Effect of reciprocal teaching strategy on students' academic performance in genetics: A quasi-experimental study

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ABSTRACT

The purpose of this study was to investigate the effect of the Reciprocal Teaching Strategy (RTS) on Senior High School students' academic performance in genetics in the Sekyere South District of the Ashanti Region, Ghana. The study adopted a quantitative approach using a quasi-experimental non-equivalent control group pretest–posttest design. A total of 121 SHS 3 biology students participated in the study, comprising 70 students in the experimental group and 51 students in the control group. The experimental group received instruction using the Reciprocal Teaching Strategy, whereas the control group was taught using the Conventional Teaching Method. Data were collected using the Students' Performance in Genetics (SPG) test, which served as both the pretest and posttest. Independent-samples and paired-samples t-tests were employed to analyze the data at a 0.05 level of significance. The findings revealed no statistically significant difference in pretest scores between the experimental and control groups, indicating comparable prior knowledge before the intervention. However, the posttest results showed a statistically significant difference in favour of the experimental group, with students taught using the Reciprocal Teaching Strategy achieving higher academic performance than those taught using the Conventional Teaching Method. The paired-samples t-test further demonstrated a significant improvement in the experimental group's posttest performance, with a large effect size, indicating that RTS had a substantial positive impact on students' achievement in genetics. The study concludes that the Reciprocal Teaching Strategy is an effective instructional approach for improving students' understanding of genetics and recommends that the Ghana Education Service and biology teachers integrate RTS into classroom instruction and teacher professional development programmes to enhance learning outcomes in genetics and other conceptually challenging science topics.

Keywords: *Academic performance, Biology Education, Genetics education, Reciprocal teaching strategy, Senior high school biology, Science Education Student-centered learning.*

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Highlights of this paper

- Reciprocal Teaching Strategy significantly improved Senior High School students' academic performance in genetics compared with the Conventional Teaching Method.
- Students taught using the Reciprocal Teaching Strategy demonstrated substantial learning gains, indicating a strong positive effect of the intervention on genetics achievement.
- The findings support the integration of Reciprocal Teaching Strategy into biology instruction to enhance conceptual understanding and learning outcomes in conceptually challenging science topics.

1. INTRODUCTION

The nature and physiological processes of how teachers and students teach and learn nowadays are evolving (Vygotsky, 1978). As teaching and learning progress, its incorporation to accelerate deep learning and critical thinking becomes a top priority. When a teacher tries to teach anything to the entire class at once, chances are that one-third of the students already know it, one-third will understand it, and the remaining one-third will not. Thus, two-thirds of children are wasting their time (Pollock & Tolone, 2020). This is especially true because students come to class with a wide range of skill sets, degrees of confidence, and interests. Any group of students is likely to exhibit significant variety in learning traits and behaviors. A science class is characterized by diversity skills, making it difficult to engage all of these pupils. Because of the different learning qualities demonstrated by today's learners, teachers must incorporate a wide range of activities into their classes. With the introduction of inclusive education, disabled children, as well as brilliant and talented students, are increasingly being taught in ordinary education settings (Sumardi, Rohman, & Wahyudiati, 2020). This results in a more diverse collection of students. Even the best-trained and most eager teachers struggle to fulfill the different demands of their diverse classrooms, l*et al*one a particular need of students with moderate to severe disabilities. To satisfy the requirements of all students in a mixed ability classroom, teachers must use a variety of instructional strategies or teaching methods, resources/materials, and suitable grouping tactics based on the students' levels and the content being taught. Educators can fulfill the needs of all children by using diversified teaching strategies to help them reach and surpass defined standards.

This goal can be achieved by selecting appropriate teaching strategyes that are tailored to each student's specific learning demands. Teaching and learning often require teaching, which can be teacher-centered or student-centered.

The authors, drawing on Sengupta-Irving and Enyedy (2015) defined the distinction between student- and teacher-centered strategyes via the perspective of student agency in ways that accord with Aliyu, Osman, Kumar, and Jamil (2023) review of observational learning (guided) and inquiry learning (open). At the heart of a teacher-centered method, the teacher guides students "to and through the science concepts" required to address a problem selected by the instructor. While students have some autonomy in defining the problem and its solution in their own terms or justifying the use of a solution strategy in new difficulties, the teacher nevertheless assigns a solution strategy and wants them to duplicate it in new situations (Lamon, 2020). A student-centered strategy, on the other hand, help students design a unique solution path, discuss and refine it with other students, and then justify both their solutions and their process for arriving at an answer. Importantly, as Ali (2019) and Arman (2018) point out, student-centered teaching does not imply that students receive no supervision at all. Instead, teacher interventions are less frequent, and the focus of these scaffolding moments moves to targeted problem solving and questioning tactics rather than correcting student errors and One of the student-centered strategyes is reciprocal teaching.

Reciprocal teaching is a constructivist educational strategy that aims to improve students' text understanding (Islam, 2020). According to Mafarja (2023) collaborative comprehension training that emphasizes on the methods of predicting, questioning, clarifying, and summarizing. A teacher who uses this method of instruction must be willing to delegate responsibility to students, emphasize process over output, and encourage students to be strategic readers and critical thinkers (Dew, Swain, & Paniagua, 2021). Reciprocal teaching helps students to improve their understanding of text by teaching them how to predict, question, clarify, and summarize information.

This strategy helps students to engage with the text and develop a deeper understanding of the material. Reciprocal teaching helps students to develop critical thinking skills by teaching them how to analyse and evaluate information. By predicting, questioning, clarifying, and summarising information, students learn how to think critically about the text and develop their own perspectives and opinions. Reciprocal teaching promotes active learning by encouraging students to participate in the learning process. By engaging in the four key strategies of reciprocal teaching, students become active learners, rather than passive recipients of information (Oczkus, 2018). Reciprocal teaching supports different instruction by allowing teachers to tailor the instruction to the needs of individual students. By providing students with different reading materials and allowing them to work in small groups, teachers are able to differentiate instruction to meet the needs of all learners. Reciprocal teaching increases student motivation by providing students with a sense of ownership over their learning (Oczkus, 2018). By engaging in the four key strategies of reciprocal teaching, students feel more invested in the learning process and are more motivated to continue learning. Reciprocal teaching encourages collaboration by requiring students to work in small groups and share their ideas and perspectives with each other. This strategy helps students to develop their social and emotional skills, such as communication, collaboration, and empathy. Overall, reciprocal teaching is a structured strategy to teaching that has many benefits for both students and teachers. By improving understanding, developing critical thinking skills, promoting active learning, supporting different instruction, increasing student motivation, and encouraging collaboration, reciprocal teaching helps to create a more engaging and effective learning environment (Mafarja, 2023).

Genetics encompasses not only facts, concepts, and principles but also the methodology of their discovery and application in daily life (Schmid-Hempel, 2021). It examines heredity broadly and genes specifically. Genetics constitutes a fundamental pillar of biology and intersects with numerous other disciplines. Genetics originated from the discovery of genes; the essential components responsible for inheritance (Templeton, 2021). Panchal and Desai (2021) defines genetics as the comprehensive study of genes, encompassing their cellular functions and their transmission from progenitors to descendants. The scientific discipline of genetics originated with Gregor Mendel's research in the mid-19th century (Sandler & Sandler, 1986). Mendel hypothesized that qualities were inherited as distinct units, and despite his ignorance of the physical or chemical structure of genes, his units laid the foundation for contemporary understanding of heredity. In the twenty-first century, students must possess advanced cognitive skills that will enable them to not only assimilate knowledge from educators but also articulate their pre-existing understanding or transform supplied material into novel insights. Thus, through scientific discovery, students can apply their knowledge rather than merely envision it. It is posited that scientific discoveries would enable learners to comprehend genetic concepts and subsequently evolve those ideas into novel ones. However, student have been demonstrating poor performance in genetics which is a great concern according to WAEC chief examiners report for Biology (2018, 2019, 2020 & 2021).

Exploring science education through the perspective of reciprocal teaching (RT), current research has demonstrated that when students engage in well-designed (and efficiently implemented) open pedagogical tasks, they learn a diverse variety of scientific skills and knowledge. Student-centered pedagogical strategies provide the context for students to develop rich conceptual understandings of genetics beyond procedural knowledge by asking them to develop their own solution process rather than showing them how to solve a given problem (Mafarja, 2023; Wood & Copur-Gencturk, 2024). Hence, the need for this study.

1.1. Purpose of the Study

The purpose of the study was to assess the effectiveness of the reciprocal teaching strategy on students' academic performance in genetics in senior high schools in Sekyere South District.

1.2. Research Question

1. What is the difference in performance when students are taught genetics using the reciprocal teaching strategy as compared to the conventional method?
2. What is the effect of the reciprocal teaching strategy on students' performance in genetics?

2. LITERATURE REVIEW

2.1. Conceptual Framework of the Study

The conceptual framework of this study is based on the premise that instructional strategies significantly influence students' academic outcomes in science education, particularly in conceptually demanding topics such as genetics. Genetics is widely regarded as one of the most difficult areas of biology because it involves abstract processes that cannot be directly observed, including DNA replication, gene expression, and inheritance mechanisms. These complexities often result in misconceptions and poor academic performance when instruction is dominated by teacher-centered strategeyes (Duncan & Tseng, 2011; Kampourakis, 2017). Consequently, recent science education research advocates learner-centered pedagogies that actively engage students in constructing their understanding of scientific concepts (Gericke, Hagberg, & Jorde, 2023).

In this study, instructional strategy serves as the independent variable, while students' academic performance in genetics is the dependent variable. Two instructional strategeyes are examined: Reciprocal Teaching Strategy (RTS) and the Conventional Teaching Method (CTM). Reciprocal Teaching Strategy is a collaborative instructional strategy that engages students in structured dialogue through four key processes: predicting, questioning, clarifying, and summarizing. These processes encourage active participation, critical thinking, and reflection, enabling students to construct meaning from instructional content (Oczkus, 2018). In contrast, the Conventional Teaching Method mainly relies on lectures and teacher explanations with limited opportunities for student interaction.

The theoretical foundation of reciprocal teaching is rooted in social constructivism, particularly Vygotsky's concept of the Zone of Proximal Development, which emphasizes learning through social interaction and guided collaboration (Vygotsky, 1978). Through structured dialogue and peer discussion, students develop deeper conceptual understanding and enhanced cognitive skills. Studies have shown that collaborative instructional strategyes grounded in constructivist theory improve students' academic achievement and critical thinking (Mafarja, 2023; Wood & Copur-Gencturk, 2024).

The framework further suggests that the effect of instructional strategy on academic performance is mediated by classroom learning processes such as peer collaboration, activation of prior knowledge, metacognitive monitoring, and conceptual clarification. These processes enhance students' cognitive engagement and understanding of genetics concepts (Khalil & Elkhider, 2016; Walck-Shannon, 2025). Consequently, the framework assumes that implementing Reciprocal Teaching Strategy will promote deeper learning and lead to improved students' academic performance in genetics compared to conventional teaching method.

Figure 1 illustrates the Conceptual framework diagram of the study.

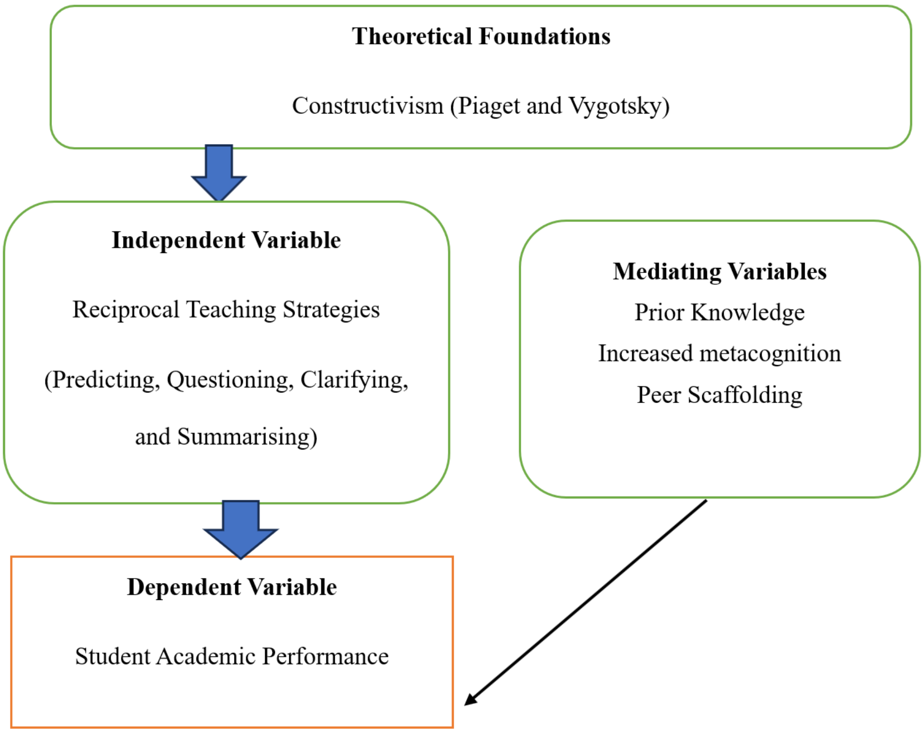

Figure 1: Conceptual framework of the study.

2.2. The Concept of Reciprocal Teaching

The teaching style of each science instructor is unique. A teacher may select a specific teaching technique and method based on the benefits they hope to achieve, as per Ruiz-Rojas (2023). In reading classes, English instructors implement reciprocal instructional strategies.

Reciprocal teaching is an instructional method that is intended to improve students' comprehension of text (Ayun & Yunus, 2017; Nurdianti, 2019). Reciprocal teaching is a method that is employed to enhance students' comprehension of text. Here, the teacher and students alternate in conducting a dialogue about specific sections of the text. The technique includes four activities: prediction, quesioning, summarizing, and clarifying misleading or complex sections of the text (Rodli, 2017). The objective of this strategy is to enhance reading comprehension by fostering collaboration between students and teachers. It is conducted in the form of a dialogue between the teacher and a group of students (Howe, Hennessy, Mercer, Vrikki, & Wheatley, 2019). In this dialogue, the teacher and students alternate in the role of the instructor, leading the discussion about a passage of text.

Mafarja (2023) define reciprocal teaching as a collaborative comprehension instruction that emphasizes the strategies of predicting, interrogating, clarifying, and summarizing. Three critical components of reciprocal teaching in the Primary Grades are the teacher's modeling of reciprocal teaching, student discussions, and correlations with texts. A teacher who employs this instructional strategy must be prepared to delegate responsibility to students, emphasize the process over the product, and instruct students in the development of strategic reading skills (McGuire & McGuire, 2015). The four primary strategies that instructors and students employ in tandem to comprehend text in reciprocal teaching are: predicting, questioning, clarifying, and summarizing. He indicates that he prefers to refer to the strategies as the "Fabulous Four" or "Be the Teacher."
Nurdianti (2019) defined reciprocal teaching as a dialogue between the teacher and students (or student leader and group members) that enables students to construct meaning in situations that require them to read (such as a test or assignment). The writer's conclusion is that Reciprocal Teaching comprises four comprehension strategies: summarizing, querying, clarifying, and predicting, as per the aforementioned theories. Initially, the strategies are modeled and explained by the teacher; however, students progressively begin to implement them on their own.

2.3. The Three Features of Reciprocal Teaching

The theory of reciprocal teaching presents three key features: scaffolding and explicit instruction, four main strategies, and social interaction.

2.3.1. Scaffolding and Explicit Instruction

Vygotsky (1978) social constructivist learning is the foundation of the scaffolding concept. Vygotsky (1978) posits that each mental function in a child's development is initially manifested in collaboration with an adult or expert. This collaboration takes place in the zone of proximal development, a region that lies between the tasks that infants can independently perform and the tasks that require assistance. Children can work independently in new contexts once they have internalized this collaborative form in their mental process through sufficient practice. Reiser (2023); Taber (2018) and Kim (2019) have identified scaffolding as a viable strategy to help students achieve their superior capabilities by assisting in completing a task that they were unable to complete independently. The teacher's responsibility diminishes as the students assume greater responsibility for their reading assignments until they achieve full independence (Boushey & Moser, 2023). The teachers should offer sufficient support to prevent the learners from abandoning the task, but they should not excessively scaffold in a manner that deprives the learners of sufficient opportunities to work independently. Three aspects of scaffolding and its efficacy are examined by Suwastini, Puspawati, Adnyani, Dantes, and Rusnalasari (2021): Scaffolding is adaptable and assists students in the development of fundamental skills and advanced reasoning. It permits explicit instruction and enables educators to instruct students with a variety of requirements. Reciprocal teaching offers scaffolding through explicit instruction that includes the modeling and explication of the four primary strategies, guided practice, independent practice, and the application of the strategies by the students themselves. According to Hsu, Wenting, and Hughes (2018), it is effortless to memorize strategies; however, it is challenging to implement or transfer independent strategic thinking. Teachers must provide explicit instruction to their students, which includes limiting tasks to make them manageable, motivating the learners, highlighting critical features, and demonstrating solutions to problems.

2.4. The Strategies of Reciprocal Teaching

Reciprocal teaching necessitates students to collaborate in groups, engaging in a discussion of the material (reading passage) through a series of strategies (Lundberg & Reichenberg, 2013). In essence, reciprocal teaching consists of four strategies: predicting, clarifying, interrogating, and summarizing, as previously mentioned. Reciprocal instruction encompasses four comprehension strategies: summarizing, questioning, clarifying, and predicting. Initially, the strategies are modeled and explained by the teacher; however, students progressively begin to implement them on their own.

2.4.1. Predicting

Predicting is the initial strategy of reciprocal instruction. This strategy motivates students to anticipate future events. The learner is predicting the subsequent events in the text by utilizing relevant prior knowledge and the text's structure and content. This was done to stimulate students' pertinent prior knowledge (Kramarski, 2017). This facilitates the identification of new information and existing knowledge as we read the passage. We can guarantee that students are not overwhelmed with an excessive amount of new information as they read by assisting them in the transfer of this skill to a foreign language, if necessary. According to Perfetti and Roth (2017), prediction is not a technique, but rather a skill that is a component of all reading techniques and the reading process in general. It is the ability to anticipate or conjecture the next step by utilizing grammatical, logical, and cultural cues. It appears that this strategy step in actual practice promotes increased engagement in the reading of a variety of texts by encouraging students to invest something in the reading experience personally. Students have been required to read the preceding paragraph in order to make a prediction about the subsequent paragraph of a text, with the intention of identifying any indications of the passage's overall structure. They are also instructed to anticipate the text's probable content immediately upon reading its title. Consequently, their most recent hypothesis regarding the author's intention in composing the text is reflected in their prediction. Additionally, this strategy encourages them to continue reading and ascertain the precision of their prediction.

2.4.2. Clarifying

Clarification is the subsequent strategy that students should implement. Learners are confronted with textual challenges by recognizing unfamiliar vocabulary, text that is structured or organized in an unfamiliar manner, new or challenging concepts, and the loss of meaning during the clarification process (Gilakjani & Sabouri, 2016; Vaughn, 2024). It is evident that this strategy enables students to identify alternative methods of resolving their textual issues. As a result, they will engage in active thinking and communicate with one another. The students' attention is drawn to the fact that there may be numerous reasons why text is difficult to understand when they are asked to clarify, according to Collins, Brown, and Newman (2017). These reasons include unfamiliar and potentially difficult concepts, ambiguous reference words, and new vocabulary. Clarification is a term that refers to the strategies that learners employ to verify their comprehension of a rule or language item, as summarized by Williams and Burden (1997). The following strategies can be employed by learners to restore meaning after recognizing the issue: re-reading, utilizing the context of the passage, utilizing their knowledge of written language (vocabulary, structure, or grammar), and utilizing a dictionary or thesaurus to verify meaning. Additionally, they may consult additional reference materials, including a road map or atlas. Additionally, it may be necessary for them to reread the entire passage in order to comprehend its significance. The teacher and students have the opportunity to share "fix-up" strategies to construct meaning during this stage of reciprocal teaching, as per (Oczkus, 2018).

2.4.3. Questioning

Questioning is the third strategy. The learner is conducting a thorough examination of the text's meaning during this phase of the strategy (Irawati, 2019). This strategy enables the learner to identify the information that serves as the foundation for an appropriate question and to formulate queries prior to, during, and following the reading process (Tofade, Elsner, & Haines, 2013). Questioning is a critical strategy for excellent readers, according to Oczkus (2018). In reciprocal teaching lessons, students acquire the ability to ask inquiries regarding the primary idea, significant details, and textual inferences of a text, thereby enhancing their reading comprehension abilities. Furthermore, a significant number of students frequently adopt the strategy of inquiring.

2.4.4. Summarizing

Summarizing is the final strategy that must be implemented. In this phase of the strategy, the learner is recognizing and incorporating critical information that is presented in the text. Oczkus (2018) elucidates that summarizing is a multifaceted endeavor that necessitates the coordination of a variety of strategies and abilities. In order to effectively summarize a text, students must recall and organize in order only the most significant events. The learner must initially identify the most critical content of the reading section in order to implement this strategy. Integration and ownership of the information that suggests comprehension are also essential. It is evident that this strategy phase serves as a clear indicator of whether the material has been comprehended. According to List and Alexander (2020) research studies indicate that the capacity to summarize is a valid indicator of comprehension and implementation. Consequently, the teacher is strongly encouraged to reevaluate the process of text comprehension when students are unable to summarize (Hwang, Sung, Hung, & Huang, 2019).

2.5. The Concept of Academic Performance

Kumar, Agarwal, and Agarwal (2021) define academic performance as the knowledge that a student has acquired and is assessed by a teacher using marks or educational objectives that the student and instructor have established to be achieved within a specific time frame. According to Lamas (2015) the academic performance of a student is evaluated by the extent to which they achieve the objectives and objectives outlined in the course in which they are enrolled. Grades are a representation of these and are the outcome of an assessment that entails the passing or failing of specific tests, subjects, or courses. Paudel (2021) posits that academic performance is employed to improve the capabilities of individuals. In other words, students who require additional support from the teacher can be identified and provided with the necessary support to unlock their potential through their performances. The concept of academic performance, as defined by Suvarna and Ganesha Bhata (2016), encompasses the multifaceted abilities of the learners. Consequently, it should be regarded as a multidimensional construct that encompasses various learning domains. Paudel (2021) identifies cognitive, affective, and psychomotor domains as learning domains.

The cognitive aspect is concerned with the development of mental abilities and comprehension. This includes the capacity to recall or recognize specific information, procedural sequences, and concepts that are essential for the development of intellectual capabilities. Conversely, the psychomotor aspect pertains to the utilization of motor skills, coordination, and bodily actions. The acquisition of these skills requires consistent practice and is evaluated by factors such as distance, accuracy, swiftness, processes, or methods during performance. The affective domain also incorporates the emotional engagement with matters, such as feelings, perceptions, values, motivations, and attitudes (Sonmez, 2017). Consequently, all three domains must be taken into account when instructors evaluate students' academic performance in order to obtain a comprehensive understanding of the instructional process, specifically whether the students have achieved the objectives. In Ghana, students' academic performance is evaluated through class exercises, classes assessments, homework, project work, and end-of-term/semester examinations.

2.6. The Concept of Genetics

Genetics is a fundamental branch of biology that focuses on the study of heredity and variation in living organisms. It examines how biological information is stored, transmitted, and expressed across generations through genes and chromosomes. Genetics plays a crucial role in understanding how traits are inherited, how organisms develop, and how genetic variation contributes to diversity within populations. Modern genetics integrates molecular biology, biotechnology, and genomics to explain the mechanisms that regulate inheritance and gene expression. Because genetics involves microscopic processes such as DNA replication, gene expression, and chromosomal behavior, students often find the subject abstract and conceptually demanding (Gericke et al., 2023; Kampourakis, 2017). Understanding the fundamental components of genetics therefore requires knowledge of genes, DNA, and chromosomes and how these elements interact to control biological functions.

The concept of the gene has evolved significantly over time as scientific discoveries have expanded understanding of molecular biology. Traditionally, the Mendelian concept defined a gene as a discrete unit of inheritance responsible for determining specific phenotypic characteristics (Germain, 2018). Early genetic theories described genes as fundamental hereditary units that control traits and are passed from parents to offspring. With the advancement of molecular genetics, the gene came to be understood as a DNA segment capable of directing the synthesis of RNA and proteins, which are essential for the functioning of living organisms (Cairns-Smith, 1982).

Historically, geneticists adopted the "one gene–one polypeptide" model, which proposed that each gene encodes a single protein product. However, contemporary research has shown that gene structure and function are more complex than previously assumed. Mechanisms such as alternative splicing and trans-splicing allow a single gene to produce multiple protein products, thereby increasing the diversity of proteins generated within cells (Ponzoni, 2018). Furthermore, genes consist of coding regions and regulatory elements that control when and how gene expression occurs. These regulatory regions, including promoters and enhancers, may be located within or far from the coding sequences, sometimes even on different regions of the genome.

Modern genetics therefore defines a gene as a region of DNA that contains information required to produce a functional product, either a protein or a functional RNA molecule. This updated understanding highlights the dynamic and complex nature of genes in regulating biological processes and contributing to genetic variation. In educational contexts, the gene is commonly described as a unit of heredity located on chromosomes that influences the transmission of traits from one generation to another (Duker, Bonney, Gbormittah, & Dzidzinyo, 2020).

Chromosomes are organized structures that package DNA within the nucleus of eukaryotic cells. Each chromosome consists of a single long DNA molecule associated with proteins known as histones, which help condense and stabilize the DNA structure. This packaging allows the extremely long DNA molecules to fit within the limited space of the cell nucleus while maintaining accessibility for gene expression and replication (Potapova & Gerton, 2019).

2.7. Comparative Effectiveness of Reciprocal Teaching Strategy

Reciprocal Teaching Strategy (RTS) has gained sustained empirical support in recent years as an effective instructional strategy for improving students' academic performance, metacognitive awareness, engagement, and higher-order thinking skills. Contemporary studies between 2020 and 2025 consistently affirm that RTS produces significant gains in learners' achievement compared to conventionalteacher-centered methods. For instance, Mafarja (2023) reported that reciprocal teaching significantly enhanced students' comprehension, cooperative learning outcomes, and problem-solving skills across multiple subject areas. Similarly, Alsalhi et al. (2024) found statistically significant differences in post-test scores between students taught using RTS and those taught using conventional instruction, indicating that the strategy positively influences academic achievement. Arisandi (2025) also demonstrated notable improvements in students' post-instruction performance following the implementation of reciprocal teaching, further confirming its instructional effectiveness.

A central reason for the effectiveness of Reciprocal Teaching lies in its structured emphasis on metacognition. By engaging learners in predicting, questioning, clarifying, and summarizing, the strategy encourages students to actively monitor and regulate their understanding. Abdelmoati Mohamed (2023) found that reciprocal teaching significantly strengthened students' metacognitive skills, particularly in planning, monitoring, and evaluating their learning processes. These findings are supported by recent meta-analytical evidence showing moderate to high effect sizes of RTS on learning outcomes, indicating meaningful academic gains across disciplines (Rosenshine & Meister, 1994). Such improvements are particularly relevant in conceptually demanding subjects where deep cognitive processing is required.

Beyond cognitive outcomes, reciprocal teaching has been shown to promote higher-order thinking and analytical reasoning. Khalil and Elkhider (2016) emphasize that structured academic dialogue enhances critical thinking by requiring students to generate questions, interpret information, and synthesize ideas collaboratively. Likewise, Li and Zhang (2023) observed that students engaged in reciprocal teaching activities demonstrated improved reasoning and analytical skills compared to peers in lecture-based classrooms. The dialogic nature of the strategy compels students to articulate explanations and justify responses, thereby deepening conceptual understanding.

Recent research also highlights the strategy's effectiveness in fostering active engagement and collaborative learning environments. Vuong (2025) in a systematic review of reciprocal teaching research trends, concluded that RTS consistently increases classroom participation and learner interaction across diverse educational contexts. Utama and Hidayatullah (2025) further reported that reciprocal teaching improved student engagement and learning outcomes among both high- and low-achieving learners, suggesting its inclusive potential. By distributing responsibility among learners and promoting peer scaffolding, RTS supports meaningful participation and shared cognitive responsibility.

eta-analytic evidence further supports these findings. A 2023 meta-analysis on reciprocal teaching reported moderate to high effect sizes in favor of the strategy when compared with traditional instruction, indicating substantial academic gains across disciplines, including science and mathematics (Rosenshine & Meister, 1994). These performance differences are largely attributed to the cognitive and metacognitive scaffolding inherent in reciprocal teaching, which enhances students' ability to analyze, interpret, and synthesize information. Vuong (2025) in a systematic review of recent reciprocal teaching studies, concluded that the strategy consistently produces higher academic achievement than lecture-based strategies, particularly in contexts requiring higher-order thinking skills.

The difference in academic performance is especially pronounced in conceptually demanding subjects where students must interpret symbolic representations and solve complex problems. Reciprocal teaching promotes dialogue and peer explanation, enabling learners to clarify misconceptions and refine understanding through collaborative reasoning. Utama and Hidayatullah (2025) observed that students in reciprocal teaching groups demonstrated significantly improved comprehension and application skills compared to those taught conventionally. These findings suggest that reciprocal teaching enhances not only recall but also conceptual mastery.

Furthermore, the performance gap between RTA and CTM can be explained through the lens of cognitive engagement theory. Students in reciprocal teaching classrooms are cognitively active participants, engaging in questioning, reflection, and summarization, which are linked to deeper learning outcomes (Mafarja, 2023). Conversely, conventional classrooms often limit student agency, reducing opportunities for metacognitive reflection and collaborative problem-solving. As a result, students taught through CTM may rely more on memorization, leading to comparatively lower performance on higher-order assessment tasks (Alsalhi et al., 2024).

In summary, contemporary research from demonstrates clear and statistically significant differences in academic performance between students taught using the Reciprocal Teaching Strategy and those taught through Conventional Teaching Methods. The evidence consistently favors reciprocal teaching due to its emphasis on structured dialogue, metacognitive engagement, collaborative learning, and higher-order thinking development (Abdelmoati Mohamed, 2023; Arisandi, 2025; Vuong, 2025). These findings suggest that reciprocal teaching is a more effective instructional strategy for improving students' academic achievement, particularly in subjects that require deep conceptual understanding and analytical reasoning.

3. METHODOLOGY

The study employed a quasi-experimental research design, specifically the non-equivalent control group pretest–posttest design, to examine the effect of Reciprocal Teaching Strategy on students' performance in genetics. This design was appropriate because intact classes were used, making random assignment of individual students impractical within the natural school environment. Two groups participated in the study: an experimental group that received instruction using the Reciprocal Teaching Strategy (RTS) and a control group that was taught using the Conventional Teaching Method (CTM). Both groups were given a pretest before the intervention to determine their initial equivalence and a posttest after the instructional treatment to measure changes in performance. Guided by the positivist research paradigm, the study adopted a quantitative strategy, emphasizing objective measurement, empirical observation, and statistical analysis to examine the relationship between instructional strategy and students' academic outcomes.

The population consisted of General Science students in Senior High Schools in the Sekyere South District, with an overall population of 485 students from three schools. Two schools were purposively selected for the main study based on criteria such as offering elective Biology, comparable class sizes, and availability of instructional resources, while one school was used for the pilot study. Within the participating schools, intact SHS 3 Biology classes were randomly assigned to experimental and control groups to reduce selection bias. In total, 121 students participated, including 70 students in the experimental group and 51 students in the control group. Data were collected using Students' Performance in Genetics (SPG) test. SPG assessed students' academic performance, the same test items were administered as both pretest and posttest to allow accurate comparison of students' learning gains after the intervention.

3.1. Reliability and Validity of the Instrument

The Cronbach's alpha was employed to evaluate the questionnaire's reliability levels, and the inter-rater reliability (Kappa value) was assessed to evaluate the achievement test.

The SPG scores were evaluated using inter-rater reliability, as the items were scored polytomously. Consequently, two raters who had been instructed in the scoring key were provided with the answered scripts from the pilot test to evaluate the students' responses. Cohen's kappa measure of agreement was employed to ascertain the inter-rater reliability by comparing the scores of both raters. The results are presented in Table 1.

Lecturers in the department of science education were given the instrument to go through whether there are any factual errors, grammatical errors and whether or not it is in line with the syllabus.

The inter-rater reliability of the SPG was assessed using Cohen's kappa, and the results are presented in Table 1.

Table 1. Inter-rater reliability results for SPG.

		Value
Measure of Agreement	Kappa	0.812
N of Valid Cases		62

As observed from Table 2 the value of Kappa's measure of agreement was 0.812. According to McHugh (2012) values ≤ 0 indicate no agreement and 0.01-0.20 indicate none to slight agreement, 0.21–0.40 indicate fair agreement, 0.41-0.60 indicate moderate agreement, 0.61–0.80 as substantial agreement, and 0.81-1.00 as almost perfect agreement. Therefore, per the scale given by McHugh (2012) the Kappa's measure of agreement as presented in Table 3.2 indicated a perfect agreement. Therefore, the results from the pilot test of the SPG were deemed reliable for the instrument to be used in the main study.

3.2. Data Collection Procedure

3.2.1. Intervention

The pretest was effectively concluded, and the second phase of data collection commenced. The subject matter was taught in two (2) groups by the researcher at this juncture to account for teacher differences. The intervention stage, which lasted for a period of four (4) weeks, involved teaching the same material to both experimental and control groups, but different treatments, where the experimental group was exposed to RTS, while the control group was taught without the RTS.

A standardized observation checklist was developed and used during classroom visits. The checklist included the following indicators:

Teacher introduces the lesson using prediction.

Students generate questions from the content.

Students clarify difficult concepts collaboratively.

Students summarize the lesson in their own words.

Teacher facilitates rather than dominates discussion.

Students rotate roles during group discussion.

The checklist served as a monitoring tool to determine whether teachers were implementing the RTS model as intended.

After each observation session, constructive feedback was provided to the researcher to address any deviations and to improve adherence to the RTS framework. This continuous monitoring and feedback mechanism ensured consistency, strengthened implementation fidelity, and enhanced the internal validity of the study.

The implementation of RTS followed the process summarized in Table 2.

Table 2. Implementation of the RTS.

Phase	Description	Activity
Phase 1	Predicting	Two activities occurred here. First: Students were allowed to predict what will happen throughout a text by using the title, images, or even a brief summary. Then use those clues to make predictions of what happens in the entire piece of text. Second: Students were made to skim the next bit of text assigned to them to read and pick certain words and sentences then use that to make prediction as to what is going to happen next.
Phase 2	Questioning	Students pause within the text they are reading and write down questions.
Phase 3	Clarifying	Explanations and resolving confusions among the students took place here. Words are explained and explanations are provided to resolve what students finds it difficult to understand.
Phase 4	Summarizing	Students pause often throughout the reading and make summative notes. Students verbalized their summaries to classmates.

3.2.2. Post-Intervention

Students were granted one week to review their notes following the intervention stage, following which the posttest was administered. The posttest items were administered to students from both groups (experimental and control) for a period of 1 hr. Subsequently, the questionnaires were administered to the students from both groups to quantitatively ascertain their attitudes toward Genetics following their exposure to Reciprocal Learning Pedagogy. By providing students with an explanation of the questionnaire's, the researcher facilitated their completion.

4. RESULTS AND DISCUSSIONS

1. What is the difference in performance when students are taught genetics using reciprocal teaching strategy as compared to the conventional method?
2. What is the effect of reciprocal teaching strategy on students' performance in genetics?

Table 3. Test for Normality table on the Study's Data.

Test	Group	Statistic	df	Sig. (Shapiro-wilk)
Pretest	Experimental	0.971	70	0.106
	Control	0.962	51	0.103
Posttest	Experimental	0.975	70	0.164
	Control	0.960	51	0.082

4.1. Data Suitability

From Table 3, it can be seen that the Shapiro-Wilk values for pretest and posttest scores of both experimental and control groups were significant. Notably, in the pretest scores, the experimental group obtained Shapiro-Wilk value of 0.971 ($p=0.106$), while the control group obtained a Shapiro-Wilk value of 0.962 ($p=0.103$). Also, in the posttest scores, the experimental group obtained a Shapiro-Wilk value of 0.975 ($p=0.164$) and that of the control group was 0.960 ($p=0.082$). Therefore, it can be concluded that experimental group under post-test was normally distributed. As a result, parametric tests were conducted on the data.

4.2. Results for Research Question 1

The difference in performance when students are taught genetics using reciprocal teaching strategy as compared to the conventional method.

To examine this, an independent sample t-test was utilized on the pretest and posttest scores of the experimental and control groups. The results of the independent sample t-test on the pre-test scores and posttest scores are shown in Table 4 and 5.

Table 4. An independent Sample t-test on Pretest scores of student's taught genetics using Reciprocal Teaching Strategy and those taught using Conventional method.

Groups	N	Mean	SD	t	df	*p*
Control Group	51	17.22	8.63	0.79	119	0.43
Experimental Group	70	17.56	6.15			

An independent-samples *t* test was conducted to compare the pretest scores of students taught genetics using the Reciprocal Teaching Strategy and those taught using the Conventional Method. The results indicated that there was no statistically significant difference between the control group (M = 17.22, SD = 8.63) and the experimental group (M = 17.56, SD = 6.15), $t(119) = 0.79$, $p = .43$. This suggests that both groups were statistically equivalent in their performance before the intervention. Therefore, any observed differences in posttest scores can reasonably be attributed to the instructional treatment rather than pre-existing differences between the groups.

Table 5. An independent Sample t-test on Posttest scores of student's taught genetics using Reciprocal Teaching Strategy and those taught using Conventional method.

Groups	N	Mean	SD	t	df	Cohen's d	*p*
Control Group	51	23.53	8.12	12.13	119	1.23	0.001*
Experimental Group	70	39.29	6.22				

Note: Significant since $p<0.05$.

An independent-samples *t* test was conducted to compare the posttest scores of students taught genetics using the Reciprocal Teaching Strategy and those taught using the Conventional Method. The results revealed a statistically significant difference between the control group (M = 23.53, SD = 8.12) and the experimental group (M = 39.29, SD = 6.22), $t(119) = 12.13$, $p < .001$. The magnitude of the difference was very large (Cohen's $d = 1.23$), indicating a substantial effect of the Reciprocal Teaching Strategy on students' performance in genetics. These findings suggest that students exposed to Reciprocal Teaching Strategy performed significantly better than those taught using the Conventional Method.

4.3. Results for Research Question 2

The effect of reciprocal teaching strategy on students' performance in genetics.

Table 6 presents the Paired Sample T-test results on the effect of Reciprocal Teaching Strategy on students' performance in genetics.

Table 6: Paired Sample T-test results on the effect of Reciprocal Teaching Strategy on students' performance in genetics.

Groups	N	Mean	SD	t	df	*Cohen's d*	*p*
Pretest	70	17.56	3.81	16.08	69	1.97	0.001
Posttest		38.32	5.01				

Note: Significant since $p<0.05$

A paired-samples *t* test was conducted to determine whether there was a significant difference in students' performance in genetics before and after being taught using the Reciprocal Teaching Strategy. The results revealed a statistically significant increase in scores from the pretest (M = 17.56, SD = 3.81) to the posttest (M = 38.32, SD = 5.01), $t(69) = 16.08$, $p < 0.001$. The large t-value indicates a substantial improvement in students' performance following the intervention. The effect size was large (Cohen's $d = 1.97$), suggesting that the Reciprocal Teaching Strategy had a strong positive effect on students' academic performance in genetics.

4.4. Discussion of Research Question 1

The difference in performance when students are taught genetics using reciprocal teaching strategy as compared to the conventionalmethod.

The findings of this study revealed no statistically significant difference between the control and experimental groups at the pretest stage, $t(119) = 0.79$, $p = .43$. This indicates that both groups were statistically equivalent in their prior knowledge of genetics before the intervention. The equivalence at baseline strengthens the internal validity of the study, as it suggests that subsequent differences observed at posttest can reasonably be attributed to the instructional treatment rather than pre-existing differences between the groups.

However, the posttest results showed a statistically significant difference in favour of the experimental group, $t(119) = 12.13$, $p < 0.001$. Students taught using the Reciprocal Teaching Strategy (M = 39.29, SD = 6.22) significantly outperformed those taught using the Conventional Strategy (M = 23.53, SD = 8.12). The effect size (Cohen's $d = 1.23$) indicates a very large practical effect, suggesting that the Reciprocal Teaching Strategy had a substantial impact on students' academic performance in genetics.

These findings are consistent with previous studies which consistently reported that reciprocal teaching leads to higher academic achievement compared to teacher-centered strategies (Abdelmoati Mohamed, 2023; Alsalhi et al., 2024; Mafarja, 2023). The superiority of reciprocal teaching is largely attributed to its emphasis on structured dialogue, metacognitive engagement, peer collaboration, and active knowledge construction. Unlike the conventional method, which often promotes passive reception of information, reciprocal teaching requires students to predict, question, clarify, and summarize content, thereby enhancing deeper cognitive processing.

The findings also align with meta-analytical evidence indicating moderate to large effect sizes in favour of reciprocal teaching over traditional lecture-based instruction (Rosenshine & Meister, 1994; Vuong, 2025). The large effect size observed in this study further confirms that reciprocal teaching is particularly effective in conceptually demanding subjects such as genetics, where students must analyze inheritance patterns, interpret abstract processes, and resolve misconceptions.

Furthermore, the performance gap between RTA and CTM can be explained through the lens of cognitive engagement theory. Students in reciprocal teaching classrooms are cognitively active participants, engaging in questioning, reflection, and summarization, which are linked to deeper learning outcomes (Mafarja, 2023). Conversely, conventional classrooms often limit student agency, reducing opportunities for metacognitive reflection and collaborative problem-solving. As a result, students taught through CTM may rely more on memorization, leading to comparatively lower performance on higher-order assessment tasks (Alsalhi et al., 2024).

4.5. Discussion of Research Question 2

Effect of the Reciprocal Teaching Strategy on students' performance in genetics.

The findings of this study revealed a statistically significant and substantial improvement in students' performance in genetics following the implementation of the Reciprocal Teaching Strategy (RTS). The paired-samples t test showed that students' mean scores increased markedly from the pretest (M = 17.56, SD = 3.81) to the posttest (M = 38.32, SD = 5.01), $t(69) = 16.08$, $p < 0.001$. This significant increase demonstrates that the intervention had a strong positive impact on students' academic achievement. Furthermore, the large effect size (Cohen's d = 1.97) indicates that the magnitude of the improvement was not only statistically significant but educationally meaningful. Such a large effect suggests that Reciprocal Teaching did not produce marginal gains but rather transformative improvement in students' mastery of genetics concepts.

The substantial improvement observed may be attributed to the core mechanisms of Reciprocal Teaching Strategy predicting, questioning, clarifying, and summarizing which promote active engagement and metacognitive regulation. These structured strategies require students to monitor their understanding, identify misconceptions, and construct meaning collaboratively. Previous empirical studies support this finding. For example, Mafarja (2023) reported significant improvements in students' comprehension and academic performance when reciprocal teaching was implemented. Similarly, Abdelmoati Mohamed (2023) found that students exposed to reciprocal teaching demonstrated enhanced metacognitive skills, which mediated improved achievement outcomes. Alsalhi et al. (2024) also documented statistically significant academic gains among students taught using reciprocal teaching compared to conventionalinstructional methods.

The present findings further align with meta-analytic research showing that Reciprocal Teaching produces moderate to large effect sizes across different educational contexts (Vuong, 2025). These studies collectively indicate that the effectiveness of RTS is not limited to reading comprehension but extends to science and other cognitively demanding subjects. Genetics, in particular, involves abstract processes such as gene expression, inheritance patterns, and molecular interactions. The dialogic and scaffolded nature of reciprocal teaching appears particularly suitable for addressing such conceptual complexity.

Additionally, the increase in standard deviation from pretest (SD = 3.81) to posttest (SD = 5.01) suggests that while overall performance improved significantly, individual differences in mastery levels may have widened. This may indicate that some students benefited exceptionally from the strategy, highlighting the need for differentiated scaffolding within the reciprocal teaching framework.

5. CONCLUSION

This study investigated the effect of the Reciprocal Teaching Strategy (RTS) on Senior High School students' academic performance in genetics in the Sekyere South District. The findings revealed that there was no statistically significant difference between the experimental and control groups at the pretest stage, indicating that both groups had comparable prior knowledge before the intervention. However, the posttest results demonstrated a statistically significant difference in favor of the experimental group. Students who were taught using the Reciprocal Teaching Strategy performed significantly better than those taught using the Conventional Teaching Method.

Furthermore, the results showed that the Reciprocal Teaching Strategy had a strong positive effect on students' academic performance in genetics. The paired-sample t-test analysis revealed a significant improvement in students' performance after the intervention, with a large effect size. These results suggest that the structured processes of predicting, questioning, clarifying, and summarizing promoted deeper conceptual understanding and active engagement among students. The strategy enabled learners to collaborate, reflect on their understanding, and address misconceptions in genetics concepts.

Overall, the findings of this study demonstrate that Reciprocal Teaching Strategy is a highly effective instructional strategy for improving students' academic performance in genetics. The strategy promotes active participation, metacognitive awareness, and collaborative learning, which are essential for mastering complex scientific concepts. Therefore, integrating Reciprocal Teaching Strategy into biology instruction could significantly enhance students' understanding and achievement in genetics and other conceptually demanding areas of science.

5.1. Practical Implications of the Study

The findings of this study have several implications for science education, particularly in the teaching and learning of genetics in senior high schools.

- Biology teachers should incorporate Reciprocal Teaching Strategy into their instructional practices to enhance students' understanding of complex genetics concepts.
- Teacher training institutions should include training on student-centered instructional strategies such as reciprocal teaching in their professional development programs.
- Schools should encourage teaching strategyes that promote dialogue, peer interaction, and metacognitive reflection among students.
- Educational policymakers should support continuous professional development programs that equip teachers with modern learner-centered pedagogical strategies.
- The use of structured dialogue strategies such as predicting, questioning, clarifying, and summarizing should be emphasized in science classrooms to improve conceptual understanding.

5.2. Future Directions

Although the findings of this study provide valuable insights into the effectiveness of Reciprocal Teaching Strategy, several directions for future research are recommended.

- Future studies should replicate this research using larger samples across multiple districts or regions to improve the generalizability of the findings.
- Researchers may investigate the long-term effects of Reciprocal Teaching Strategy on students' retention of genetics concepts.
- Further studies could examine the effectiveness of reciprocal teaching in other areas of biology such as ecology, evolution, and molecular biology.
- Future research may explore the impact of Reciprocal Teaching Strategy on other learning outcomes such as students' attitudes toward biology, motivation, and critical thinking skills.
- Comparative studies could be conducted to examine the effectiveness of Reciprocal Teaching Strategy alongside other student-centered instructional strategyes.

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