' CRITICAL THINKING AND SCIENCE PROCESS SKILLS

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ABSTRACT

Student cognitive diversity can be a barrier to enhancing critical thinking and science process skills. The TaRL-based DSI model addresses this by facilitating learning for students at different cognitive levels. This research aims to determine the effect of the Differentiated Science Inquiry (DSI) model based on the Teaching at the Right Level (TaRL) approach on eighth-grade junior high school students' critical thinking and science process skills in the context of vibration and wave concepts. A non-equivalent control group design was used to address varied learning needs, with 55 students purposively selected for experimental and control groups. Data were collected using essay-based critical thinking tests and multiple-choice science process skills assessments. The DSI model applied four inquiry levels: Demonstrated Inquiry, Structured Inquiry, Guided Inquiry, and Self-Directed Inquiry based on students' initial abilities. Data were analyzed using descriptive and inferential methods. The average critical thinking skills in the experimental group after treatment were 13.04, and in the control group were 10.1. The average science process skills in the experimental group were 19.77, and in the control group were 18. The research results confirm that the TaRL-based DSI model significantly enhances students' critical thinking and science process skills at a significance level of $\alpha = 0.05$. This research is expected to help educators implement the DSI model to accommodate diverse learning needs and enhance crucial skills in science education.

Keywords: differentiated science inquiry learning model; teaching at the right level; critical thinking skills; science process skills

INTRODUCTION

The development of science and technology requires education to create quality human resources to compete globally (Fuad et al., 2017; Zubaidah et al., 2017). In this fast-paced era, students must have thinking skills to help them make firm decisions to acquire new knowledge quickly (Lau, 2011; Rizal et al., 2022). To foster varied thinking skills in students, the Differentiated Science Inquiry (DSI) model offers a valuable inquiry-based approach (Leonor, 2015). The DSI model is a promising strategy to meet the diversity of students' cognitive abilities (Leonor, 2015; Tindangen, 2018; Al-rsa'i & Shugairat, 2019).

The DSI model divides classes based on students' abilities from low to high. Through the implementation of the DSI model, it is hoped that each student will get the same opportunity to develop (Llewellyn, 2011). The DSI model allows for the adjustment of instruction to the level of readiness, interests, and learning styles to maximize students' potential (Estaiteyeh & DeCoito, 2023). According to Fuad et al. (2017), the effective implementation of the DSI Model can encourage student activity, facilitate the exp-

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loration of questions and hypotheses, help them build learning that suits their needs, deepen their understanding of concepts, and develop critical and higher-order thinking skills.

Teaching at the Right Level (TaRL) complements the DSI Model. TaRL focuses on the importance of adapting instruction to learners' abilities and identifying and meeting their learning needs, ensuring that they are given the appropriate level of challenge and support to facilitate their specific academic development (Smale-Jacobse et al., 2019; Asyidiqi et al., 2024). The TaRL approach begins by implementing diagnostic tests to map learners' initial characteristics and abilities, allowing educators to identify areas for improvement. The TaRL approach focuses on learners' ability levels, while DSI encourages problem-solving through independent exploration and experimentation. The TaRL approach provides flexible guidance in the Merdeka Curriculum. This approach strongly supports the Merdeka Belajar (Freedom in Learning) program by providing the freedom to implement differentiated learning according to ability and centered on learners and improving their thinking skills (Chandra Handa, 2019; Ismail et al., 2021; Gupta, 2023). The characteristics of scientific inquiry learning are suitable for improving students' critical thinking skills in identifying, analyzing, and assessing information logically to conclude solutions.

Supporting facts for using the TaRL-based DSI model in this research include the diversity of students' ability levels and learning speeds (Huang et al., 2021). This fact is based on learning principles that offer a framework for adapting science teaching to each student's needs and abilities (Oliver et al., 2021). By adjusting the instructional approach and level of guidance to the specific needs of students, the DSI model can potentially improve learning outcomes (Restiana & Djukri, 2021). This DSI model also allows educators to adjust the inquiry level based on their strengths and weaknesses so that students can optimize learning (Zubaidah et al., 2017), which aligns with the call to differentiate learning activities to suit individual needs (van Geel et al., 2019). Another supporting fact is the importance of critical thinking and science process skills in the 21st century to navigate information.

Critical thinking is one of the most important life skills (Mutakinati et al., 2018; Kim et al., 2019; Kanwal & Butt, 2021). Preparing students to think critically is one of the main goals for many professionals in education (Changwong et al., 2018). According to Bellaera (2021), critical thinking is thinking logically and reflectively and deciding what to do. From this opinion, it is concluded that thinking skills, such as utilizing various objects and concepts to solve a problem, can be used for critical thinking. In other words, critical thinking skills are tools for solving contextual and non-contextual problems (Kanwal & Butt, 2021).

Critical thinking skills are widely recognized as an essential element in modern education systems, and all educators need to implement practical learning approaches to help learners develop and strengthen their thinking skills (Moust et al., 2021). This aligns with the fourth point of the Sustainable Development Goals, SDGs-4 quality education. In order to achieve the goal of quality education, critical thinking skills are needed to facilitate learners to analyze information, solve problems, and make the right decisions. This enables learners to become lifelong learners and contribute effectively to society (French & Kotzé, 2018). Several previous studies have discussed the importance of critical thinking skills in education and their relation to the SDGs. Franco-Mariscal et al. (2024) state that critical thinking skills are important in supporting the progress of a dynamic society. Astalini et al. (2023) discuss the benefits of digital literacy, and Rico et al. (2021) reveal the integration of STEM in SDGs learning to improve the thinking skills of pre-service primary teachers.

Critical thinking skills require a rational mind with sound reasoning, the ability to follow logical rules, and scientific reasoning as the best basis for making decisions. One must use core thinking skills to think critically, such as making conclusions, investigating assumptions, making deductions or reasoning, making interpretations, and evaluating (Hajhosseini et al., 2016). Critical thinking is also considered a cognitive skill related to logical analysis and evaluation of arguments to determine logical actions (Papp et al., 2014; Orakcı, 2021; Álvarez-Huerta et al., 2022). Critical thinking has five indicators: providing simple explanations, building basic skills, making conclusions, making advanced explanations, and determining strategies and tactics (Tanti et al., 2020).

Rahmawati et al. (2020) and Yaki (2022) stated that 40% to 60% of students had difficulty explaining their answers with critical reasoning. These results indicate that students' critical thinking skills in science subjects are still low. According to Dewanti et al. (2021), Schmaltz et al. (2017), and Yaki (2022), the factor causing low critical thinking skills in students is teacher-centered learning (Utami et al., 2024). Learning that emphasizes memorization rather than conceptual understanding can hinder the development of critical thinking skills so that students cannot apply them in new situations or solve problems and hinder high-level thinking skills. The low critical thinking skills of students are also caused by the lack of opportunities for students to actively participate in learning, which makes them less able to build knowledge independently, develop concepts, and apply skills in problem-solving (Iwuanyanwu, 2019; Rahmawati et al., 2020).

In addition to critical thinking, science process skills are important for students' success (Darmaji et al., 2020). These skills aim to solve problems and find practical solutions (Tanti et al., 2020). Science process skills are procedural skills, scientific thinking habits in experimenting and investigating, scientific inquiry skills, and inquiry process skills (Chakraborty & Kidman, 2022). Ratnasari et al. (2018) stated that developing science process skills allows students to acquire the skills needed to solve everyday problems. This opinion aligns with Idris et al. (2022) and Yusnidar et al. (2024), who stated that science process skills are an important indicator for students when solving problems. Science process skills also help students develop scientific skills responsibly (Gizaw & Sota, 2023).

Science process skills are fundamental to achieving the SDG-4 goal of quality education by equipping individuals to solve problems and make evidence-based decisions (Aunzo, Jr., 2024). In addition, PPPs are also related to SDGs-13 related to climate action. Understanding climate change and developing solutions requires science process skills. Learners with these skills can analyze data, evaluate evidence, and contribute to climate change mitigation and adaptation efforts (Siegner & Stapert, 2020). Science process skills are divided into basic and integrated (Kaymakci & Can, 2021). Basic science process skills are the foundation for developing more complex science process skills, including observation, measurement, classification, quantification, inferring, predicting relationships, and communicating. Integrated science process skills are built on basic skills and involve higher-order thinking processes, including interpreting data, controlling variables, operational definitions, hypotheses, and experiments. Mastery of basic science process skills will support the development of integrated science process skills, and both are important for developing critical and scientific thinking skills.

Gizaw and Sota (2023) and Sari et al. (2020) revealed students' low science process skills. Science learning is still mostly teacher-centered, uses more memorization methods of facts and theories, and does not actively involve students in the scientific process (Hoidn & Reusser, 2020). This passive approach often fails to encourage the development of essential science process skills, such as observation, inference, classification, and hypothesis testing, which are essential for critical thinking (Purwanto et al., 2019; Dewanti et al., 2021). The lack of variety in teacher learning methods, such as lectures and assignments, causes students to be less motivated and have less opportunity to practice their science process skills Yaki (2022). Setiawan and Sugiyanto (2020) also revealed that teachers do not understand the concept and importance of science process skills, so they do not teach and practice them effectively.

In science learning in the Merdeka Curriculum, students' critical thinking and science process skills are important aspects that must be possessed (Astalini et al., 2023). Critical thinking skills are higher-order thinking skills (Siahaan et al., 2020). Likewise, science process skills are one of the elements in science learning achievements. Educators must design learning to improve critical thinking and science process skills. In the Merdeka Curriculum, educators must understand learning materials, determine appropriate methods, and manage time according to each student's interests, needs, and level of understanding.

Based on observations and interviews with the vice principal of curriculum and science teacher of junior high schools in Makassar, teachers apply various learning. The learning models applied are adjusted to the material, such as problem-based learning (PBL), project-based Learning (PjBL), inquiry, and discovery learning. However, in the learning process, the diversity of students' initial skills is one of the challenges for educators in presenting learning. Each student is unique. Some students quickly grasp lessons and can complete tasks and learning activities faster, and some students are slow in receiving learning, so they often lag in learning and need more time than other students. In this case, the role of educators in understanding students' learning needs is significant. The abilities of each student vary, so educators should not assume that all students have the same potential. Educators must prepare learning activities by considering students' needs, such as learning readiness, interests, and profiles. Thus, students' interest and enthusiasm for learning will increase with increased critical thinking and science process skills.

Interviews with junior high school science teachers in Makassar showed that students' critical thinking and science process skills were still low. When given a critical thinking skills test in the form of higher-order thinking skills questions, more than 70% of students scored below the passing grade. This aligns with Anggraeni et al. (2023) and Sutiani et al. (2021), who reveal students' difficulties in developing critical thinking skills. Meanwhile, many students could not observe, measure, or interpret data from the science process skills aspect. This result was clarified based on the initial ability test by the researcher by giving three types of questions: observing images, formulating hypotheses, and interpreting data. Based on the analysis of students' answers, 13% answered correctly in observing images, 9% in formulating hypotheses, and 7% in interpreting data. This fact is supported by Prayitno et al. (2017), who revealed differences in the acquisition of students' science process skills based on high and low levels of academic achievement. Students' low critical thinking and science process skills are undoubtedly inseparable from the use of methods, models, or approaches by educators that do not adjust to the diversity of students.

Based on the research results, the gaps in the acquisition of students' critical thinking and science process skills are an issue that continues to be a concern. Previous research revealed the low level of these skills in junior high school students, which aligns with broader research trends (Purwanto et al., 2019). Low critical thinking and science process skills can significantly impact individuals and society, including difficulty in solving problems, lack of creativity in innovating, difficulty in making decisions, and low academic achievement (Zwiers & Crawford, 2023). In order to overcome these problems, an approach to learning that integrates critical thinking skills and science process skills is needed, taking into account the learning needs of students.

This research aims to enhance students' critical thinking and science process skills by applying an appropriate learning model for the Merdeka Curriculum. The Differentiated Science Inquiry (DSI) model based on the Teaching at the Right Level (TaRL) approach was chosen as a potential solution to overcome this problem. Given the significant differences in students' learning readiness, interests, styles, experiences, and living conditions, educators must accommodate this diversity to maximize individual potential (Gibbs & McKay, 2021; Utami et al., 2024). Failure to address these differences can hinder the optimal development of students' critical thinking and science process skills. Although the potential of the TaRL-based DSI model is quite significant, empirical research that tests its effectiveness on critical thinking and science process skills is still limited. Critical thinking skills are essential for evaluating the credibility of information, identifying bias, and making informed decisions (Hajhosseini et al., 2016; Benek & Akcay, 2022). Science process skills, emphasizing observation, analysis, and interpretation, further enhance students' ability to distinguish credible information.

Bridging a critical gap in science education, this research introduces a novel approach by examining the effect of a DSI model, informed by the principles of TaRL, on students' critical thinking and science process skills. Their integration offers a unique, student-centered framework that caters to diverse learning needs and promotes more profound engagement with scientific inquiry (Fuad et al., 2017; Asyidiqi et al., 2024). By empirically testing this integrated model, this research addresses the call for innovative strategies that enhance critical thinking and science process skills, ultimately contributing to a more adaptive and effective science education paradigm. Therefore, this research is crucial to provide empirical evidence for educators. Based on these considerations, the following hypotheses were tested: 1) Implementing the DSI model based on the TaRL approach will significantly improve eighth-grade junior high school students' critical thinking skills; 2) Implementing the DSI model based on the TaRL approach will significantly improve eighth-grade junior high school students' science process skills.

This research aims to determine the effect of the Differentiated Science Inquiry (DSI) model based on the Teaching at the Right Level (TaRL) approach on eighth-grade junior high school students' critical thinking and science process skills. The concepts of differentiation were applied to the Merdeka curriculum in content, process, and product. The application of DSI is based on the principle of process differentiation or how students interpret the material studied independently or in groups by providing tiered activities. Students are divided into four levels according to their initial abilities: very high (Level 4), high (Level 3), moderate (level 2), and low (level 1) categories. The learning steps for all levels are the same; the difference is the guidance or assistance at each step.

METHODS

This type of research is quantitative research, quasi-experimental design, involving both an experimental and a control group refers to

(Fraenkel & Norman, 2012; Creswell, 2021) in eighth-grade junior high school students' to determine the effect of the Differentiated Science Inquiry (DSI) model based on the Teaching at the Right Level (TaRL) approach on students' critical thinking skills and science process skills. This research refers to the stages of implementing the DSI model (Llewellyn, 2011) in Table 1.

Table 1. Stages of the DSI Learning Model

No	Learning Stage	Learning Activities
1	Inquisition	Starting with a focus on a question to investigate
2	Acquisition	Brainstorming possible answers
3	Supposition	Selecting a question to test
4	Implementation	Design and execute a plan
5	Summation	Gathering evidence and drawing conclusions
6	Exhibition	Sharing and communicating findings

The modification made by the researcher integrates the DSI Model and differentiated learning (Bresser & Fargason, 2023). The type of differentiation carried out in this research is process differentiation as applied in the Merdeka curriculum (Kaufman & Wandberg, 2014; Anggraena et al., 2022).

The research population was 365 eighth-grade students of SMPN 6 Makassar. Using purposive sampling, class 8-A was selected as the experimental group with 26 students and class 8-E as the control group with 29 students. The sampling was conducted by selecting classes with similar baseline learning outcomes, and their teachers were willing to implement the new and existing teaching models.

The independent variable in this research is the TaRL-based DSI model, while the dependent variables are critical thinking and science process skills. This study has a Non-equivalent Control Group Design (Figure 1). The experimental group was taught with the TaRL-based DSI model, and the control group was taught with the Structured Inquiry learning model commonly used by teachers at the school.

G_1	O_1	X	O_2
G_2	O_3	-	O_4

Figure 1. Research Design (Wiersma & Jurs, 2009)

X: The TaRL-based DSI model
O_1, O_3 : Pretest
O_2, O_4 : Posttest
G_1: Experimental group
G_2: Control group

The TaRL-based DSI model begins with an initial ability test to categorize students based on their level of inquiry. Students were categorized into four levels of inquiry based on average test scores on the three previous materials and the initial test scores. The groups are categorized according to Table 2.

Table 2. Category of Groups Based on Inquiry Level

Groups Based on Inquiry Level	Score Interval	Category
Level 1 (Demonstrated Inquiry)	<60	Low
Level 2 (Structured Inquiry)	60≤69	Moderate
Level 3 (Guided Inquiry)	70≤79	High
Level 4 (Self-directed Inquiry)	80≤100	Very High

The instruments used were a critical thinking skills test of 5 essay questions and a science process skills test of 25 multiple-choice questions. The critical thinking test measured students' understanding of concepts based on 5 indicators: elementary clarification, basic support, inference, advance clarification, and strategies dan tactics. The science process skills test measured students' understanding of concepts based on 8 indicators: observing, identifying variable, problem statements, developing a hypothesis, designing an experiment, data processing, communicating, and drawing a conclusion. Experts have validated both instruments. Furthermore, the instruments were used in the data collection stage, which was carried out through a pretest and posttest.

Data were analyzed using descriptive and inferential methods. Descriptive statistics were used to determine the level of implementation of the DSI model based on the TaRL approach by describing the characteristics of the score distribution for critical thinking and science process skills. This includes reporting the number of samples, the highest, lowest, average score (mean), standard deviation, variance, and N-gain. Inferential statistics were carried out using a t-test at a significance level of 5%, which was preceded by a requirement test (normality and homogeneity tests) to determine the effect of the learning model on students' critical thinking and science process skills.

RESULTS AND DISCUSSION

The study was conducted during six meetings in which the experimental group was taught using the Differentiated Science Inquiry (DSI) learning model, and the control group was taught using the structured inquiry model at the junior high school level. Before learning, students were grouped based on their initial abilities according to the learning outcomes from the material Pressure of Substances and Its Application in Daily Life and the material Human Respiratory System studied previously. Before grouping, students were also given a test to formulate problems, formulate hypotheses, and identify variables. Then, they were grouped according to low, moderate, and high abilities. The daily test scores and test results were accumulated later. The scores were used as the basis for grouping students by applying each level of inquiry with the help of teachers as educators who understand the competencies of their students.

Descriptive analysis in this study aims to describe students' critical thinking and science process skills in the experimental and control groups. The results of the descriptive analysis are presented in Table 3.

Table 3. Results of Descriptive Analysis of Students' Critical Thinking Skills

No.	Statistics	Experimental Group		Control Group	
		Pretest	Posttest	Pretest	Posttest
1	Sample	26	26	29	29
2	Highest Score	12	18	10	16
3	Lowest Score	1	8	1	3
4	Average Score	6.81	13.04	4.72	10.10
5	Standard Deviation	2.87	2.70	2.05	3.37
6	Variance	8.24	7.39	4.20	11.36

Based on Table 3, there was an increase in scores from pretest to posttest in the experimental and control groups, with an increase in the average score of the experimental group higher than the control group. The highest pretest score in the experimental group was 12, and in the control group was 10. The lowest pretest score in the experimental and control groups was the same, namely 1. The highest posttest score for critical thinking skills in the experimental group was 18, and in the control group, it was 16. The lowest posttest score in the experimental group was 8, and in the control group was 3. The average pretest score of critical thinking skills in the experimental group was 6.81, and in the control group was 4.72. The average posttest score in the experimental group was 13.04, and in the control group was 10.10. The results of the descriptive analysis of students' science process skills in the experimental and control groups are presented in Table 4.

Table 4. Results of Descriptive Analysis of Students' Science Process Skills

No	Statistics	Experimental Group		Control Group	
		Pretest	Posttest	Pretest	Posttest
1	Sample	26	26	29	29
2	Highest Score	14	23	14	22
3	Lowest Score	3	13	4	11
4	Average Score	8.27	19.77	9.30	18
5	Standard Deviation	2.72	3.11	2.56	2.66
6	Variance	7.38	9.70	6.56	7.07

Based on Table 4, the experimental and control groups showed differences in calculating descriptive statistics. The experimental and control groups received the same highest pretest score, 14. The lowest pretest scores in the experimental group were 3 and 4 in the control group. The highest posttest score for science process skills was 23 in the experimental group and 22 in the control group. The lowest posttest score in the experimental group was 13 and 11 in the control group. The experimental group's average pretest score of science process skills was 8.27, and 9.30 in the control group. The average posttest score for science process skills in the experimental group was 19.77, and in the control group, it was 18. The results of the N-Gain analysis of critical thinking revealed moderate improvements in critical thinking skills for both experimental (N-gain=0.47) and control (N-gain=0.35) groups, with posttest scores of 13.04 (high) and 10.10 (moderate), respectively, following pretest scores of 6.81 and 4.72. These results indicate that the experimental group experienced a more significant increase in critical thinking skills after receiving treatment (Benek & Akcay, 2022). While both groups progressed, the experimental group exhibited greater improvement, suggesting the intervention's efficacy. The results of the N-Gain analysis of science process skills also revealed moderate improvements. The average increase in science process skills scores in the experimental group was 0.69, and in the control group was 0.55. Both are in the moderate category, indicating the effectiveness of the intervention in enhancing these skills (Özdeniz et al., 2023).

The results of the N-Gain analysis of each critical thinking skills indicator are presented in Figure 1.

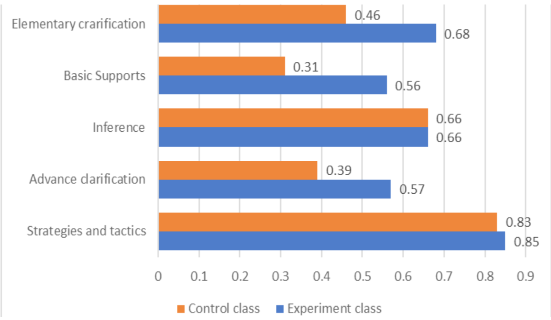

Figure 1. Average N-gain Score of Each Critical Thinking Skills Indicator

Figure 1 compares N-gain scores on five indicators of critical thinking skills between the experimental and control groups. The lowest N-Gain was on the indicator of building basic skills: 0.56 (moderate category) in the experimental group and 0.31 (moderate category) in the control group. The highest N-Gain was on the indicator of arranging strategies and tactics: 0.85 (high category) in the experimental group and 0.83 (high category) in the control group. The average N-Gain score for each indicator of students' critical thinking skills was 0.66 in the moderate category in the experimental group and 0.53 in the moderate category in the control group. This aligns with Alpizar et al. (2022), who revealed the development of critical thinking skills in secondary school students in an immersive science learning environment by involving students deeply and interactively. These results demonstrate that applying the TaRL-based DSI model in the experimental group yielded substantially greater improvements in critical thinking skills compared to the control group (Stein et al., 2016). This aligns with research highlighting the effectiveness of integrating direct instruction with inquiry-based learning to foster critical thinking (Ku et al., 2014) and the overall benefits of inquiry-based instruction in promoting higher-order thinking skills (Chu et al., 2016).

Science process skills are related to students' ability to conduct scientific investigations. Science process skills involve a series of cognitive processes and physical actions. The results of the N-Gain analysis of each indicator of students' science process skills in both groups are presented in Figure 2.

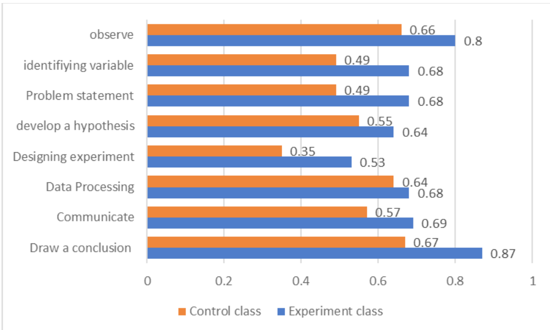

Figure 2. Average N-gain Score of Each Science Process Skills Indicator

Based on Figure 2, the lowest N-Gain of science process skills was in the indicator of designing experiments: 0.53 (moderate category) in the experimental group and 0.35 (moderate category) in the control group. The highest N-Gain was in the indicator of concluding: 0.87 (high category) in the experimental group and 0.67 (high category) in the control group. The average N-Gain score of each indicator of students' science process skills is 0.70 (moderate category) in the experimental group and 0.55 (moderate category) in the control group. This acquisition is supported by Derilo (2019), who reveals basic and integrated science process skill data of seventh-grade students in the Philippines at an average level.

Students are grouped into four according to the level of Inquiry: Demonstrate Inquiry (low cognitive ability), Structured Inquiry (moderate cognitive ability), Guided Inquiry (moderate cognitive ability), and Self-directed Inquiry (high cognitive ability). At level 1 (Demonstrate Inquiry), the teacher gives a problem, plans a procedure, and analyzes the results. At level 2 (Structured Inquiry), the teacher gives a problem and planning procedure while the students analyze the results. At level 3 (Guided Inquiry), the teacher only gives a problem while the students plan and analyze the results. At level 4 (Self-directed Inquiry), students do all activities, starting from giving a problem, planning a procedure, and analyzing the results. The control group uses the Structured Inquiry model by dividing students into four heterogeneous groups. This is in line with Llewellyn (2011) and Osae and Papadopoulos (2024) that activities in the Differentiated Science Inquiry (DSI) learning model are carried out by dividing students into four homogeneous learning groups. Each group represents one level of Inquiry learning. The division of learning groups is based on students' initial abilities, readiness levels, interests, and learning styles (Kazempour & Amirshokoohi, 2014; Asiri, 2018). The N-Gain analysis of the experimental group's critical thinking and science process skills based on grouping are presented in Table 5 and Table 6.

Table 5. Average N-Gain of Critical Thinking Skills of Experimental Group Based on Grouping

No	Group	Level	Score		Average N-Gain	Category
			Pretest	Posttest		
1	Group 1	Demonstrate Inquiry	3.00	10.00	0.42	Moderate
2	Group 2	Structured Inquiry	5.83	12.00	0.44	Moderate
3	Group 3	Guided Inquiry	7.57	13.29	0.46	Moderate
4	Group 4	Self-directed Inquiry	10.14	16.29	0.63	Moderate

Based on Table 5, the N-Gain level is in the moderate category at all levels. In group 1, with the demonstrated inquiry level, the N-Gain score is 0.42. In group 2, with the Structured Inquiry level, the N-Gain score is 0.44. In group 3, with the Guided Inquiry level, the N-Gain score is 0.46; in group 4, with the Self-directed Inquiry level, the N-Gain score is 0.63.

Table 6. Average N-Gain of Science Process Skills of Experimental Group Based on Grouping

No	Group	Level	Score		Average N-Gain	Category
			Pretest	Posttest		
1	Group 1	Demonstrate Inquiry	5.14	15.43	0.51	Moderate
2	Group 2	Structured Inquiry	8.00	19.60	0.68	Moderate
3	Group 3	Guided Inquiry	8.43	21.43	0.78	High
4	Group 4	Self-directed Inquiry	11.43	22.57	0.82	High

According to Table 6, the N-Gain level is in the moderate and high categories. In group 1, with the demonstrated inquiry level, the N-Gain score is 0.51 in the moderate category. In group 2, with the Structured Inquiry level, the N-Gain score is 0.68 in the moderate category. In group 3, with the Guided Inquiry level, the N-Gain score is 0.78; in group 4, with the Self-directed Inquiry level, the N-Gain score is 0.82; both groups are in the high category. The TaRL-based DSI model generally increases students' science process skills at each level, but the Self-directed Inquiry group has the most significant impact. Providing opportunities for students to be more independent in the inquiry process can improve their abilities more optimally.

The inferential analysis in this study aims to conclude the effect of the TaRL-based DSI model based on critical thinking and science process skills in the experimental and control groups.

The results of the normality test of the experimental and control groups' critical thinking and science process skills are presented in Tables 7 and 8.

Table 7. Normality Test of Critical Thinking Skills

Normality Test	Critical Thinking Skills	
	Experimental	Control
N	26	29
χ^2_{count}	4.79	3.83
χ^2_{table}	11.07	9.49
Decision	$\chi^2_{ount} < \chi^2_{table}$ **Normally Distributed**	$\chi^2_{\mathrm{count}} < \chi^2_{table}$ **Normally Distributed**

In Table 7, the results of the normality test of critical thinking skills of students in the experimental group obtained a value of χ^2_{ount} of 4.79, while the value of χ^2_{table} at a significant level (α) = 0.05 and the degree of freedom is 11.07. Based on the results of the data analysis, it is stated that $\chi^2_{ount} < \chi^2_{table}$, 4.79 < 11.7, so it can be concluded that the experimental group data is normally distributed. Similarly, in the control group, the value of χ^2_{ount} was obtained as 3.83 while the value of χ^2_{table} at the significance level α = 0.05, and the degree of freedom was 9.49. Based on the analysis results, it is stated that $\chi^2_{ount} < \chi^2_{table}$, which is 3.83 < 9.49, so it can be concluded that the control group data is normally distributed.

Table 8. Normality Test of Science Process Skills

Normality Test	Science Process Skills	
	Experimental	Control
N	26	29
χ^2_{count}	5.37	2.70
χ^2_{table}	11.07	9.49
Decision	$\chi^2_{ount} < \chi^2_{table}$ **Normally Distributed**	$\chi^2_{count} < \chi^2_{table}$ **Normally Distributed**

In Table 8, the results of the normality test of students' science process skills in the experimental group obtained a value of χ^2_{count} of 5.37, while the value of χ^2_{table} at a significant level (α) = 0.05 and degrees of freedom is 11.07. Based on the results of the data analysis, it is stated that $\chi^2_{count} < \chi^2_{table}$, which is 5.37 < 11.07, it can be concluded that the experimental group data is normally distributed. Similarly, in the control group, the value of χ^2_{count} was obtained as 2.70 while the value of χ^2_{table} at the significance level α = 0.05 and the degree of freedom was 9.49. Based on the analysis results, it is stated that $\chi^2_{count} < \chi\ \chi^2_{table}$, namely 2.70 < 9.49, it can be concluded that the control group data is normally distributed.

]The results of the homogeneity test of students' critical thinking and science process skills data are presented in Table 9.

Table 9. Homogeneity Test of Critical Thinking and Science Process Skills

Homogeneity Test	Critical Thinking Skills	Science Process Skills
F_{count}	2.8	1.37
F_{table}	3.17	4.03
Decision	$F_{count} < F_{table}$ **Data is homogenous**	$F_{count} < F_{table}$ **Data is homogenous**

The calculation results for data from the experimental and control groups obtained an F_{count} value of 2.8, while the Ftable value at a significance level of α = 0.05 and degrees of freedom = n-1 obtained *Ftabel* = 3.17. Based on the results of the data analysis, it is stated that Fcount < Ftable, which is 2.8 < 3.17, it can be concluded that the critical thinking skills data are homogeneous. The calculation results for data from the experimental and control groups obtained a Fcount value of 1.37, while the Ftable value at a significance level of α = 0.05 and degrees of freedom = n-1 obtained Ftable = 4.03. Based on the results of the data analysis, it is stated that Fcount < Ftable, which is 1.37 < 4.03, it can be concluded that the science process skills data are homogeneous.

The prerequisite tests for normality, distribution, and homogeneity of variance of the experimental and control groups were met, and then hypothesis testing was carried out. The results of the hypothesis test of critical thinking and science process skills are presented in Table 10 and Table 11.

Table 10. Hypothesis Test of Critical Thinking Skills

Statistics	Experimental Group	Control Group
Average ()	12.89	10
Variants	6.66	12.18
S_{gab}	3.14	
t_{count}	6.17	
t_{table}	1.67	
Conclusion	**H0 is rejected, and H1 is accepted**	

The hypothesis test results of critical thinking skills obtained Sgab = 3.14 and the tcount value = 6.17. From the t distribution table with a significance level = 0.05 Db 53, ttable (0.05; 81) = 1.67 is obtained. Because the tcount is greater than or equal to ttable (6.66> 1.67), Ho is rejected, and H1 is accepted. H1 states that the critical thinking skills of students taught using t the TaRL-based DSI model are higher than those taught using Structured Inquiry. The statistically significant results confirm that employing the TaRL-based DSI model demonstrably enhances students' critical thinking skills compared to the Structured Inquiry method.

Table 11. Hypothesis Test of Science Process Skills

Statistics	Experimental Group	Control Group
Average ()	19.77	18
Variants	7.38	7.08
S_{gab}	2.69	
t_{count}	2.39	
t_{table}	1.67	
Conclusion	**H0 is rejected, and H1 is accepted**	

The hypothesis test results for science process skills obtained Sgab = 2.69, and the tcount value was obtained = 2.39. From the t distribution table with a significance level = 0.05 Db 53, the ttable (0.05; 81) = 1.67 was obtained. Because the tcount is greater than or equal to ttable (2.39> 1.67), Ho is rejected, and H1 is accepted. H1 states that the critical thinking skills of students taught using t the TaRL-based DSI model are higher than those taught using Structured Inquiry. The results of this study significantly affected the acquisition of science process skills of students with TaRL-based DSI model treatment at the significance level $\alpha = 0.05$. This finding is supported by Variacion et al. (2021), who state that differentiated learning can provide transformative experiences for students in improving critical thinking and science process skills. Furthermore, Putra et al. (2023) revealed that teachers' differentiated instructions positively affect students' progress and current and future learning scenarios. Students' critical thinking and science process skills are further described.

Critical thinking skills do not happen by chance but through structured explanations that students intentionally and repeatedly structure to develop deep thinking (Changwong et al., 2018). The Differentiated Science Inquiry (DSI) learning model affects students' critical thinking skills (Mohamed Nor & Sihes, 2021). Through the TaRL-based DSI model, students can maximize their understanding. Ferreira and Valente (2024) state that scientific inquiry can help students develop independent and student-centered learning skills.

Analysis of the pretest and posttest results shows that the TaRL-based DSI model positively affects students' critical thinking skills. The average posttest score of the experimental group was higher than the control. This shows that the TaRL-based DSI model can maximize students' understanding. The results of the N-Gain category analysis of students' critical thinking skills showed a higher increase in the experimental group taught and guided using the TaRL-based DSI model than the control group taught using the Structured Inquiry model. These results are supported by Pursitasari et al. (2020), who stated that critical thinking is an intellectual process that actively and skillfully understands, applies, analyzes, synthesizes, and evaluates information collected through observation, experience, reflection, and reasoning.

The improvement of critical thinking skills in the experimental group showed similar results in each group, although the average scores differed. This differs from the control group, which showed an increase in N-Gain, which varied between groups. The division of homogeneous groups based on a cognitive level in the experimental group allows each student to improve their critical thinking skills optimally. On the other hand, the division of heterogeneous groups in the control group makes it difficult for students to improve their critical thinking skills because it only applies one level of Inquiry without considering students' basic abilities. This study's results align with Fuad et al. (2017), who stated that the application of the DSI Model can be used as an alternative solution to improve students' learning outcomes. The DSI Model facilitates students by giving assignments to most students with less or more straightforward guidance or instructions for students with learning difficulties (Gaitas et al., 2024).

The DSI learning model is closely related to developing critical thinking skills. The DSI model emphasizes differentiated scientific investigations, in which students are encouraged to explore science concepts in various ways according to their interests and abilities. Utami et al. (2024) stated that inquiry-based learning models, including the DSI model, can optimize students' physical and mental activities while building their knowledge, which aligns with developing critical thinking skills. This can be identified based on the conformity between the critical thinking skills indicators and the scores on the student worksheets, showing that the indicators provide simple explanations practiced at the stages of observing, formulating problems, determining variables, designing experiments, collecting data, and processing data. The indicators for building basic skills are also related to determining variables, designing experiments, collecting data, and processing data, which are also in the low category. Based on research, students are still not optimal in observing phenomena on student worksheets at the observation stage, so they are given directions to explain these phenomena based on learning objectives. Students also lack in designing experiments, so answering critical thinking questions on the indicators of providing simple explanations and building basic skills are still in the low category.

Critical thinking skill indicators in the form of concluding are in the moderate category, providing further explanations are in the low category, and arranging strategies and tactics are in the high category. This likely stems from learning activities prioritizing analyzing existing data and forming conclusions based on that information. Students may be comfortable with the provided data formats and skilled at identifying patterns or trends to make logical inferences. Conversely, the design experiment indicator showed the lowest achievement in science process skills. This is because designing experiments is complex, encompassing identifying variables, formulating hypotheses, selecting methods, and controlling variables. To enhance experiment design skills, several key steps can be implemented: emphasize understanding of basic science concepts, provide structured practice in identifying variables, guide the formulation of clear hypotheses, explore various scientific methods, and offer opportunities for open-ended experiments. Furthermore, constructive feedback and integration with real-world applications can aid students in developing the skills necessary to design effective and meaningful experiments, thereby improving their overall science process skills.

The three indicators of critical thinking skills are trained at the concluding stage. This can be seen from the student worksheets in the aspect of concluding. Students can draw conclusions well based on the results of the experiments that have been carried out. When students answer critical thinking skill questions on the indicators of concluding, providing further explanations, and arranging strategies and tactics, they can conclude, explain, and arrange strategies and tactics well and correctly (Mutakinati et al., 2018; Ramirez & Paderna, 2024).

The Differentiated Science Inquiry learning model has been proven to be effective in significantly improving the critical thinking skills of junior high school students. This is proven by Zubaidah et al. (2017) and Fuad et al. (2017), who show that the effectiveness of the DSI Model lies in grouping students based on cognitive abilities, interests, and learning readiness, thus enabling students to develop critical thinking skills optimally according to their initial needs and abilities. The DSI Model encourages active learning by providing easy access to learning outcomes, opportunities for question exploration, hypothesis development, and conceptual deepening, ultimately leading students to become critical thinkers with higher-order thinking skills.

The TaRL-based DSI learning model can improve students' science process skills based on science and inquiry, a technique scientists use to conduct research. Through differentiated learning, teachers help students understand concepts and apply science process skills. The analysis shows that the TaRL-based DSI learning model can affect students' science process skills. The average posttest score of the experimental group was higher than the average posttest score of the control group. These results align with García-Carmona et al. (2024), which shows that students' science process skills can be gradually improved, such as formulating questions and hypotheses, identifying variables, planning measurements, and interpreting data. Differentiated research-based learning applied to the high school science curriculum can develop students' conceptual understanding and process skills in science learning. Differentiated science learning through understanding requires the use of science process skills. The results of the N-Gain category analysis of science process skills obtained differences in improving science process skills between the experimental and control groups. Higher improvements occurred in the experimental group taught using the TaRL-based DSI learning model.

The increase in science process skills scores in the experimental group was higher than in the control group because, in the learning process in the experimental group, students were divided into four homogeneous groups based on their cognitive levels. This division allows each student to have the same opportunity to improve their critical thinking skills despite having different basic cognitive abilities. On the other hand, in the experimental group, students were divided into four groups with a heterogeneous division that only applied one level of Inquiry without paying attention to the basic abilities of students, so students found it challenging to improve their critical thinking skills (Gaitas et al., 2024). A learning model that accommodates this diversity is very much needed. Differentiated learning, developed by Llewellyn

(2011), can overcome the diversity of students in the group. Therefore, the TaRL-based DSI model was introduced, which applies several types of inquiries according to the needs of students (Zubaidah et al., 2017).

The highest achievement in the experimental group is in the indicator of concluding. This is because students have been trained to conclude activities in the learning process, especially in conducting practicums. Students can solve problems given during the practicum process by conducting direct investigations. According to Idris et al. (2022), science process skills in inquiry-based learning will improve students' science process skills because they will involve students' curiosity to explore investigations in science experiments. Oriented inquiry learning can form the intellectual discipline needed to ask questions, find answers to students' curiosity based on existing knowledge, and develop reasoning skills.

Meanwhile, the indicator that obtained the lowest score was designing experiments, which were included in the moderate category. This is because, in the learning process, the activities carried out by students only carry out practicum activities where the steps of the activities listed are not made by students but are listed in the student worksheet. Also, designing experiment indicators is complex, encompassing identifying variables, formulating hypotheses, selecting methods, and controlling variables. To enhance experiment design skills, several key steps can be implemented: emphasize understanding of basic science concepts, provide structured practice in identifying variables, guide the formulation of clear hypotheses, explore various scientific methods, and offer opportunities for open-ended experiments. Furthermore, constructive feedback and integration with real-world applications can aid students in developing the skills necessary to design effective and meaningful experiments, thereby improving their overall science process skills.

The experimental group outperformed the control group in procedural understanding and application of science process skills through the DSI learning model. According to Ceylan (2024), the Differentiated learning model affects students' science process skills, where they can demonstrate conceptual understanding characterized by integrating various concepts into a coherent whole and expanding them to make connections within and beyond the given subject area. They can conceptualize at a higher level of abstraction and view ideas in new and different ways. Furthermore, they demonstrate information retention, decide how to approach a problem, demonstrate in-depth knowledge using reasoning, planning, and evidence, and choose or design one approach among many alternatives to resolve a situation. Therefore, students fully apply science process skills when engaged in investigations.

Existing literature shows a strong correlation between implementing differentiated science learning and developing science process skills in students. The results of this study are supported by Özdeniz et al. (2023), which showed that students use reasoning in identifying problems, thinking about ways to solve problems, and developing designs for solutions. Furthermore, using assessment tools that encourage students to identify and explain the science skills they use during laboratory activities effectively improves their understanding of scientific investigations and experiments. Based on this literature, differentiated learning can be an effective strategy to encourage the development of science process skills (Neuhaus, 2020; Waruwu et al., 2023). By tailoring learning experiences to students' needs, educators can create an environment that encourages active engagement, critical thinking, and the application of scientific principles (Bean & Melzer, 2021; Halpern & Dunn, 2022).

Based on the analysis and discussion, the DSI learning model based on the TaRL approach has been proven to positively improve students' critical thinking and science process skills. This is indicated by the increase in students' critical thinking and science process skills after going through the stages in the DSI model. These results are supported by Plass and Pawar (2020) and Kamarudin et al. (2024) by combining a differentiated learning approach into science teaching, especially inquiry-based learning, which can improve students' critical thinking skills and science processes. However, applying the DSI model in learning still faces several challenges. Students' thinking and science process skills are not optimal because learning has not fully considered their learning needs, such as readiness, interests, and profiles. The Merdeka Curriculum also demands a change in the paradigm and role of educators. Educators are no longer conveyors of information only but must become learning facilitators who can create a conducive learning environment, build closeness with students, and facilitate learning according to each student's interests, needs, and level of understanding. This is supported by Asyidiqi et al. (2024), who revealed that teachers still do not have adequate skills to implement and interpret differentiated instruction as an instructional strategy to support students who experience learning difficulties. This seems particularly relevant to Tomlinson and Imbeau (2023), who found that most teacher educators who reported they need to use strategies that support differentiation indicated they may be willing to do so in the future. Furthermore, Oliveira et al. (2021) stated that with the help of differentiated learning, it is hoped that it can provide transformative experiences for students to improve their critical thinking and science process skills. The learning needed today is learning that not only repeats ideas but can also explore new ideas from students (Mustofa & Hidayah, 2020; Del Rosario & Chua, 2023; Lagoudakis et al., 2023; Amin et al., 2024).

CONCLUSION

Based on the research results and analysis, the Differentiated Science Instruction learning model based on the Teaching at the Right Level approach affects eighth-grade junior high school students' critical thinking and science process skills. The average critical thinking skills in the experimental group after treatment were 13.04, and in the control group were 10.1. The average science process skills in the experimental group were 19.77, and in the control group were 18. This research is expected to help educators implement learning models that accommodate students' learning needs. The limitation of this research is that the Teaching at the Right Level approach is implemented specifically at different cognitive levels of students, not accommodating differences in learning styles and other characteristics of students. Future research should explore these factors to optimize students' science process skills.

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