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Research Article

Improving Students' Critical Thinking Skills through a Deep Learning-Oriented Group Investigation Model

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ABSTRACT

Purpose of the study: This research aims to improve the critical thinking skills of junior high school students through the application of the Group Investigation cooperative learning model oriented to deep learning on the interaction of living things and their environment.

Methodology: This study uses a quantitative approach with a quasi-experimental design of one group pretest-posttest multiple groups. The subject of the study is the students of grade VII of junior high school which consists of two classes. Data was collected through observation of students' learning implementation and activities, critical thinking skills tests, and student response questionnaires, then analyzed using percentage, N-gain, Wilcoxon test, and effect size.

Main Findings: The main findings of this study show that the application of the Group Investigation cooperative learning model oriented to deep learning is able to strengthen the critical thinking skills of junior high school students significantly and meaningfully. The integration of deep learning approaches at each stage of investigation encourages a high level of cognitive engagement through the process of analysis, evaluation, and conceptual reflection.

Novelty/Originality of this study: The Group Investigation model in general, this study presents a novelty in the form of integrating a deep learning approach into each stage of GI to encourage the process of analysis, evaluation, and conceptual reflection of students, so that the improvement of critical thinking skills does not only occur quantitatively, but also in every critical thinking indicator.

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1. INTRODUCTION

Science learning has a strategic role in developing science literacy and 21st century skills, especially critical thinking skills that include the ability to analyze information, evaluate evidence, and solve problems logically and reflectively. In line with these demands, the Independent Curriculum emphasizes meaningful learning through contextual, reflective, and project-based approaches to develop students' knowledge competencies, skills, and attitudes [1], [2]. Therefore, strengthening critical thinking skills is one of the main goals of science learning at the junior high school level.

However, the implementation of science learning in junior high schools still faces various obstacles. Learning tends to be teacher-centered, less inquiry-based, and limited learning resources such as laboratories and contextual teaching materials. This condition has an impact on the low opportunity of students to be actively involved in the higher-level thinking process. Studies show that external factors, especially the limitations of the learning environment and supporting facilities, are the biggest contributors to the low quality of science learning and the development of students' critical thinking [3]. This condition is reflected in the results of the Programme for International Student Assessment (PISA) 2022 which shows that the critical thinking skills of Indonesian students are still in the lower group internationally [4]. This finding is strengthened by a preliminary study conducted by researchers in one of the junior high schools, which shows that students' thinking skills in five critical thinking indicators according to Ennis, are still in the low category, where the overall percentage is below 60%. This is because students are not used to being trained in critical thinking because learning is still dominated by remembering and understanding activities, not analyzing and evaluating. This fact shows that there is a gap between the demands of the curriculum and the learning conditions in the field.

One of the learning models that has the potential to develop critical thinking skills is the Group Investigation (GI) cooperative model. This model encourages learners to be actively involved in the process of investigation, discussion, and concept discovery independently in groups [5], [6]. A number of studies report that the application of the GI model is able to improve students' critical thinking skills [7], [8]. However, other research findings show that GI has not been fully effective in improving students' critical thinking skills [9], especially due to the emergence of the free rider phenomenon, uneven group participation, and investigative focus that is still descriptive and does not emphasize in-depth reflection and information synthesis [10], [11].

Based on this description, it can be identified that there is a research gap, namely although the Group Investigation cooperative model has the potential to improve critical thinking skills, its implementation in junior high schools has not shown optimal results because it is still limited to descriptive investigative activities and has not emphasized deep conceptual understanding and critical reflection. Previous research has examined the effectiveness of GI in general, but has not specifically integrated deep learning approaches as a systematic effort to strengthen students' higher-level thinking processes. Thus, different from previous research that applied the Group Investigation model in general, this study presents a novelty in the form of integrating deep learning approaches into each stage of GI to encourage the process of analysis, evaluation, and conceptual reflection of students, so that the improvement of critical thinking skills does not only occur quantitatively, but also in every critical thinking indicator.

Therefore, this study aims to improve the critical thinking skills of junior high school students through the application of the Group Investigation cooperative learning model oriented to deep learning on the interaction of living things and their environment. The research questions asked in this study are: (1) How to improve students' critical thinking skills after applying the deep learning-oriented Group Investigation model? (2) How is the achievement of each indicator of students' critical thinking skills after the application of the model? (3) How do students respond after applying the deep learning-oriented Group Investigation model?

2. RESEARCH METHOD

This study uses a descriptive quantitative approach with a quasi-experimental type. The research design used is a one group pretest-posttest design with multiple groups. This design aims to determine the improvement of students' critical thinking skills after the application of the deep learning-oriented Group Investigation learning model, as well as to see the achievement of critical thinking skills in each indicator and the students' response to the learning applied. The quasi-experimental design was chosen because the research was carried out on an existing group without randomizing the subjects individually [12], [13]. The study did not involve a control group, as the focus of the study was on the achievement of improved critical thinking skills after the application of the learning model, not on the comparison of effectiveness with other learning models.

The subjects in this study are students in grade VII of junior high school which consists of two classes, namely classes VII-A and VII-C, class VII-A with 26 students and class VII-C with 25 students. The selection of research subjects was carried out by purposive sampling technique, which is the selection of samples based on certain considerations relevant to the research objectives [14], with the consideration that the two classes have relatively equivalent characteristics in terms of class level, curriculum used, and learning materials studied. Both classes received the same treatment and were treated as experimental groups to test the consistency of the impact of the application of the learning model.

The research procedure began with the administration of a pretest to measure students' initial critical thinking skills (O_1). Furthermore, students participate in learning by applying a deep learning-oriented Group Investigation model, which is carried out in accordance with the learning syntax (X). During the learning process, observation of the implementation of learning is carried out to ensure that each stage of the learning model is implemented according to the plan. After the entire learning series is completed, students are given a

posttest to measure critical thinking skills after the application of the learning model (O_2) [15]. The design scheme of the research is shown in Figure 1.

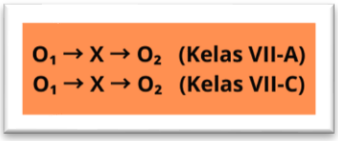


Figure 1. Research Design Scheme

The research instruments used included learning observation sheets, critical thinking skills tests, and student response questionnaires. The learning implementation observation sheet is based on the stages of the Group Investigation model syntax and is used to systematically observe the implementation of learning and student activities in the learning process. Critical thinking skills tests are used during the pretest and posttest and are prepared based on critical thinking skill indicators according to Ennis, (1985), namely Elementary Clarification, Basic Support, Inference, Advanced Clarification, and Strategy and Tactics [16]. The critical thinking skills test sheet has been validated by two validators, where very valid results were obtained in each aspect for multiple-choice and description questions, while for reliability exceeding 0.90 which means that the multiple-choice questions and descriptions are very reliable [17]. The student response questionnaire is used to find out the students' responses to the application of the applied learning model.

Data collection was carried out through observation, test, and questionnaire techniques. Learning implementation data is analyzed by calculating the percentage of student implementation and activity in each aspect, then interpreted based on the criteria for learning implementation and student activities in Table 1. and Table 2. [18], [19].

Table 1. Learning Implementation Assessment Category

Feasibility (%)	Categori
$80 \leq x \leq 100$	Excellent
$60 \leq x < 80$	Good
$40 \leq x < 60$	Enough
$20 \leq x < 40$	Ugly
$0 \leq x < 20$	Very Ugly

Table 2. Categories of Student Activities

Implementation Value (%)	Criteria
81 – 100	Highly Active
61 – 80	Active
41 – 60	Moderately Active
21 – 40	Less Active
0 – 20	Inactive

The data on the implementation of learning here is used as supporting data to ensure that the application of the Group Investigation model oriented to deep learning has been carried out properly and in accordance with the learning syntax, so that the results of improving critical thinking skills obtained can be scientifically accounted for. Data on the improvement of critical thinking skills was analyzed using N-gain to determine the level of improvement in student learning outcomes by calculating the data of pretest and posttest results of students which were then seen in the categories in table 3. [20]. The achievement of improvement in each critical thinking skill indicator was analyzed using N-gain as well.

Table 3. Classification of N-Gain Values

Interval	Category
$(\langle g \rangle) \geq 0.7$	High
$0.7 > (\langle g \rangle) \geq 0.3$	Medium
$(\langle g \rangle) < 0.3$	Low

Furthermore, the data from the pretest and posttest results were analyzed using the normality test to see whether the data was distributed normally or not. This test uses the Shapiro-Wilk test adjusted to the number of samples less than 50, the test utilizes SPSS software. The data is said to be normal, if the significant value is greater than 0.05 at (sig>0.05). Conversely, if the significant value is less than 0.05 at (sig<0.05) the data cannot be said to be normal [21]. If the data is normally distributed, it can be followed with a homogeneity test to find

out whether several groups of research data have the same variance or not. This test utilizes SPSS software. Data can be said to be homogeneous if the Sig. (P Value) Based on Mean value > 0.05 concludes that the Homogeneity Data Variant (Homogeneity Test is met), on the other hand, if the Sig. (P Value) Based on Mean < 0.05 concludes that the Homogeneity Data Variant (Homogeneity Test is not met) [22]. Pretest and posttest data that are normally and homogeneously distributed can be continued in parametric hypothesis tests, namely dependent t-test. The t-test was performed using SPSS with a significance level of $\alpha = 0.05$, with the assumption criterion that if the significance (P) <0.05, then Ho was rejected, meaning that there was a significant difference between before/after the intervention. If the significance (P) > 0.05, then Ho is accepted, meaning there is no significant difference between before/after the intervention. If the data is abnormally distributed and inhomogeneous, it can be continued with a non-parametric test, i.e. the Wilcoxon test. The Wilcoxon test was used to compare two paired (dependent) samples or repeated measurements (before/after) conducted using SPSS with the assumption criterion that if the significance (P) <0.05, then Ho was rejected or there was a significant difference between before/after the intervention. If the significance (P) > 0.05, then Ho is accepted or there is no significant difference between before/after the intervention. Furthermore, it is continued to conduct an effect size test to measure the effectiveness of the learning model or to assess the extent of the effectiveness of the learning method or model that has been tested and applied to students [28]. The difference with normalized gain is that normalized gain is used to determine the effectiveness/ineffectiveness of a study, while Effect Size analysis in statistics is used to determine the magnitude of the scale of the effectiveness of a study. To see the effective magnitude of the deep learning-oriented GI cooperative model, it can be seen in the categorization of the effect size test score [23] in Table 4.

Table 4. Effect size test category

Measures	Interpretation
0.0 – 0.20	Very weak effect
0.21 – 0.50	Weak effect
0.51 – 1.00	Medium effect
> 1.00	strong effect

Student response data was analyzed using percentage analysis and interpreted based on student response criteria [24] in Table 5.

Table 5. Categories Student Responses

Student Response (%)	Category
$75 < RS \leq 100$	Very positive
$50 < RS \leq 75$	Positive
$25 < RS \leq 50$	Negative
$0 < RS \leq 25$	Very Negative

3. RESULTS AND DISCUSSION

Before discussing the improvement of students' critical thinking skills, the results of the implementation of learning are first presented to ensure that the deep learning-oriented Group Investigation model is really applied in accordance with the learning syntax. The results of observations showed that the implementation of learning in both classes was in the very good category. All aspects consisting of perception and motivation, delivery of competencies and goals, mastery of materials, application of cooperative group investigation learning strategies, implementation of group investigation model stages, use of learning resources or media, authentic assessments or assessments, student involvement, use of language, and learning conclusions are in the very good category. The high level of learning implementation is in line with the findings of previous research showing that investigation-based cooperative learning can be implemented effectively in the classroom context and provide space for meaningful student interaction [25]. In addition, the results of other studies prove that the implementation of the group investigation learning model is running well and there is an influence between the implementation of the group investigation learning model and students' critical thinking skills [26] [27].

In addition to the implementation of learning, observations were also made on the implementation of student activities which included collaboration and communication activities during the learning process. The results of the observation showed that the students' activities were in the very active category, which was characterized by the active involvement of students in working together to complete group assignments, sharing roles, exchanging ideas, and conveying the results of discussions through presentations. These findings are in line with the literature that states that collaborative learning can improve critical thinking skills while strengthening communication and cooperation skills between students [28]. In addition, collaborative strategies

involving intensive group discussions have been shown to contribute positively to students' collaboration and communication skills in a variety of learning contexts [29].

The high level of implementation shows that the learning tools used have been designed systematically and are easy to implement in learning activities. This result is important because the implementation of good learning is the main prerequisite in interpreting the results of improving students' critical thinking skills. Creswell asserts that the effectiveness of a learning intervention can only be validly assessed if its implementation is in accordance with a predetermined design [13]. Thus, the results of the implementation of this learning confirm that the improvement of students' critical thinking skills can be associated with the application of the deep learning-oriented Group Investigation model.

Based on the results of the analysis of pretest and posttest scores of students' critical thinking skills, an increase was obtained after the application of the deep learning-oriented Group Investigation model. The increase was shown by the difference in the average score of the pretest and posttest in both classes. In detail, the results of improving students' critical thinking skills are presented in Figure 2.

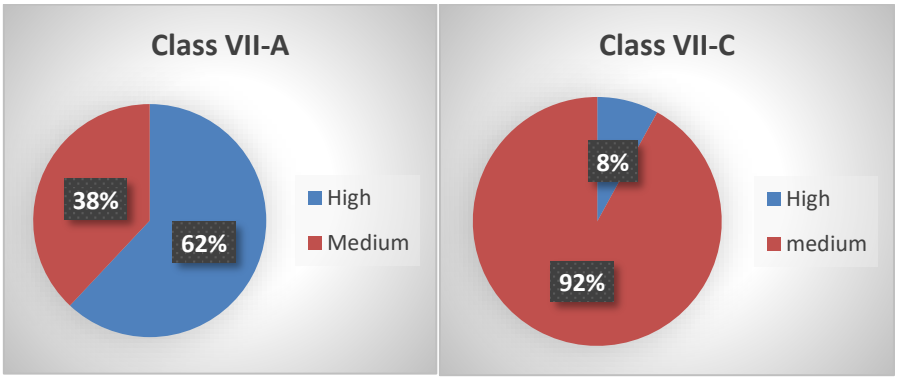


Figure 2. Critical Thinking Skills Analysis Chart with N-Gain Test Classes VII-A and VII-C

Based on Figure 2, it is known that the distribution of improving students' critical thinking skills in class VII-A is mostly in the high category, with the number of students as many as 16 people, while 10 students are in the medium category. Meanwhile, the distribution of improving students' critical thinking skills in grades VII-C showed that most of the students were in the medium category, with a total of 23 people, and a small number were in the high category, namely 2 people. The difference in the distribution of improvement categories in the two classes showed that there was a variation in the level of improvement in students' critical thinking skills, even though both classes received the same learning treatment. This variation reflects differences in students' initial characteristics and abilities, but in general still shows an improvement in critical thinking skills after learning is implemented.

To find out whether the improvement of students' critical thinking skills after the application of the deep learning-oriented Group Investigation model occurred significantly, statistical tests were conducted on pretest and posttest scores. Before the statistical test is carried out, a data normality test is first carried out as the basis for determining the type of statistical test used. The results of the normality test for class VII-A showed that the data was not normally distributed, where the pretest data was smaller than 0.05 with a significance value (Sig.) of 0.004 (sig. <0.05), while the posttest data was greater than 0.05 with a significance value (Sig.) of 0.056 (sig.> 0.05), although the posttest data was normally distributed, but the pretest data was not normally distributed, so the statistical test used was a nonparametric test, namely the Wilcoxon test. The results of the normality test for class VII-C showed that the data was not normally distributed, where the pretest data was greater than 0.05 with a significance value (Sig.) of 0.513 (sig.> 0.05), while the posttest data was smaller than 0.05 with a significance value (Sig.) of 0.003 (sig. < 0.05), so the statistical test used was a non-parametric test, namely the Wilcoxon test. The results of the wicoxon test showed that there was a significant difference between the pretest and posttest scores of students' critical thinking skills in the two classes. Where the results of the wilcoxon test in class VII-A were obtained with an asymp value. sig (2-tailed) of 0.000, where the results show that there is a significant difference between the pretest and posttest scores before and after the application of the deep learning-oriented group investigation cooperative model. Meanwhile, the results of the wilcoxon test in class VII-C were obtained with an asymp value. sig (2-tailed) of 0.000, where the results show that there is a significant difference between the pretest and posttest scores before and after the application of the deep learning-oriented group investigation cooperative model. The findings indicate that the improvement of students' critical thinking skills after the application of the deep learning-oriented Group Investigation model occurred statistically significantly.

The results of the above study show that the application of the Group Investigation learning model oriented to deep learning is able to significantly improve students' critical thinking skills. The findings of

improving critical thinking skills are in line with a number of previous studies that confirm that collaborative learning strategies, such as Group Investigation, are effective in stimulating students' high-level thinking skills. Collaborative learning strategies that involve learners in discussion, problem solving, and joint inquiry can improve the ability to analyze, evaluate, and synthesize information which is at the core of critical thinking skills [30][31]. Learning activities structured in the Group Investigation model facilitate students to work in groups in formulating problems, seeking and evaluating information, and conveying the results of discussions. This learning approach that encourages learners to be actively involved socially and cognitively is also in line with the findings of other research that states that collaborative learning can encourage the emergence of critical thinking skills through social interaction and the exchange of ideas within groups [32].

In addition to statistical significance testing, effect size analysis was also carried out to evaluate the magnitude of the impact of learning treatment on students' critical thinking skills. Effect size measures the extent to which a learning intervention has a meaningful, practical, rather than merely statistically significant effect. Effect size helps to strengthen the interpretation of the magnitude of the change in learning outcomes caused by the treatment (learning model) given. In this study, the effect size of class VII-A was 3.82 while class VII-C was 4.25, both of which were included in the very strong category. From these results, it shows that the deep learning-oriented group investigation cooperative learning that has been implemented has a very strong influence on improving students' critical thinking skills. The effect size findings, which are in the very strong category, indicate that the change in critical thinking skill scores that occur after learning is quite substantial and has practical meaning in the context of science learning in the classroom. This interpretation is also strengthened by the results of meta-analyses in other learning contexts which show that learning models that stimulate students' active involvement and collaboration tend to have a significant effect size in improving critical thinking skills and general learning outcomes [33].

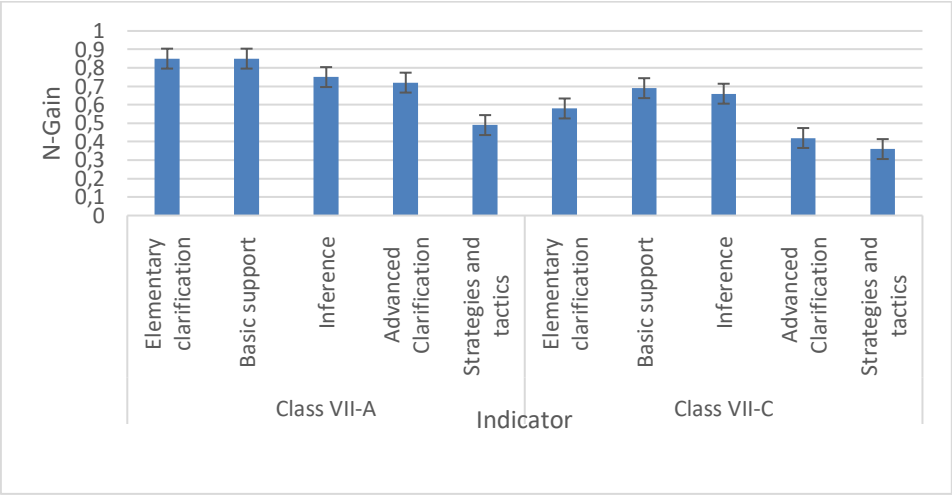


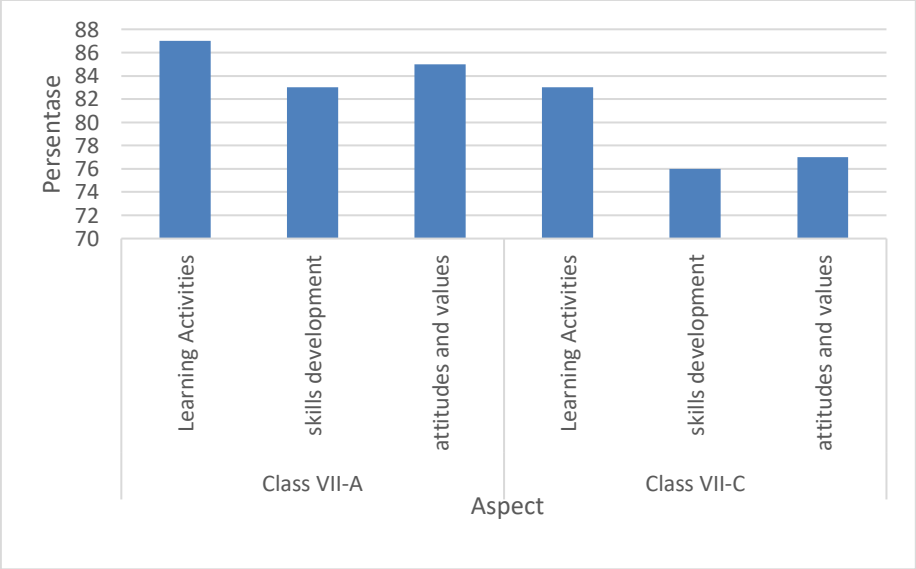
Figure 3. Graph of Improvement on Each Critical Thinking Skill Indicator of Classes VII-A and VII-C

In addition to improving critical thinking skills in general, analysis based on critical thinking indicators shows variations in improvement between indicators in Figure 3. Indicators related to elementary clarification and basic support experienced a relatively higher increase for class VII-A, for class VII-C the indicator that experienced a relatively higher increase was basic support. These findings are understandable because early indicators of critical thinking tend to be more easily developed through group discussions, where learners are trained to explain ideas and give reasons directly in group interactions. In contrast, more complex thinking indicators often demand higher information processing skills and longer habituation, although they still show positive improvements. In addition, the existence of an error bar on the graph shows the level of variation in N-Gain scores between students in each indicator. Relatively small error bars on some indicators such as in class VII-A indicate that the improvement of critical thinking skills occurs more evenly and consistently. In other words, most students in class VII-A experienced an increase in critical thinking skills with a relatively uniform level in each indicator. Such a more uniform distribution is often associated with more effective collaboration and homogeneous student engagement, where each student actively contributes to the learning process (social interaction enhances shared understanding) [34]. On the other hand, a larger error bar such as in classes VII-C, indicates a fairly high variation in students' abilities. This condition shows that not all learners experience an increase in critical thinking skills at the same level. Some students experienced a fairly high increase, while others still showed a lower increase. This variation can be influenced by differences in initial abilities, the level of involvement in group discussions, and the readiness of students to participate in cooperative learning. The phenomenon of variation is in line with the findings of other studies that show that differences in students'

cognitive characteristics, learning styles, and levels of participation in collaborative learning can affect responses to certain learning strategies [35]. The findings of the variation in the increase show that although the applied learning model is effective in general, differentiatory learning strategies are needed, one of which is through the provision of more intensive scaffolding for students who experience difficulties. Proper scaffolding can help learners develop high-level thinking skills gradually through guidance, triggering questions, and learning support tailored to individual needs [36]. Furthermore, Hattie emphasized that the effectiveness of learning is not only determined by the model used, but also by the teacher's ability to adjust learning support based on students' responses and progress. Thus, the variation of error bars that appear on the graph can be used as a basis for reflection for teachers to strengthen mentoring strategies and ensure that the improvement of critical thinking skills can be achieved more optimally and evenly by all students [37].

In the context of 21st century skills learning, collaboration and communication skills are an integral part of critical thinking skills. Learners' implementation activities that demonstrate active involvement in collaboration and communication during learning show that the Group Investigation model supports not only the development of critical thinking skills, but also social skills relevant to the demands of 21st century learning. This is consistent with research findings that show that the application of the Group Investigation model can improve students' collaboration and communication skills, which in turn contributes to the development of critical thinking skills through meaningful social interaction [38][39]. In addition, other research states that the group investigation cooperative learning model requires student activities in its implementation [40]. This research also emphasizes the importance of a learning model that integrates elements of deep learning in each stage of learning activities. Deep learning-oriented learning emphasizes deep understanding, reflection, and interconnectedness between concepts, thus not only encouraging improved test scores, but also authentic critical thinking engagement. These findings are in line with the theoretical argument that learning that requires learners to think independently, realistically, and reflectively will result in a more significant improvement in higher-level thinking skills than conventional one-way instructional approaches [30], [31].

Furthermore, the results of the analysis of student responses in grades VII-A and VII-C which were calculated with a percentage formula to see the students' responses to the application of the group investigation cooperative model learning tools are shown in Figure 4.



Picture 4. Percentage Analysis Graph of Response Analysis of Grade VII-A and VII-C Students

Based on Figure 4. It is known that the average percentage of Class VII-A obtained results of 85% with very positive criteria, where the highest percentage results were found in the aspect of students' response to learning activities of 87% with very positive criteria, while the lowest percentage was found in skill development of 83% with very positive criteria, while the average percentage of class VII-C obtained results of 79% with very positive criteria, Where the highest percentage results were found in the aspect of students' response to learning activities of 83% with very positive criteria, while the lowest percentage was found in skill development of 76% with very positive criteria. Based on this, the response of students from both classes showed very positive response results if the percentage was >75%. Based on this, it shows that the application of science learning tools of the deep learning-oriented cooperative group investigation model in class VII-C is on average included in the very positive category.

The findings indicate that the deep learning-oriented Group Investigation cooperative model science learning tool that has been implemented has been well received by students, both in grades VII-A and grades

VII-C. Positive responses of students reflect high learning engagement, which includes affective and cognitive aspects, and indicate that students feel interested and helped by the learning process [41]. The highest response aspect in both classes was in the learning activities, which showed that the design of the Group Investigation learning activity was able to create an interesting and meaningful learning atmosphere. The Group Investigation model provides opportunities for students to be actively involved in discussions, investigations, and presentation of results, thereby increasing their sense of belonging to the learning process [42], [43]. The activity is aligned with a deep learning approach that emphasizes active engagement and deep conceptual understanding.

The positive response from students here can be understood as an indicator that the learning model is well received and is able to trigger active involvement of students in the learning process. This is in line with research findings that show that Group Investigation is able to create an active, collaborative, and meaningful learning environment for students. In previous studies, students' responses and enthusiasm for Group Investigation were also reported to be very positive, especially in learning activities that facilitated students' active involvement in group discussions, investigations, and presentations [44], [45]. In addition, a meta-analysis of the application of cooperative learning shows that the cooperative learning model has a positive effect on the affective domain, including students' motivation and attitudes towards learning. These findings underscore that students are not only more intellectually active, but also more interested and emotionally motivated in cooperative learning [46], [47]. Group Investigation is a form of cooperative learning that specifically requires students to work in groups to investigate problems, discuss, present results, and reflect on the learning process. This learning structure naturally encourages affective engagement (e.g., high interest and confidence in group discussions and presentations in front of the class) and cognitive engagement (e.g., critical thinking and deep conceptual processing), as students not only receive information, but interrogate, process, and communicate their own findings. This model is aligned with deep learning principles that emphasize conceptual understanding and critical reflection on learning [48]. Other research has also shown that the use of the Group Investigation model significantly increases learners' activity and positive responses to learning [49].

Overall, the response of students in grades VII-A and VII-C who were in the very positive category showed that the application of the deep learning-oriented Group Investigation cooperative model science learning tool was not only effective in improving critical thinking skills, but also obtained good acceptance from students. This positive response can be used as an indicator of the practicality and acceptability of the learning tools developed, as well as strengthen the results of the learning effectiveness analysis. The high positive response, especially in the aspects of learning activities and skill development, shows that the Group Investigation model is not only accepted but also effective in activating students' critical thinking, collaboration, and problem-solving skills, components designed to be improved through deep learning. These results reinforce the argument that these learning tools are not only practical but also effective in the context of higher science learning objectives [50].

Based on the consistency of improving critical thinking skills in the two classes above, the findings of this study can be generalized in a limited way that the deep learning-oriented Group Investigation cooperative learning model has the potential to be applied effectively to junior high school science learning, especially in materials that require conceptual understanding and high-level reasoning, one of which is the interaction material of living beings and their environment, with the record that the implementation is adjusted to characteristics of students and teacher readiness. Theoretically, the results of this study strengthen the view that collaborative learning combined with a deep learning approach is able to stimulate critical thinking skills more deeply and also in the mastery of each critical thinking indicator. Practically, these findings provide implications for teachers and learning developers as a reference in designing learning tools that are in harmony with other materials and subjects. The novelty of this research lies in the systematic integration of deep learning approaches into each stage of the Group Investigation model as well as the analysis of improving critical thinking skills up to the indicator level, which has not been widely studied in previous research. However, this study has limitations, including not involving control groups and a relatively limited duration of learning implementation, which is only 4 meetings. Therefore, further research is recommended to use experimental designs with comparison groups, apply learning over a longer period of time, and integrate scaffolding and differentiation strategies so that the improvement of critical thinking skills can take place more optimally and evenly among all students.

4. CONCLUSION

This study emphasizes that strengthening the critical thinking skills of junior high school students is not enough to be achieved through the application of cooperative learning models alone, but requires the integration of deep learning approaches that consciously direct the investigation process to analysis, evaluation, and conceptual reflection. The findings of this study contribute to the development of cooperative learning theory by showing that deep learning-oriented Group Investigation functions as a pedagogical framework that is able to systematically link social interactions with high-level cognitive processing. The study's main theoretical contribution lies in the assertion that increased critical thinking occurs more meaningfully when each stage of

investigation is designed to encourage conceptual clarification, reason-based proofing, and reflective decision-making, rather than just collaborative activities. Practically, the results of this study provide implications for the development of junior high school science learning tools and strategies that are in line with the Independent Curriculum, especially in an effort to strengthen meaningful learning and 21st century skills. At the policy level, this research supports the need to strengthen teacher professional development policies that not only focus on learning model variations, but also on deepening the cognitive orientation of learning so that collaborative processes truly produce sustainable critical thinking quality.

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AUTHOR CONTRIBUTIONS

ZNA was responsible for the research design, data collection, data analysis, and manuscript preparation. SI NS, contributed to conceptual development, research methodology guidance, and critical review of the manuscript. All authors have read and approved the final version of the manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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