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The Effect of the Reciprocal Teaching Learning Model Assisted by Interactive Diagram Media on Collaboration Skills and Cognitive Learning Outcomes of Grade X Students in Biogeochemistry Material

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Abstract

The low levels of collaborative skills and inadequate cognitive learning achievement among students in the complex topic of biogeochemistry have motivated this study. A preliminary investigation at SMAN 1 Mojosari revealed that 26 out of 36 students failed to meet the Minimum Competency Standard, and their collaborative skills were rated as only moderate on two key indicators: productive teamwork (57.1%) and showing respect (58.3%). This research aimed to evaluate the effectiveness of the reciprocal teaching model enhanced with interactive diagram media in improving students' collaboration abilities and enhancing cognitive learning outcomes. A quasi-experimental design with a nonequivalent pretest-posttest control group was employed. Two classes of grade X students (36 students per class) were selected using purposive sampling. Data were collected using cognitive tests and collaboration questionnaires, then analyzed using ANOVA. The findings indicate that the intervention did not significantly influence students' collaborative skills ($p = 0.345 > 0.05$), although it significantly improved cognitive learning outcomes ($p = 0.000 < 0.05$). These results suggest that the reciprocal teaching model, combined with interactive diagram media, effectively enhances cognitive achievement and shows potential for fostering improvements in collaborative skills over time. The effectiveness of this approach is influenced by several factors, including students' initial ability, limited implementation time, and students' ability to adapt to the new learning model.

Keywords: *reciprocal teaching; interactive diagrams; biogeochemistry; collaborative skills; cognitive learning outcomes; quasi-experimental design.*

Abstrak

Permasalahan rendahnya keterampilan kolaborasi serta pencapaian hasil belajar kognitif siswa dalam topik biogeokimia yang kompleks menjadi latar belakang penelitian ini. Studi pendahuluan di SMAN 1 Mojosari menunjukkan bahwa 26 dari 36 siswa belum memenuhi Standar Ketuntasan Minimal dan keterampilan kolaborasi mereka dalam kategori cukup pada dua indikator, yakni bekerja secara produktif (57,1%) dan menunjukkan rasa hormat (58,3%). Studi ini dimaksudkan untuk menilai sejauh mana penerapan model reciprocal teaching berbantuan media diagram interaktif memengaruhi kemampun siswa dalam berkolaborasi dan meningkatkan capaian kognitifnya. Metodologi yang diterapkan dalam penelitian ini adalah kuasi-eksperimental dengan desain nonequivalent pretest-posttest control group. Dua kelas X beranggotakan 36 siswa per kelas yang ditentukan melalui teknik purposive sampling sebagai sampel penelitian. Pengumpulan data dilakukan melalui tes kognitif dan angket kolaborasi, lalu dianalisis menggunakan uji Anakova. Temuan penelitian mengungkapkan bahwa model ini tidak memberikan pengaruh signifikan pada keterampilan kolaborasi siswa (sig = 0,345 > 0,05), namun secara signifikan meningkatkan hasil belajar kognitif (sig = 0,000 < 0,05). Hasil tersebut menunjukkan bahwa model ini mampu meningkatkan hasil belajar kognitif siswa dan berpotensi mendorong peningkatan kolaboratif mereka dari sebelum ke sesudah perlakuan. Efektivitas ini dipengaruhi beberapa faktor, antara lain kemampuan awal siswa, waktu implementasi yang terbatas, serta adaptasi siswa.

Kata Kunci: *reciprocal teaching; diagram interaktif; biogeokimia; keterampilan kolaborasi; hasil belajar kognitif; desain kuasi-eksperimen.*

INTRODUCTION

In the era of globalization, the goals of education have extended beyond mere academic achievement to include the mastery of 21st-century skills, commonly known as the 4Cs (critical thinking, communication, collaboration, and creativity). These skills are essential provisions for students to face challenges and adapt to the rapid development of the modern world (Realitawati et al., 2024). Therefore, the success of learning is no longer measured solely by final scores, but also by the extent to which these objectives are achieved. Learning is considered successful when the majority of students are actively engaged physically, cognitively, mentally, and socially in the learning process (Wali et al., 2020). Considering this urgency, one of the relevant 21st-century skills that becomes the focus of this study is collaboration skills. This skill has the potential to improve students' learning outcomes, as it can enhance motivation, facilitate problem-solving processes, and strengthen their social skills (Anggristia et al., 2023).

Although collaboration skills are essential in the 21st century, several studies indicate that students' level of mastery in this area still needs improvement. For instance, a study by Hendrawan et al. (2024) revealed low levels of collaboration skills, with 24% of students categorized as highly uncollaborative and 76% as uncollaborative. To gain further insight, a preliminary study was conducted at SMAN 1 Mojosari, particularly in classes 10.1 and 10.2. The results showed a "moderate" category in two indicators of collaboration skills according to Greenstein, namely working productively (57.1%) and demonstrating respect (58.3%). These findings were supported by an interview with a Biology teacher, who stated that collaboration skills had never been explicitly trained or emphasized among students, resulting in an unclear initial level of mastery of these skills. This condition has the potential to affect both the learning process and students' cognitive learning outcomes, as collaboration skills have been shown to contribute to cognitive achievement (Shofiyah et al., 2022). Therefore, efforts to improve collaboration skills are important to consider.

In line with this urgency, improving students' collaboration skills has the potential to significantly enhance their cognitive learning outcomes (Ilma & Sam, 2024). In this regard, a preliminary study was conducted to measure students' cognitive achievement in one class that had completed the Biology subject, particularly on biogeochemical cycles. The results showed that 26 out of 36 students scored below the minimum mastery criterion (75). These findings were supported by an interview with a Biology teacher, who stated that, in general, students' cognitive abilities in Biology were relatively good; however, several topics were considered difficult to learn, namely ecology (biogeochemical cycles) and technological innovation (genetic engineering and cloning). The low cognitive learning outcomes are indirectly related to the results of the preliminary study on collaboration skills, which were categorized as "moderate." This indicates that both aspects may influence each other (Shofiyah et al., 2022). Therefore, there is an urgent need for instructional innovation that can effectively improve both collaboration skills and students' cognitive learning outcomes, particularly in complex Biology topics.

The selection of an effective learning model, such as reciprocal teaching, can serve as a strategic effort to promote the improvement of students' collaboration skills as well as their cognitive achievement. This model adopts a constructivist approach, grounded in the principles of questioning and the development of students' metacognition. Reciprocal teaching consists of four main strategies, namely questioning, clarifying, predicting, and summarizing (Palinscar & Brown, 1984). Compared to other models such as Problem-

Based Learning (PBL) or Project-Based Learning (PjBL), this model places greater emphasis on enhancing students' understanding through metacognitive dialogue, while also facilitating students' active participation in examining and responding to issues within their surrounding environment (Sari et al., 2023). Based on these characteristics, reciprocal teaching offers several advantages, including fostering meaningful collaborative learning, assisting students in understanding and applying knowledge in real-life contexts, improving critical thinking skills, increasing interest and motivation, and developing students' social skills. These strengths contribute to the overall improvement of learning quality, thereby enhancing students' cognitive learning outcomes and providing them with meaningful learning experiences (Novianti, 2024; Zai et al., 2025).

In addition to learning models, instructional media also play a crucial role in maximizing learning effectiveness and optimizing the implementation of instructional models (Wulandari et al., 2023). Media considered suitable for the reciprocal teaching model include interactive diagrams, as they can help visualize concepts that are difficult to imagine and understand, while also being integrated with technology (Biassari & Putri, 2021). The selection of interactive diagram media over similar media such as posters, dioramas, videos, and others is based on its ability to present images and diagrams that respond dynamically when interacted with. Moreover, this media provides integrated explanations, enabling students to understand the learning material more easily (Batubara et al., 2023). Research conducted by Rukmana and Fitrihidajati (2022) supports this argument, showing that the use of interactive learning media has a positive impact on the learning achievement of Grade X students. This improvement is supported by the characteristics of the media, which can stimulate collaboration, foster interest, and enhance students' motivation during the learning process. Ideally, the use of interactive diagram media within the reciprocal teaching model is expected to effectively increase student engagement, optimize collaboration, and strengthen overall conceptual understanding (Rahman et al., 2024).

Reciprocal teaching and interactive diagram media have been proven to have a positive impact on the learning process. A study by Sulistiana et al. (2024) reported that reciprocal teaching has a significant effect on improving students' learning outcomes, as indicated by increased scores in tests and assignments, as well as enhancing students' collaborative abilities, although the study did not specifically focus on collaboration skills. In addition, research by Pratiwi and Rachmadtullah (2024) indicates the positive impact of interactive media on collaboration skills, while a study by Rukmana and Fitrihidajati (2022) revealed that interactive learning media have a beneficial effect on students' learning outcomes. However, despite the theoretical effectiveness of implementing the reciprocal teaching model supported by interactive diagram media, there is still a lack of research that specifically examines the combination of both in improving students' collaboration skills and cognitive achievement.

This research gap becomes increasingly relevant when associated with topics that are considered challenging by most students, one of which is biogeochemistry. Based on observations conducted at SMAN 1 Mojosari, students experience difficulties in understanding biogeochemical cycles due to their integration of chemical and biological concepts, as well as the inherent complexity of the material. This observation is consistent with the findings of Rahmawati et al. (2021), in which the majority of respondents reported difficulties in learning biogeochemical cycles. These difficulties are influenced

by several factors, including limited access to learning resources, inappropriate teaching methods, the absence of instructional media, and insufficient understanding of the material (Rahmawati et al., 2021). In light of these conditions, an instructional innovation is needed by implementing a combination of the reciprocal teaching model and interactive diagram media. This suitability is further reinforced by the nature of biogeochemical material, whose complex cycles can be effectively visualized through interactive diagram media (Batubara et al., 2023).

METHOD

2.1. Research Design

This study was designed within a quantitative approach using a quasi-experimental method, aimed at analyzing the effect of the reciprocal teaching model assisted by interactive diagram media on the improvement of students' collaboration skills and cognitive learning outcomes in biogeochemistry learning at SMAN 1 Mojosari. The research employed a nonequivalent pretest–posttest control group design. Table 1 presents the research design applied in this study.

Table 1. Research Design

Pemilihan sampel	*Pretest*	Treatment	*Posttest*
Experimental	O_1	X	O_2
Control	O_3	Y	O_4

Description:
X : Implementation of the reciprocal teaching model assisted by interactive diagram media
Y : Implementation of conventional learning without interactive diagram media (discussion, lecture, and question–answer methods)
O_1 : Initial assessment (pretest) in the experimental group
O_2 : Final assessment (posttest) in the experimental group
O_3 : Initial assessment (pretest) in the control group
O_4 : Final assessment (posttest) in the control group

2.2. Population and Sample

This study was conducted at SMAN 1 Mojosari from February 11 to 19 in the 2024/2025 academic year. The population consisted of 360 Grade X students in the second semester, distributed across 10 classes. Two classes, namely X.1 and X.2, each consisting of 36 students, were selected as samples using purposive sampling to ensure similarity in characteristics and initial abilities between groups.

2.3. Research Prosedure

Data collection was carried out in both sample classes through two meetings in each class. Data collection began with (1) an initial data-gathering phase, which included interviews with the Biology teacher and the distribution of a collaboration skills questionnaire to all samples in order to identify students' baseline conditions prior to the intervention. Next, (2) a pretest on biogeochemical material was administered to measure students' cognitive achievement before the instructional intervention. (3) The treatment phase was then conducted, in which the control class received conventional instruction (through lectures, discussions, and question–answer sessions), while the experimental class was taught using the reciprocal teaching model assisted by interactive diagram media. The final stage was (4) administering a posttest at the end of the learning process, consisting of a cognitive achievement test on biogeochemical material as well as a

collaboration skills questionnaire for all samples, to determine students' level of conceptual understanding and collaboration skills after the intervention.

2.4. Instrument Research

This study utilized two types of instruments, namely test and non-test instruments. The test-based instrument was designed to assess students' cognitive achievement through pretest and posttest questions, consisting of ten multiple-choice items and two essay questions. Meanwhile, the non-test instrument, in the form of a questionnaire with 20 statements, was used to measure students' collaboration skills based on the indicators proposed by Greenstein (2012).

2.5. Data Analysis

All collected data were analyzed using a combination of descriptive and quantitative methods. The implementation of the reciprocal teaching model syntax assisted by interactive diagram media was analyzed using descriptive analysis. In this study, syntax refers to the fundamental guideline that outlines the sequence of activities required to systematically implement the concepts of a learning model (Sarumaha et al., 2023). The syntax of the reciprocal teaching model includes the stages of predicting, questioning, clarifying, and summarizing (Palinscar & Brown, 1984). Meanwhile, to examine the effect of the implementation of the reciprocal teaching model assisted by interactive diagram media on students' collaboration skills and cognitive achievement in biogeochemistry, the data were analyzed quantitatively. This analysis employed the Analysis of Covariance (ANCOVA) test, with the criterion that if the significance value (p-value) exceeds 0.05, the relationship between the independent and dependent variables is considered not significant (Sugiyono, 2019). Conversely, if the p-value is less than 0.05, it can be concluded that there is a significant effect. Prior to conducting the ANCOVA test, the data were required to meet the prerequisite assumptions of normality and homogeneity. All data analyses were performed using SPSS version 22 for Windows.

RESULT AND DISCUSSION

Prior to analyzing the main data, validity and reliability tests of the instruments were conducted to obtain accurate measures of students' collaboration skills and cognitive learning outcomes. Content validity was first assessed by expert lecturers, followed by empirical testing of validity and reliability on students outside the research sample. This step is essential to ensure that the instruments accurately measure the intended constructs (validity) and to guarantee the consistency of the results (reliability) (Sugiyono, 2019). The detailed results of the validity assessment obtained from expert judgment are presented in Table 2.

Table 2. Result of Expert Validity Assessment

Instrument	Validator	Score	Criteria
Collaboration Skills Questionnaire	Assessment expert	88%	Very valid, usable without revision (Akbar, 2013)
Cognitive Learning Outcomes Test	Instructional design expert	80,6% (needs revision)	Highly relevant (Putri et al., 2023)
		98,1%	Highly relevant (Putri et al., 2023)
Interactive Diagram Media	Media expert	3,9 / 5	Valid or usable with minor revisions (Aka et al., 2018)
Interactive Diagram Media	Subject matter expert	4,4 / 5	Valid or usable with minor revisions (Aka et al., 2018)

		5 / 5	Very valid or usable without revision (Aka et al., 2018)
Teaching Module	Instructional design expert	4,5 / 5	Valid or usable with minor revisions (Aka et al., 2018)

Table 2 presents the results of the validity assessment conducted by expert lecturers in their respective fields, indicating a high level of validity and relevance, although some components required minor revisions. Subsequently, validity and reliability tests were administered to students outside the research sample. The validity of the collaboration skills questionnaire and cognitive learning outcomes test was analyzed using the Pearson Product Moment correlation. For the collaboration skills questionnaire, 20 out of 22 items were declared valid, as their calculated correlation coefficients (r-count) exceeded the r-table value of 0.329 (N = 36), while 2 items were deemed invalid and therefore excluded from the instrument. In addition, the validity test for the cognitive learning outcomes instrument showed that all items (10 multiple-choice questions and 2 essay questions) were valid, as indicated by r-count values greater than the r-table value (0.329 for N = 36). Furthermore, reliability testing was conducted using the Cronbach's alpha method. The results indicated that both the collaboration skills instrument (0.810) and the cognitive learning outcomes instrument (0.839) were reliable, as their coefficients exceeded the established reliability criterion of 0.6.

After the research instruments were confirmed to be valid and reliable, the next stage was the implementation of the learning model. The observation results indicated that the implementation of the reciprocal teaching model assisted by interactive diagram media was carried out effectively, with all syntax stages (question generating, clarifying, predicting, and summarizing) being well executed. Further details are presented in Table 3 below.

Table 3. Result of the Observation Shee ton the Implementation of Reciprocal Teaching Syntax by the Teacher

No.	Syntax	Description	Assessment		Remarks
			Ya	Tidak	
1.	*Question generating*	The teacher prepares biogeochemical cycle materials using interactive diagram media and presents them to the students.	✓		The learning activities were conducted in accordance with the prescribed syntax; however, they were implemented somewhat hastily, particularly in the first stage (question generating).
2.	*Clarifying*	The teacher facilitates students in acquiring knowledge and understanding after the presentation and discussion process.	✓		
3.	*Predicting*	The teacher provides questions to be completed collaboratively by students. These questions include extensions of the material being discussed.	✓		
4.	*Summarizing*	The teacher facilitates students in drawing conclusions from the material that has been learned.	✓		

These findings indicate that all syntax stages were fully implemented, with none only partially executed. Therefore, it can be concluded that the implementation of this learning model was carried out in accordance with the planned procedures. However, based on the observer's notes, there is a potential constraint related to time allocation, particularly in the first stage (question generating). This issue may be influenced by several factors. First, the reciprocal teaching model can be considered relatively new for students, meaning they are not yet familiar with it and require time to adjust. This statement is supported by

Gunawan and Nahdi (2023), who reported that students are not accustomed to the implementation of the reciprocal teaching model, resulting in difficulties in following the learning stages during the initial meetings. In addition, this model requires a considerable amount of time for effective implementation. However, due to time limitations, the learning process had to be condensed into only two meetings. This condition reflects one of the limitations of the reciprocal teaching model, namely its demand for a relatively long duration of implementation (Shoimin, 2014).

In addition to these factors, less conducive classroom conditions may have also influenced the teaching and learning activities, thereby requiring additional time to manage and organize the class effectively. Research by Pandi et al. (2024) further emphasizes the importance of creating a conducive classroom environment to ensure students' readiness to engage in learning. After observing and describing the implementation of the reciprocal teaching model assisted by interactive diagram media, this study subsequently analyzes the combined effect of the model and media on students' collaboration skills and cognitive learning outcomes. The findings reveal a disparity between the group of students taught using conventional approaches and those taught using the reciprocal teaching model. More detailed information is presented in Table 4.

Table 4. Descriptive Statistics of Collaboration Skills and Cognitive Learning Outcomes

Variable	Kelompok	N	Mean	Std. Deviation
Collaboration Skills	Control (10.1)	36	83.17	6.864
	Experimental (10.2)	36	84.81	7.731
Cognitive Learning Outcomes	Control (10.1)	36	71.36	11.480
	Experimental (10.2)	36	80.44	9.512

Based on Table 4, each class consisted of 36 students. The mean score of collaboration skills in the experimental class was slightly higher than that of the control class, although the difference was relatively small, at approximately 1.64. In addition, the standard deviation of the experimental group (7.731) was higher than that of the control group (6.684), indicating greater heterogeneity in collaboration skills within the experimental group. Furthermore, the average cognitive score of students in the experimental class exceeded that of the control class, with a difference of 9.08. The standard deviation of the control group (11.480) was higher than that of the experimental group (9.512), suggesting that the level of heterogeneity in cognitive achievement among students was greater in the control class than in the experimental class. After conducting descriptive statistical analysis, the next step was the ANCOVA test, with the prerequisite assumption tests of normality and homogeneity having been satisfied. Table 5 presents the results of the normality test for collaboration skills and cognitive learning outcomes.

Table 5. Normality Test Result

Variabel	Class	Kolmogorov-Smirnov	Interpretation
Collaboration Skills	Control (10.1)	.095[c]	Normal
	Experimental (10.2)	.200[c,d]	Normal
Cognitive Learning Outcomes	Control (10.1)	.178[c]	Normal
	Experimental (10.2)	.200[c,d]	Normal

Table 5 indicates that the prerequisite test, namely the normality test, employed the one-sample Kolmogorov–Smirnov method because the data size exceeded 50. Both the collaboration skills data and the overall cognitive learning outcomes are normally distributed. This is supported by the fact that all normality test values are greater than

0.05; specifically, collaboration skills in the control group (0.095) and the experimental group (0.200), as well as cognitive achievement in the control group (0.178) and the experimental group (0.200). Since the normality assumption has been satisfied, the analysis proceeds to the homogeneity test, as presented in Table 6.

Table 6. Homogenity Test Result

	Variable	Uji Levene	Keterangan
Before Treatment	Collaboration Skills	.286	Homogeneous
	Cognitive Learning Outcomes	.634	Homogeneous
After Treatment	Collaboration Skills	.421	Homogeneous
	Cognitive Learning Outcomes	.327	Homogeneous

Table 6 shows the prerequisite test results, namely the homogeneity test using Levene's test. Before the treatment, the homogeneity value for collaboration skills was 0.286 (> 0.05), and students' cognitive achievement was 0.634 (> 0.05). In addition, after the treatment, the homogeneity value for collaboration skills was 0.421 (> 0.05), while students' cognitive achievement was 0.327 (> 0.05). Based on these results, both variables are considered homogeneous, both in the pre-test and post-test measurements. Therefore, hypothesis testing using the ANCOVA test can be conducted, and the results are presented in Table 7.

Table 7. ANCOVA Test Result for Collaboration Skills

Source	*Type III Sum of Squares*	df	*Mean Square*	F	Sig.	*Partial Eta Squared*
Corrected Model	48.347[a]	1	48.347	.905	.345	.013
Intercept	507864.014	1	507864.014	9503.853	.000	.993
Kelas	48.347	1	48.347	.905	.345	.013
Error	3740.639	70	53.438			
Total	511653.000	72				
Corrected Total	3788.986	71				

The results of the ANCOVA test on collaboration skills, as presented in Table 7, show a significance value of 0.345 (> 0.05). Therefore, it can be concluded that the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected. This implies that there is no statistically significant difference in collaboration skills between the control group and the experimental group. In other words, the implementation of the reciprocal teaching model assisted by interactive diagram media in the experimental class did not result in a significant improvement in collaboration skills compared to the control class. The effect size between groups is very small, with only 1.3% explained by the Partial Eta Squared value. Nevertheless, the collaboration skills of the experimental class still showed an improvement from pretest to posttest. A more detailed explanation can be found in Table 8, which presents the N-Gain test results.

Table 8. N-Gain Test Result for Collaboration Skills

Class		N	Minimum	Maximum	Mean	Std. Deviation
Control Class (10.1)	N-Gain score	36	.24	.95	.5579	.18156
	N-Gain percentage	36	23.57	95.48	55.7887	.18.15617
Experimental Class (10.2)	N-Gain score	36	.18	.97	.5850	.21888
	N-Gain percentage	36	17.60	97.24	58.5046	21.88848

Based on Table 8, the N-Gain test was conducted to assess the level of improvement between the initial and final conditions in each group. The results indicate that students' collaboration skills improved in both the control and experimental classes. This is evidenced by the positive mean N-Gain values in both groups, namely 0.5579 for the control group and 0.5850 for the experimental group. According to Sukarelawan et al. (2024), the average N-Gain values in both groups fall into the "moderate" improvement category. In addition, there is a slight difference in the mean N-Gain between the experimental and control groups, with the experimental class showing a higher value by 0.0271. However, the variability of improvement in the experimental class (Std. Deviation = 0.21888) appears to be higher than that of the control class (Std. Deviation = 0.18156).

The results of the ANCOVA test (indicating no significant difference between the control and experimental groups) and the N-Gain test (indicating improvement before and after the treatment) in collaboration skills are influenced by several factors, one of which is the students' initial collaboration skills, which were already at a relatively adequate level. Improving performance from a "fairly good" level to a "very good" level presents its own challenges and requires greater effort, as the room for substantial improvement becomes more limited. A study by Sari and Atiningsih (2023) further supports these findings, showing that the Project-Based Learning (PjBL) model successfully enhanced students' collaborative abilities. This improvement was reflected in the shift of most students' scores from the "fair" category to the "good" category between Cycle I and Cycle II. However, achieving a "very good" level still requires additional effort and more intensive learning strategies.

In addition to students' initial abilities, the duration of implementation also influences the effectiveness of the model in improving students' collaboration skills. The implementation of the reciprocal teaching model assisted by interactive diagram media was relatively short (only two meetings), whereas collaboration skills generally require a longer period of adaptation and practice to develop significantly. This is consistent with the findings of Devi et al. (2023) and Sari and Atiningsih (2023), which indicate that significant improvement in students' collaboration skills requires at least two learning cycles or more than two meetings. This is because students may not have sufficient time to develop their collaboration skills substantially within a short period (one cycle). Therefore, the limited duration of the intervention may explain why the improvement in collaboration skills did not reach a statistically significant difference in the ANCOVA test, despite the positive N-Gain results.

Table 9. ANCOVA Test Result for Cognitive Learning Outcomes

Source	*Type III Sum of Squares*	df	*Mean Square*	F	Sig.	*Partial Eta Squared*
Corrected Model	1485.125[a]	1	1485.125	13.364	.000	.160
Intercept	414808.681	1	414808.681	3732.598	.000	.982
Kelas	1485.125	1	1485.125	13.364	.000	.160
Error	7779.194	70	111.131			
Total	424073.000	72				
Corrected Total	9264.319	71				

The results for collaboration skills show a contrasting trend compared to students' cognitive learning outcomes. Based on Table 9, the significance value of 0.000, which is less than 0.05, indicates that the null hypothesis (H_0) is rejected and the alternative

hypothesis (H_1) is accepted. This finding suggests that there is a significant difference in cognitive achievement between the two groups. Moreover, the effect size (Partial Eta Squared = 0.160) indicates that the differences between groups have a meaningful influence on the variability of cognitive learning outcomes. This suggests that the implementation of the reciprocal teaching model assisted by interactive diagram media in the experimental class effectively improved students' cognitive learning outcomes. This success can be attributed to the advantages of the reciprocal teaching model in facilitating deeper conceptual understanding through strategies such as questioning, clarifying, predicting, and summarizing (Palinscar & Brown, 1984). This statement is consistent with the study conducted by Rianti et al. (2022), which found that the application of the reciprocal teaching model had a positive effect on students' learning outcomes, as evidenced by the higher average scores of the experimental group compared to the control group.

In addition to the learning model, the use of interactive diagram media likely contributed to the improvement in students' cognitive learning outcomes. This is closely related to the advantages of interactive diagrams, which are capable of visualizing complex biogeochemical cycles, thereby helping students better understand processes that are otherwise difficult to conceptualize (Biassari & Putri, 2021). Furthermore, interactive diagram media are technology-based, allowing them to be accessed anytime and anywhere, and enabling repeated use according to students' learning needs when concepts are not yet fully understood. In this way, students can directly interact with the content, which supports the development of deeper conceptual understanding (Yuniarti et al., 2023). A study by Fadma and Kristanto (2021) reported similar findings, reinforcing this result by showing that interactive multimedia plays a significant role in improving students' learning outcomes, particularly on the topic of biogeochemical cycles.

CONCLUSION

Based on the research findings above, this study concludes that the reciprocal teaching model supported by interactive diagram media does not have a significant effect on the collaboration skills of tenth-grade students at SMAN 1 Mojosari (sig. value = 0.345 > 0.05). Nevertheless, there is a noticeable improvement in collaboration skills between the pre- and post-treatment conditions, as reflected in the mean N-Gain value of 0.5850, which falls into the "moderate" improvement category. In contrast, the combination of the learning model and media was proven to have a significant effect on students' cognitive learning outcomes at SMAN 1 Mojosari (significance value = 0.000 < 0.05). This finding highlights that the instructional approach not only enhances cognitive learning outcomes but also has the potential to support the improvement of students' collaboration skills across pre- and post-treatment phases. Several factors influencing these outcomes include students' initial abilities, the limited duration of implementation, and the students' adaptation process.

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