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The Effect of Cognitive-Level-Based Differentiated Instruction on Students' Learning Outcomes in Straight-Line Equations

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Abstract: *This study examined the effect of cognitive-level-based differentiated instruction on Grade VIII students' learning outcomes in straight-line equation material at SMPN 1 Sambelia. A quantitative quasi-experimental design with a nonequivalent control group pretest-posttest structure was employed. Two intact classes participated: Class VIII E as the experimental group (n = 27) and Class VIII F as the control group (n = 25). The experimental group received differentiated instruction organized around cognitive levels C1-C6 over two 90-minute meetings, while the control group received conventional lecture-based instruction. Learning outcomes were measured through pretest and posttest essay tests covering remembering, understanding, applying, analyzing, evaluating, and creating. The test was developed from a C1-C6 blueprint and scored using an analytical rubric with weighted indicators for each cognitive level. The experimental mean increased from 59.81 to 79.85, whereas the control mean increased from 61.32 to 76.16. Normality and homogeneity assumptions were met, and the independent samples t-test showed a significant posttest difference favoring the experimental group, t(50) = 3.653, p = 0.001, mean difference = 3.692, Cohen's d = 1.01, η^2 = 0.21. The normalized gain was 0.50 for the experimental group and 0.38 for the control group, both in the moderate category. These findings indicate that differentiated instruction, when guided by diagnostic cognitive mapping and supported through active group tasks, can improve students' conceptual and procedural achievement in straight-line equations. The study offers empirical support for adaptive mathematics instruction in heterogeneous junior secondary classrooms.*

Keywords: *cognitive-level-based instruction, differentiated instruction, mathematics learning outcomes, straight-line equations.*

INTRODUCTION

Mathematics learning is commonly associated with conceptual understanding, procedural fluency, and the ability to reason with multiple representations. However, mathematics instruction cannot be reduced to the transmission of content alone. It also requires attention to students' readiness to interpret, represent, and justify mathematical relationships, especially when they encounter non-routine tasks. This issue is particularly relevant for junior secondary students, who are expected to move from arithmetic routines toward algebraic, graphical, and functional reasoning. During this transition, students must coordinate symbols, diagrams, contextual information, and solution procedures. Research on adaptive reasoning in mathematics emphasizes that students need opportunities to connect, justify, and apply mathematical ideas rather than merely reproduce rules (Susilawati et al., 2021). In addition, contemporary mathematics education is increasingly expected to prepare students to reason, think creatively, and adapt to changing educational demands (Saputra et al., 2023). These expectations require classroom instruction that is not only content-oriented but also responsive to differences in students' cognitive readiness.

Despite these expectations, mathematics classrooms still face persistent instructional challenges. Low motivation, weak conceptual understanding, and uneven achievement are not only individual student problems, but also reflect instructional practices that often treat students as if they have the same prior knowledge, learning pace, and cognitive readiness. Student engagement has been shown to be closely related to mathematics performance (Awofala et al., 2024), while studies in mathematics teacher education indicate that students' frustrations and learning voices should be considered when designing responsive instruction (Andersson et al., 2023). Therefore, the central instructional issue is not only whether teachers can explain mathematical content clearly, but also how learning can be organized so that students with different readiness levels can access, process, and develop the same mathematical ideas productively.

Straight-line equations are one topic in which differences in students' cognitive readiness become highly visible. Although the topic may appear procedurally simple, it requires students to coordinate several mathematical meanings, including gradient, intercept, coordinate points, graphical representation, equation forms, and contextual interpretation. Students may be able to substitute values into formulas but still fail to interpret the meaning of a gradient or to explain the relationship between graphs and algebraic equations. Previous studies have shown that students' difficulties in straight-line equations are related to their ability to interpret information, select appropriate procedures, and connect mathematical representations (Setyaningsih & Firmansyah, 2022). Other research has also found that students may demonstrate different mental model levels when learning straight-line equations, indicating that the same topic can be understood through different cognitive structures (Laili et al., 2021). This variability makes straight-line equations an appropriate context for studying instruction that responds explicitly to students' cognitive levels.

The local problem underlying this study was found in Grade VIII mathematics learning at SMPN 1 Sambelia. Preliminary classroom data showed that students' achievement in straight-line equation material remained low. Of 30 students observed before the intervention, only 12 students, or 40%, achieved scores above the learning mastery criterion of 70, while 18 students, or 60%, remained below that criterion. Most scores were between 55 and 68, indicating difficulties in understanding gradients, general equation forms, and the relationship between graphs and algebraic equations. A simple interview and student survey also indicated that approximately 70% of students had difficulty understanding the topic and lacked confidence when solving related problems. Although the teacher had used visual media, group discussion, contextual exercises, and heterogeneous grouping, these practices had not fully addressed differences in students' cognitive readiness. Thus, the problem was not only low achievement, but also the absence of a systematic instructional mechanism for mapping students' cognitive levels and adjusting learning support accordingly.

Differentiated instruction offers a relevant approach to this instructional problem. It is based on the assumption that students differ in readiness, interest, learning profile, and pace, and that teachers can respond by adapting content, process, product, and the learning environment. A systematic review in secondary education reported that differentiated instruction is promising because it addresses within-class differences in readiness, learning profile, and achievement, although empirical evidence in secondary contexts remains relatively limited (Smale-Jacobse et al., 2019). In Indonesia, differentiated instruction is also consistent with the Merdeka Curriculum and the principle of Teaching at the Right Level because both emphasize the need to adjust instruction to students' learning needs and readiness (Fauzia & Hadikusuma Ramadan, 2023; Samsudi et al., 2024). Other studies also support the idea that differentiation can be implemented through varied instructional materials, assessment forms, and learning supports, while equityoriented learning environments require strategies that help all students access and succeed in learning (Achmad et al., 2024; Anis, 2023; Marlina et al., 2023; Maulidiawati & Darmawan, 2024). However, these studies generally discuss differentiation as a broad instructional approach and provide limited explanation of how differentiation can be operationalized through specific cognitive levels in mathematics learning.

However, differentiated instruction becomes more analytically meaningful when the basis of differentiation is clearly defined. In this study, the basis of differentiation was students' cognitive level. Bloom's taxonomy provides a practical framework for classifying learning outcomes from remembering and understanding to applying, analyzing, evaluating, and creating. This classification is not merely a list of operational verbs, but a structure for designing mathematical tasks that guide students from recognizing and explaining concepts to applying procedures, analyzing relationships, evaluating strategies, and constructing mathematical models. Research on the revised taxonomy has shown that Bloom-based cognitive levels are useful for classifying educational objectives, designing assessment tasks, and organizing learning activities from lower- to higher-order thinking (Krathwohl, 2002). In this study, the six cognitive levels were used to organize student worksheets, teacher support, learning activities, and assessment indicators in straight-line equation material. Accordingly, cognitive level was used not only as an assessment category, but also as the basis for differentiating instructional support and task complexity.

The rationale for using differentiated instruction is also supported by evidence on active and student-centered learning. Meta-analytic studies have shown that active learning can improve STEM performance among Asian students and enhance academic achievement and retention in K-12 settings (Ting et al., 2023; Özgür, 2023). Similarly, a meta-analysis of student-centered methods in mathematics found positive effects on achievement, attitude, and anxiety (Ay Emanet & Kezer, 2021). These findings are important because differentiated instruction should not be understood merely as ability grouping. It becomes instructionally meaningful when grouping is connected to active tasks, teacher guidance, feedback, and opportunities for students to represent and discuss mathematical ideas. Research on collaborative and contextual learning in straight-line equation material also supports the importance of mathematical communication, representation, and discussion in helping students understand this topic (Kristiani et al., 2024). Nevertheless, the specific integration of active learning, cognitive-level mapping, and differentiated support in straight-line equation instruction remains insufficiently examined.

Based on this background, the present study examined whether cognitive-level-based differentiated instruction affects Grade VIII students' learning outcomes in straight-line equation material at SMPN 1 Sambelia in the 2024/2025 academic year. The novelty of this study lies in its integration of differentiated instruction with Bloom-based cognitive mapping in a junior secondary mathematics classroom. Previous studies have mainly emphasized differentiated instruction as flexible grouping, varied learning materials, or general readiness-based teaching, whereas this study explicitly used C1-C6 cognitive levels to guide diagnostic mapping, worksheet design, teacher support, learning activities, and assessment indicators. The hypothesis was that cognitive-level-based differentiated instruction would produce a significant positive effect on students' learning outcomes. Therefore, the objective of this study was to determine the effect of cognitive-level-based differentiated instruction on students' learning outcomes in straight-line equation material.

METHOD

This study employed a quantitative approach with a quasi-experimental design. This method was selected in accordance with the purpose of the study, which was to examine whether a specific instructional treatment could produce a measurable difference in students' learning outcomes. The study did not merely describe students' difficulties in understanding straight-line equations, but also tested the effect of cognitive-level-based differentiated instruction on students' achievement. Since the research was conducted in an existing school setting with fixed classroom structures, individual random assignment was not applied. Instead, intact classes were used as the experimental and control groups.

The research design used was a nonequivalent control group pretest-posttest design. This design is appropriate for educational research contexts in which random assignment is difficult because students are already organized into established classes. The use of intact classes in quasi-experimental research requires attention to baseline comparability before treatment effects are interpreted (Bulus, 2021; Denny et al., 2023). In this study, both groups completed a pretest before the treatment and a posttest after the treatment. The experimental group received cognitive-level-based differentiated instruction, whereas the control group received conventional lecture-based instruction.

The independent variable was the instructional model, namely cognitive-level-based differentiated instruction. The dependent variable was students' learning outcomes in straight-line equation material. This design enabled the researcher to identify students' initial ability, implement the instructional treatment, and compare final learning outcomes between the experimental and control groups. The research design is presented in Table 1, while the complete sequence of the research procedure and intervention flow is presented in Figure 1.

Table 1. Nonequivalent Control Group Pretest-Posttest Design

Group	Pretest	Treatment	Posttest	Description
Experimental	O1	X	O2	Differentiated instruction based on cognitive level
Control	O3	-	O4	Conventional lecture-based instruction

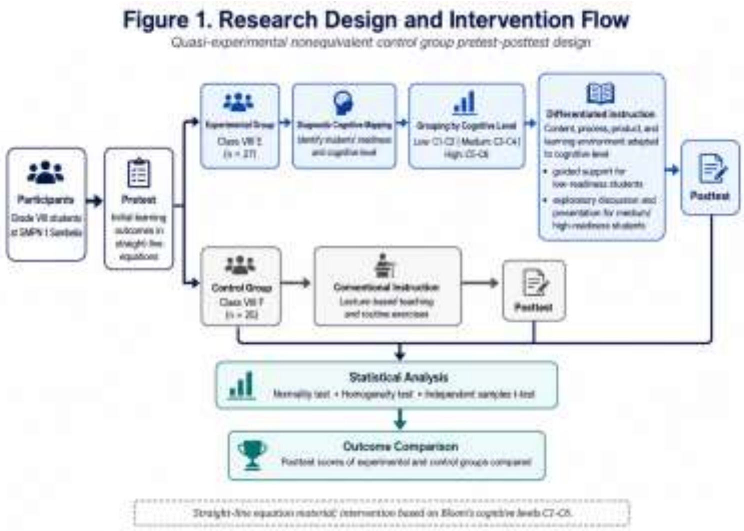

Figure 1. Research Design And Intervention Flow

The procedure shown in Figure 1 illustrates the sequence of the study from participant selection, pretest administration, diagnostic cognitive mapping, cognitive-level grouping, implementation of cognitive-level-based differentiated instruction in the experimental group, implementation of conventional instruction in the control group, posttest administration, statistical analysis, and outcome comparison. This flow was used to ensure that the treatment process was systematically organized and that the comparison between the two groups was based on the same instructional topic and assessment structure.

The population of this study consisted of all Grade VIII students at SMP Negeri 1 Sambelia, located in Sambelia Village, Sambelia District, East Lombok Regency, East Nusa Tenggara. The study was conducted in the even semester of the 2024/2025 academic year. The sample was selected using purposive sampling by considering the suitability of the classes for statistical comparison, particularly in terms of class size and relatively balanced prior mathematics achievement. The selection was also based on teacher recommendation, students' regular attendance, and the similarity of classroom characteristics before the intervention.

Two classes were selected as the research sample. Class VIII E was assigned as the experimental group, consisting of 27 students, while Class VIII F was assigned as the control group, consisting of 25 students. The selection criteria included adequate class size, relatively balanced previous mathematics achievement, and the absence of intensive special learning needs requiring separate individual intervention. Classes with high absenteeism or those receiving additional remedial programs were not selected because such conditions could affect the comparison between the two instructional models. This sampling procedure was intended to strengthen baseline comparability between the experimental and control groups in the absence of individual random assignment.

The treatment in the experimental group was cognitive-level-based differentiated instruction. The instruction was implemented through several stages, namely diagnostic assessment, student grouping, differentiated teacher support, student worksheets, group discussion, and presentation. The treatment was conducted in two meetings, each lasting 2 × 45 minutes. Diagnostic testing is an important element of differentiated instruction because it helps teachers identify students' initial readiness and learning difficulties before instruction begins (Alifiana et al., 2024). In addition, the development of differentiated instruction emphasizes the importance of identifying students' readiness, interests, and learning profiles before selecting appropriate instructional strategies (Faiz et al., 2022; Hidayat et al., 2022).

Students in the experimental group were organized into six groups representing three cognitive categories: low level, aligned with C1-C2; medium level, aligned with C3-C4; and high level, aligned with C5-C6. The first meeting emphasized C1-C3 abilities, including identifying elements of straight-line equations, explaining their use, and calculating gradients from graphs or two points. The second meeting emphasized C4-C6 abilities, including analyzing relationships between lines, evaluating contextual applications, and designing graphs or models to solve problems. Inquiry-based and problem-oriented learning designs can support the development of cognitive processes from lower to higher levels, particularly when students are directed to remember, understand, apply, analyze, and explore solutions (Fadhillah & Novianti, 2021; Serang et al., 2021). Because the treatment was conducted in two meetings, the duration was acknowledged as a methodological limitation and the findings should be interpreted as evidence of short-term learning improvement.

The instructional materials included a mathematics textbook, PowerPoint slides, learning videos, an LCD projector, a laptop, and student worksheets. Differentiation was implemented in terms of content, process, product, and learning environment. Students with lower readiness received more explicit explanations, concrete examples, and direct guidance. Students with medium and higher readiness received more exploratory tasks, group discussion opportunities, and chances to present their mathematical reasoning. This strategy was intended to ensure that all students learned the same mathematical topic while receiving different levels of support and cognitive challenge according to their learning readiness.

The control group learned the same straight-line equation material through conventional lecture-based instruction. In this class, students listened to the teacher's explanation, took notes, and completed exercises without cognitive-level grouping or differentiated learning support. This comparison was necessary because conventional instruction may still improve students' learning outcomes, but it does not explicitly accommodate differences in readiness, learning pace, and conceptual understanding.

The main instrument of this study was a mathematics learning outcome test administered as both pretest and posttest. The test consisted of essay questions designed to measure students' understanding of straight-line equations across cognitive levels. The cognitive indicators followed Bloom's taxonomy, while affective aspects were observed through students' perseverance and active participation in group problem solving. The use of C1-C6 indicators was intended to ensure that the test measured not only remembering, but also understanding, applying, analyzing, evaluating, and creating mathematical models. The test was developed from a cognitive-level blueprint and accompanied by an analytical scoring rubric. However, separate expert-validation scores and pilot-test reliability coefficients were not available; therefore, the study reports the blueprint and scoring rubric as evidence of instrument construction rather than claiming full empirical validity and reliability.

Data collection was carried out in three stages. The first stage was the administration of the pretest to determine students' initial ability. The second stage was the implementation of cognitive-level-based differentiated instruction in the experimental group and conventional instruction in the control group. The third stage was the administration of the posttest to both groups to determine students' learning outcomes after the treatment. The test blueprint is presented in Table 2.

Table 2. Test Blueprint For Straight-Line Equation Learning Outcomes

Item	Competency Focus	Indicator	Form	Cognitive Level
1	Straight-line equation elements	Identify and explain gradient and intercept	Essay	C1 - Remembering
2	Gradient in context	Explain the meaning of gradient in a real learning-time and score context	Essay	C2 - Understanding
3	Use of equations	Calculate gradient, form a line equation, and predict a value	Essay	C3 - Applying
4	Relationship between lines	Determine whether two lines are parallel, perpendicular, or intersecting	Essay	C4 - Analyzing
5	Contextual application	Evaluate profit or loss in a linear product-sales context	Essay	C5 - Evaluating
6	Model creation	Create and solve a contextual problem involving two lines	Essay	C6 - Creating

To ensure consistent scoring, the essay test was evaluated using an analytical rubric based on Bloom's cognitive levels. The rubric assigned weighted scores to each indicator from C1 to C6 according to the expected level of cognitive performance, as presented in Table 3.

Table 3. Analytical Scoring Rubric for Essay Test

Cognitive Level	Assessment Focus	Weight
C1 – Remembering	Identifying the elements of straight-line equations, including gradient and intercept	10%
C2 – Understanding	Explaining the meaning of gradient in a contextual situation	15%
C3 – Applying	Calculating gradient, constructing a line equation, and predicting a value	20%
C4 – Analyzing	Analyzing the relationship between two lines	15%
C5 – Evaluating	Evaluating a contextual linear situation and justifying the result	20%
C6 – Creating	Creating and solving a contextual problem involving two straight lines	20%
Total	All cognitive levels	100%

The data were analyzed using SPSS Statistics version 28.0.1.1. The analysis began with a normality test using the Kolmogorov-Smirnov test. The data were considered normally distributed when the significance value was greater than or equal to 0.05. The Kolmogorov-Smirnov test is commonly used in quantitative educational research to examine distributional assumptions before conducting parametric analysis (Kiliçoğlu, 2021).

The homogeneity of variance was then tested using Levene's test. Homogeneity testing is required in comparative analysis to determine whether the groups being compared have equal variances (Sianturi, 2022). The data were considered homogeneous when the significance value was greater than 0.05. After the assumptions of normality and homogeneity were met, the hypothesis was tested using an independent samples t-test at a significance level of 0.05. If the parametric assumptions had not been met, the planned alternative analysis was the Mann-Whitney U test. To address practical significance, Cohen's d and eta squared were calculated from the posttest comparison. In addition, normalized gain (N-gain) was calculated to compare the relative improvement of students' learning outcomes in the experimental and control groups.

RESULTS AND DISCUSSION

The pretest was administered to identify students' initial ability before the instructional treatment. This step was important because, in a nonequivalent control group design, baseline data provide evidence of whether the groups began from comparable conditions before the intervention was implemented (Denny et al., 2023). In the experimental class, 27 students completed the pretest. The scores ranged from 55 to 65, with a total score of 1,615 and a mean score of 59.81. The most frequent score was 63, achieved by five students. In the control class, 25 students completed the pretest. The scores ranged from 55 to 70, with a total score of 1,533 and a mean score of 61.32. Most students in the control class scored between 59 and 65, and only one student achieved a score of 70.

Table 4. Pretest Score Distribution In The Experimental and Control Classes.

Score	Experimental Frequency	Control Frequency
55	2	2
56	2	0
57	3	2
58	3	1
59	3	4
60	3	1

61	3	3
63	5	4
64	2	5
65	1	2
70	0	1
Total n	27	25
Mean	59.81	61.32

The results in Table 4 indicate that both classes began with relatively low achievement in straight-line equation material. Although the control class had a slightly higher mean score than the experimental class, the difference was small, suggesting that the two groups were reasonably comparable before the treatment. These findings also show that many students had not yet developed sufficient understanding of gradient, intercept, coordinate points, graphs, and algebraic equations. This condition is consistent with previous studies showing that students often experience difficulty in interpreting information, selecting procedures, and connecting representations in straight-line equation tasks (Laili et al., 2021; Munawarah et al., 2023; Setyaningsih & Firmansyah, 2022). The low pretest results also indicate that straight-line equations had not yet become a stable conceptual field for many students. Recent work on conceptual and procedural errors in gradient and straight-line equations reinforces the view that this topic requires strong conceptual treatment because procedural performance alone may not indicate deep understanding (Pratama & Azizah, 2025).

Before comparing the posttest scores, assumption testing was conducted on the pretest data. The normality test showed that both groups met the normality criterion. The Kolmogorov-Smirnov significance value was 0.167 for the experimental class and 0.088 for the control class, both of which were greater than 0.05. The homogeneity test produced Levene Statistic = 0.693 with p = 0.409, indicating that the pretest variance was homogeneous across the two groups.

Table 5. Assumption Testing For Pretest Data.

Test	Group/Variable	Statistic	p-value	Decision
Normality	Pretest experimental	K-S = 0.148	0.167	Normal
Normality	Pretest control	K-S = 0.162	0.088	Normal
Homogeneity	Pretest scores	Levene = 0.693	0.409	Homogeneous

The results in Table 5 confirm that the two groups met the statistical assumptions required for further comparison. This baseline condition is important because the interpretation of treatment effects in a quasi-experimental design depends on the extent to which the groups are comparable before the intervention. Although the control class had a slightly higher pretest mean, both classes were below the expected mastery level. This strengthens the rationale for applying an instructional model that can respond to differences in students' readiness and cognitive starting points.

After the instructional treatment, both groups completed the posttest. The experimental class obtained posttest scores ranging from 76 to 90, with a total score of 2,156 and a mean score of 79.85. The highest score was 90 and the lowest score was 76. The most frequent scores were 83 and 76, each achieved by eight students. Compared with the pretest mean of 59.81, the experimental group improved by 20.04 points. The control class also showed improvement after conventional instruction. Posttest scores ranged from 71 to 83, with a total score of 1,904 and a mean score of 76.16. The control mean increased by 14.84 points from its pretest mean of 61.32. The experimental group also obtained a higher normalized gain (N-gain = 0.50) than the control group (N-gain = 0.38), although both were in the moderate category.

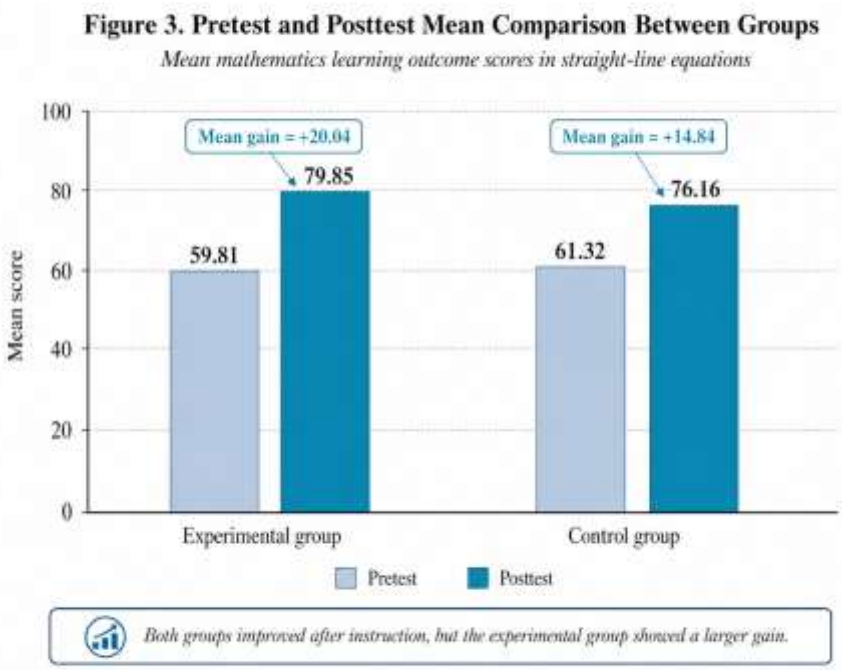

Figure 2. Pretest and posttest mean comparison between the experimental and control groups

Table 6. Posttest Score Distribution And Mean Gain In The Experimental And Control Classes.

Score	Experimental Frequency	Control Frequency
71	0	4
73	0	5
76	8	7
78	3	3
80	7	3
83	8	3
90	1	0
Total n	27	25
Mean	79.85	76.16
Mean gain	20.04	14.84
N-gain	0.5	0.38
N-gain category	Moderate	Moderate

The results in Table **6** show that both groups improved after instruction, indicating that learning activities on straight-line equations supported students' achievement. However, the experimental group showed a larger gain than the control group. The experimental class was initially lower than the control class by 1.51 points, yet after the intervention it became higher by 3.69 points. This change is both statistically and pedagogically meaningful because it shows that differentiated instruction did not merely maintain the initial achievement pattern; instead, it shifted learning outcomes in favor of the group that received cognitive-level-based support. The higher N-gain in the experimental group also indicates that its improvement was not only larger in raw score, but also stronger when the initial score and maximum possible score were considered.

This finding suggests that differentiated instruction can function as an instructional response to students' initial cognitive variation. Students in the same grade level do not always share the same readiness to understand algebraic symbols, coordinate geometry, graphical representation, and contextual interpretation. The intervention addressed this condition by using pretest information as a diagnostic basis for instruction. Differentiated instruction is therefore not simply a set of varied classroom activities, but a form of instructional decision-making in which teachers use evidence of readiness and learning needs before adapting content, process, product, and learning environment. This interpretation is consistent with studies showing that diagnostic assessment supports differentiated learning design (Alifiana et al., 2024) and that teachers need to identify students' readiness, interests, and learning profiles before selecting instructional strategies (Faiz et al., 2022).

Assumption testing was also conducted on the posttest data before hypothesis testing. The posttest normality test showed that the experimental class had a Kolmogorov-Smirnov statistic of 0.166 with $p = 0.073$, while the control class had a statistic of 0.157 with $p = 0.115$. Because both significance values were greater than 0.05, the posttest data were considered normally distributed. The homogeneity test produced Levene Statistic = 0.260 with $p = 0.612$, indicating that the posttest variance was homogeneous.

Table 7. Assumption Testing For Posttest Data.

Test	Group/Variable	Statistic	p-value	Decision
Normality	Posttest experimental	K-S = 0.166	0.073	Normal
Normality	Posttest control	K-S = 0.157	0.115	Normal
Homogeneity	Posttest scores	Levene = 0.260	0.612	Homogeneous

The results in Table 7 justified the use of an independent samples t-test to examine whether the final achievement of the experimental and control groups differed significantly. The use of assumption testing also strengthens the interpretability of the quasi-experimental comparison because it confirms that the posttest data met the requirements for parametric analysis.

The independent samples t-test showed a significant posttest difference between the experimental and control groups. Under the equal variances assumed line, the result was $t = 3.653$, $df = 50$, $p = 0.001$, with a mean difference of 3.692 and a standard error difference of 1.011. The 95% confidence interval of the difference ranged from 1.662 to 5.722. Under the equal variances not assumed line, the result remained significant, $t = 3.639$, $df = 48.463$, $p = 0.001$. To examine practical significance, effect size was calculated. The result showed Cohen's $d = 1.01$ and eta squared (η^2) = 0.21, indicating a large and educationally meaningful effect.

Table 8. Independent Samples T-Test For Posttest Scores.

Assumption	F	Levene p	t	df	p	Mean Difference	95% CI
Equal variances assumed	0.260	0.612	3.653	50	0.001	3.692	1.662 to 5.722
Equal variances not assumed	-	-	3.639	48.463	0.001	3.692	1.653 to 5.731

As shown in Table 8, $p = 0.001$ was below the significance level of 0.05. Therefore, the null hypothesis was rejected and the alternative hypothesis was accepted. This result indicates that cognitive-level-based differentiated instruction had a significant effect on Grade VIII students' learning outcomes in straight-line equation material. The positive mean difference shows that the direction of the effect favored the experimental class. The large effect size further suggests that the difference was not only statistically significant but also meaningful for classroom learning.

The stronger improvement in the experimental group can be explained by the structure of the intervention. Students were grouped according to cognitive readiness, and teacher support was adapted to the group's level. Low-readiness students received concrete examples and direct guidance, while medium- and high-readiness students engaged in more exploratory discussion and presentation. Thus, cognitive difference was not treated as a fixed deficit, but as an instructional condition that required appropriate support. This interpretation is aligned with the broader literature on differentiated instruction. In secondary education, differentiated instruction is commonly implemented through adaptations in content, process, product, and classroom support (Smale-Jacobse et al., 2019). In the Indonesian curriculum context, it also corresponds to the principle that instruction should be matched to students' readiness rather than delivered uniformly to the whole class (Samsudi et al., 2024). However, the short duration of the intervention means that the results should be interpreted as short-term achievement improvement rather than evidence of long-term retention.

The findings also show that the effectiveness of differentiated instruction should not be attributed to grouping alone. Ability grouping without meaningful tasks can reproduce differences rather than reduce them. In this study, differentiation was combined with group discussion, worksheet-based problem solving, presentation, teacher guidance, and feedback. This combination is consistent with research showing that collaborative inquiry and discovery-oriented learning can strengthen critical thinking and collaboration (Ananta et al., 2023), and that collaborative learning may support academic motivation through peer interaction and shared responsibility (Loes, 2022). The intervention therefore functioned as a coordinated instructional system: diagnostic assessment identified students' needs, grouping organized support, LKPD structured learning tasks, discussion activated mathematical reasoning, and feedback connected students' performance to improvement. Through the C1-C6 sequence, students first strengthened basic recognition and understanding before moving to application, analysis, evaluation, and problem creation. This cognitive progression may have reduced cognitive overload while still providing appropriate challenge.

Feedback also played an important role in the experimental class. Students did not merely complete tasks, but received teacher and peer responses that helped them revise their understanding. Assessment and feedback are important because they make learning progress visible and help students correct weaknesses (Andayani & Madani, 2023). In a differentiated classroom, feedback becomes even more essential because students may work at different levels of complexity while still aiming toward the same mathematical objective. The inclusive learning environment created during the intervention may also explain why students in the experimental class achieved higher outcomes. Differentiated learning can optimize inclusive classroom environments by providing students with opportunities to participate according to their needs (Ayuningtyas et al., 2023). This is especially relevant for students who lack confidence in mathematics because supported group work can reduce dependence on one-way teacher explanation.

The control class also improved, which indicates that conventional instruction was not ineffective. The control mean increased from 61.32 to 76.16, showing that explanation and practice can still support learning in straight-line equation material. However, the improvement was smaller than that of the experimental class, and the final mean remained lower. This distinction suggests that the issue is not whether conventional instruction can produce learning, but whether it is sufficiently responsive to heterogeneous cognitive readiness. Research comparing active and conventional approaches supports this interpretation. Active learning tends to improve achievement and retention in K-12 settings, and student-centered methods in mathematics have been associated with improved achievement, attitude, and reduced anxiety (Ay Emanet & Kezer, 2021; Özgür, 2023). Similarly, a meta-analysis of active learning in Asian STEM contexts reported positive effects on student performance (Ting et al., 2023). Although the present study was smaller in scale, its result follows the same general pattern: instruction that actively organizes students' participation and adapts support can produce stronger achievement than lecture-centered instruction. Nevertheless, the moderate N-gain in the control group shows that conventional explanation and practice still contributed to learning, especially for procedural aspects of straight-line equations.

The result is also consistent with evidence that differentiated strategies are more effective when paired with meaningful learning tasks rather than implemented as a superficial classroom arrangement. For example, differentiated strategies combined with problem-based learning have been associated with improved conceptual understanding and process skills (Manalu et al., 2023). In the present study, the differentiated model worked because students encountered mathematical tasks through different levels of support and cognitive challenge, not simply because they were placed into groups. At the same time, differentiated instruction may be difficult to implement consistently because teachers must prepare diagnostic tasks, varied worksheets, different forms of support, and continuous feedback within limited classroom time.

The pedagogical implication of this study is that mathematics teachers should begin instruction on conceptually dense topics with diagnostic assessment. This assessment does not have to be complicated; a short pretest, worksheet, or oral questioning session can help the teacher identify students who need conceptual reinforcement and those who are ready for higher-order tasks. Teachers can then design task sequences that begin with basic identification and understanding before moving toward application, analysis, evaluation, and creation. Such sequencing is particularly appropriate for straight-line equations because the topic naturally moves from recognizing equation elements to interpreting and modeling linear relationships.

Another implication is that differentiated instruction should be understood as a dynamic process rather than a fixed grouping strategy. Students' cognitive readiness may change during instruction; therefore, teacher observation and feedback are essential. Students who initially require concrete examples may later engage in more independent analysis, while higher-readiness students still need guidance in reasoning, representation, and explanation. This dynamic view is consistent with the idea that differentiation supports student involvement when learning and assessment are responsive to student diversity (Marlina et al., 2019; Marlina et al., 2023). Thus, cognitive-level grouping should not be treated as permanent labeling, but as a temporary instructional arrangement that can change according to students' progress.

This study has several limitations. It involved only two Grade VIII classes in one school and focused on one topic, namely straight-line equations. The sample size was appropriate for a classroom intervention but not sufficient for broad generalization. The treatment was also conducted in two meetings, so the stability of the effect over a longer period could not be determined. In addition, the study measured learning outcomes mainly through achievement tests, while variables such as motivation, learning interest, self-regulated learning, mathematical communication, and higher-order thinking were not examined as separate outcomes. Future studies may extend the design to more schools, use longer treatment periods, and examine how differentiated instruction interacts with motivation, problem-solving ability, or digital learning environments. Further research may also apply cognitive-level-based differentiated instruction to other algebra topics, such as linear functions, systems of linear equations, or mathematical modeling tasks. The findings also suggest the value of exploring how contextual and collaborative tasks can further support students' mathematical modeling (Hidayat et al., 2022; Zheng et al., 2023).

CONCLUSION AND SUGGESTIONS

Cognitive-level-based differentiated instruction had a positive and significant effect on Grade VIII students' learning outcomes in straight-line equation material at SMPN 1 Sambelia. The findings show that students in the experimental class, who received differentiated instruction, achieved higher learning improvement than students in the control class, who received conventional instruction. The independent samples t-test also confirmed a significant posttest difference between the two groups, with better achievement in the experimental class. The effect size (Cohen's $d = 1.01$; $\eta^2 = 0.21$) indicates that the effect was not only statistically significant but also educationally meaningful. These results indicate that learning becomes more effective when teachers use diagnostic assessment to map students' cognitive readiness and then adjust learning support, task complexity, discussion activities, and feedback according to students' needs. The findings also contribute to differentiated instruction theory by demonstrating that Bloom's cognitive levels can serve not only as assessment categories but also as a practical framework for organizing instructional support, learning activities, and task complexity in heterogeneous mathematics classrooms.

Based on these findings, mathematics teachers are encouraged to apply differentiated instruction to topics that require both conceptual and procedural understanding, such as straight-line equations. Teachers may combine cognitive-level grouping with active problem solving, student worksheets, group discussion, presentation, and constructive feedback. Schools are also encouraged to support this practice by providing instructional resources and teacher training related to diagnostic assessment and differentiated learning design. This study was limited to two Grade VIII classes in a single school, focused on one mathematics topic, and implemented over a relatively short treatment period. Therefore, the findings should be interpreted within these contextual boundaries. Future studies should involve broader samples, longer treatment periods, and additional variables such as learning motivation, mathematical communication, problem-solving ability, and higher-order thinking skills. Future research may also examine the application of cognitive-level-based differentiated instruction in other algebra topics, such as linear functions, systems of linear equations, and mathematical modeling, as well as explore its integration with digital learning environments and self-regulated learning strategies.

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