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Think-Pair-Share versus Group Investigation: A Comparative Analysis of Cooperative Learning Strategies on First-Year Biology Students' Academic Performance in Plant Systems

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Abstract. This study compared the effectiveness of the Think-Pair-Share (TPS) and Group Investigation (GI) cooperative learning techniques on the learning outcomes of first-year senior secondary school students in plant systems biology. The quasi-experimental pre test-post test control group design was used. A total of 100 first year students from a senior high school in the Greater Accra Region of Ghana were randomly assigned to three groups: TPS ($n = 34$), GI ($n = 33$) and a Conventional Instructional Strategy (CIS) ($n = 33$). The Biology Achievement Test (BAT) was used as the main instrument which was developed from plant systems biology curriculum, and validated by the subject experts. Analysis of Covariance (ANCOVA) with Scheffe post-hoc tests was employed to analyse differences in post-test scores. Results indicated statistically significant differences in achievement across the three groups ($F(2,96) = 9.412$, $p < 0.05$). The TPS group recorded the highest mean post-test score ($\overline{x} = 74.18$), followed by the GI group ($\overline{x} = 68.53$), while the CIS group recorded the lowest ($\overline{x} = 58.24$). Scheffe post-hoc analysis confirmed that both cooperative strategies significantly outperformed conventional instruction; however, no statistically significant difference was found between TPS and GI ($p = 0.087$). The findings suggest that while both strategies are superior to conventional teaching, TPS confers a modest but meaningful advantage in the context of plant systems biology due to its structured peer-discourse framework. Recommendations are made for integration of these strategies in Ghanaian senior secondary biology classrooms.

Keywords: Think-Pair-Share, Group Investigation, Cooperative Learning, Plant Systems Biology, Academic Performance, Senior Secondary School

1. Introduction and background

Biology has a special place in the science education policy of senior secondary schools in Ghana. It is one of the core subjects of the natural sciences and "teaches" students important knowledge and analysis skills that they will use in medicine, agriculture, environmental science, and biotechnology. Biology, as a strategic subject, has recorded poor performance of pupils in the West African Senior School Certificate Examination (WASSCE) over the years, with high proportion of pupils not obtaining credit passes

(WAEC Chief Examiner Reports 2019, 2022). This underperformance has occasioned a large amount of scholarly research into the pedagogical factors that maintain it.

There is considerable evidence that teacher centred pedagogies are a major factor in the poor learning outcomes in secondary science. The passive learning environment with lecture-based approach has been shown to bring students into a state of ‘passive learning' which fails to involve the learners in the cognitive processes required for the development of deep understanding of complex concepts in science (Agyeman & Ofori, 2023; Baidoo & Ansah, 2022; Mensah & Adjei, 2024). In particular, Owusu-Ansah et al. (2022) reported that 78% of biology teachers in the senior high schools (SHS) of Ghana mostly employed lecture approach in teaching students; and this approach was associated with lower performance in conceptual understanding questions. In the same vein, Tindan and Godfred (2024) found that students in the classrooms with low amount of interactive learning opportunities performed significantly lower on the applications level questions than the classrooms with a higher amount of interactive learning opportunities. The results are consistent with international research that indicates that teacher-centered learning hinders the development of critical thinking and problem-solving skills necessary for the learning process in biology (Johnson & Johnson, 2023; Slavin, 2022).

Plant systems biology, involving photosynthesis, transpiration, mineral nutrition and internal transport systems, is a good example of this challenge. Learners should not just recall structures and definitions, but comprehend dynamic physiological processes, analyse experimental data and draw valid conclusions about biological phenomena. These demands require pedagogical methods which emphasize student engagement, working in groups to solve problems, and student interaction.

In general, cooperative learning is an effective alternative to traditional teaching in science classrooms; it means a small group of students working together, interdependently, to achieve shared academic objectives. Cooperative learning has consistently been shown to be beneficial in different educational settings, as demonstrated by recent meta-analyses (Johnson, Johnson, & Smith, 2023; Nguyen et al., 2022; Slavin, 2022). Think-Pair-Share (TPS) and Group Investigation (GI) are among the many cooperative learning models developed and studied that are well documented and theoretically well-founded. The process of TPS (developed by Frank Lyman), is a three-part process where students individually reflect on a teacher-posed question, discuss their thinking with a partner, and then share their ideas with the class (Kaddoura, 2013; Parker & Asare, 2021). GI is an initiative of Sharan and Sharan which involves students in forming heterogeneous groups, selecting sub-topics, designing investigative procedures, research, and presenting their synthesized findings to the rest of their group (Slavin, 2011; Ogunleye et al., 2021).

Although many cooperative learning strategies in science education exist, there are some gaps in the literature. First, there have been only a few comparative studies that have looked into secondary school settings in Indonesia, Nigeria, or the Middle East, and none of the empirical studies that have investigated Ghanaians classrooms have focused on TPS and GI. (Fauzi, Erna, & Linda, 2021; Ogunleye, Onifade, Obadipe, & Hamidu, 2021). Third, previous studies have largely approached biology as a general subject and not as a specific set of concepts which might differentially interact with the structural characteristics of each cooperative strategy. Third, little research has looked at the effectiveness of these strategies in a learning context that is usually challenging in resource-poor Ghanaian public schools. Fourth, although a few studies have investigated cooperative learning in the science curriculum in Ghana (Parker & Asare, 2021; Tindan & Godfred, 2024), there is a lack of comparative studies between TPS and GI in the same study area; this is an important gap in the understanding of the effectiveness of the two approaches.

Given the nature of the specific learning difficulties that arise in studying plant systems biology, an area of study that demands students to combine conceptual knowledge, procedural knowledge and applied knowledge, it is an excellent choice for examining the difference between TPS and GI in promoting student achievement. This study was therefore designed to address these empirical gaps in the context of plant systems biology within the context of first year students at one high school in the Greater Accra region of Ghana in a controlled comparative study of TPS and GI.

1.1 Statement of the Problem

The poor performance of the Ghanaian Senior Secondary school students in Biology is a matter of concern and poses questions about the effectiveness of the current teaching methods. The WAEC Biology examination results of the last ten years (2017–2021) show that about 45-52% of all candidates who took the exam failed to attain credit pass (grade A1-C6) with very low performance in plant systems biology questions. These reports highlighted specifically that there was inadequate knowledge of physiological processes, lack of interpretation of experimental data and poor application of concepts to new situations as areas of weakness. As a teacher and examiner of biology for more than 10 years, I have witnessed a number of pedagogical problems which lead to this under-performance. On observations conducted in the schools where I intended to teach and supervised, it has been noted that about 80% of the biology lessons in the schools are teacher-centred which offers little opportunities for student participation (Ebo 2023). Secondly, in marking WASSCE scripts, I have noticed a consistent lack of the higher order thinking skills in the students' scripts, which indicates that the lecture method has not been effective in developing these higher order thinking skills. Third, in my teaching practice I have found that students can show more understanding when they give and receive ideas from one another than when they just listen. The conventional lecture model in most public and private secondary schools of Ghana has been the subject of numerous criticisms of its tendency to encourage superficial memorisation of facts and less in-depth conceptual understanding and analytical thinking (Baidoo and Ansah, 2022; Mensah and Adjei, 2024). Recent research by Agyeman and Ofori (2023) and Owusu-Ansah et al. (2022) has offered empirical results which suggest that conventional teaching approaches are less effective in enhancing students' achievement in biology in Ghana than active learning approaches. Many cooperative learning strategies have been found to be effective in enhancing science achievement in other settings, but there is a lack of compelling, school-based comparative evidence in the Ghanaian educational system. This study aimed to fill this gap by empirically testing the relative effectiveness of TPS and GI on academic performance of first year Biology students in plant systems in a senior high school of the Greater Accra region of Ghana.

1.2 Purpose of the Study

The main objective of this study was to find out whether the Think-Pair-Share (TPS) or Group Investigation (GI) strategy of cooperative learning is more effective on improving the academic performance of first year senior secondary school students in a plant systems biology topic at a senior high school in the Greater Accra Region, Ghana. In particular, the study aimed to:

- Determine whether there is a statistically significant difference in the academic performance of students taught plant systems biology using TPS, GI, and conventional instruction.
- Determine whether TPS or GI is the more effective cooperative learning strategy for improving student achievement in plant systems biology.

1.3 Research Questions

The following research questions guided the investigation:

- Is there a statistically significant difference in the academic performance of first-year students taught plant systems biology using Think-Pair-Share (TPS), Group Investigation (GI), and Conventional Instructional Strategy (CIS) at Wesley Grammar Senior High School, Dansoman?
- Between Think-Pair-Share (TPS) and Group Investigation (GI), which cooperative learning strategy is more effective in improving students' academic performance in plant systems biology?

1.4 Research Hypotheses

H_{01}:There is no statistically significant difference in the academic performance of first-year students taught plant systems biology through TPS, GI, and CIS.

H_{02}:There is no statistically significant difference in the academic performance of students taught plant systems biology using TPS compared to those taught using GI.

2. Literature

2.1 Theoretical Framework

This study was anchored on three complementary theoretical frameworks that provide a robust foundation for understanding how cooperative learning strategies influence academic achievement in biology.

According to Vygotsky (1978) the sociocultural theory of learning, humans' cognitive development is socially mediated, and they learn more when cooperating with more knowledgeable peers than when they work alone. Per this theory, learning takes place at a social level, when one interacts with others, and at the individual level when the person internalizes these interpersonal exchanges. TPS and GI are both based on this principle and operationalise it in different ways. In the TPS, the discussion in pairs becomes a social context in which learners can test and improve their knowledge by discussing with their peers in their ZDPs. In GI, this social learning is extended to larger group learning and there are continued opportunities for knowledge construction that relies on social learning. Another approach, complementary to Johnson and Johnson's (2023) theory, is the concept of positive interdependence, the key characteristic that sets cooperative learning apart from group work and contributes to its learning benefits, as stated by Johnson and Johnson. This theory suggests that students are driven to clarify concepts, encourage others, and minimize misunderstandings through their interactions with group members when they feel they can only win if the other person does as well. Positive interdependence is present in both TPS and GI; however, in slightly different ways. In TPS, there is a shared task of discussion about a problem and consensus building, before sharing with the class, which creates interdependence. In GI, there is greater explicitness of interdependence, in the sense that the members of the group play different roles in an on-going investigation. Bandura's (1997, 2022) social cognitive theory introduces a motivation component into this model. His definition of self-efficacy (your ability to carry out something successfully) relates directly to cooperative learning environments in which students watch their peers successfully struggling with content that is difficult. Bandura theorized that there are four main sources of self-efficacy: (1) mastery experiences, (2) vicarious experiences, (3) verbal persuasion, and (4) physiological states. All four sources are rich in cooperative learning structures such as TPS and GI. Students acquire mastery experiences when they are able to explain what they have learned in a way that is successful for their peers; they see peers being successful (vicarious experiences); they are encouraged by others in the group (verbal persuasion);

and group interactions can help lower anxiety in learning difficult content (physiological states). All three theories collectively predict that both TPS and GI should be associated with improvement in academic performance on plant systems biology over the traditional approach to teaching the subject. They do note, however, possible effectiveness based on the operationalization of social interaction, interdependence and development of self-efficacy. The theoretical basis informed the study design and the interpretation of its findings.

2.2 Think-Pair-Share (TPS): Nature, Structure, and Evidence

The cooperative discussion technique, Think-Pair-Share, was first developed in Maryland by Frank Lyman for use as a cooperative discussion activity, and as a collaborative activity by others such as McTighe and Lyman (1988). It is very simple in structure and yet very potent in cognition. The "Think" phase is a time for self-reflection that asks each student to personally interact with the material, actively making sense of it before the social influence can be applied. The individual accountability is an important protection from the social loafing that often plagues group work (Kaddoura, 2013). In the "Pair" phase, the students are paired up, and a low threshold is created by which students can test, develop and elaborate their thinking by communicating with one peer. The smaller group allows for a more participatory class discussion than would occur in a larger class. The "Share" phase connects the private dyadic exchange to a wider community of ideas, by introducing students to a greater variety of ideas and giving the teacher a chance to assess the class's conceptual understanding in real time. Empirical data supporting TPS continues to be quite substantial in recent years, extending across the domains of study and between cultures. In Chemistry Education, Oloyede et al (2021) showed that the use of TPS was found to be able to improve the achievement of senior secondary school chemistry students significantly better than the conventional method. The results obtained by Tindan and Godfred (2024) in Ghana were similar in that TPS was found to be the superior method of teaching chemistry education compared with the Jigsaw method used amongst the senior high school students. Falebita and Olofin (2020) noted that TPS improved academic performance and self-efficacy of secondary school students in Mathematics. With regards to biology specifically, Ogunleye et al. (2021) reported that the mean post-test score of the TPS students in Ekiti State, Nigeria was 12.30 while the conventionally taught students had a mean post test score of 9.00. Kombat et al. (2023) found that the ‘pair’ phase of TPS is most effective for achieving biology related learning outcomes for the Ghanaian students. A number of reasons have been suggested for the success of TPS. Under the recent studies, it is suggested that the strategy helps students' develop metacognition skills because students are required to be aware of their own thinking process in every step (Didimus & Duran, 2014; Nguyen et al., 2022). The dyadic reading is also based on dialogic reading and argumentation which are known to enhance comprehension. The pair-discussion stage allows students to identify and address conceptual misunderstandings that might arise if they are considering plant systems, where they need to combine their understanding of structure, function, and physiology, in a structured way through peer explanation.

2.3 Group Investigation (GI): Nature, Structure, and Evidence

Group Investigation was developed in the 1970s and 1980s by Shlomo and Yael Sharan and is more sophisticated and student-centered versions of cooperative learning. Gathered in a circle, the students are given the freedom to initiate learning, as opposed to teacher-driven learning, and the structure is loose. The strategy consists of six stages: Identification and Allocation of Sub-topics in a General Topic, Cooperative Planning of Investigative Approach in a Sub-topic Group, Active Investigation through Reading, Experimentation and Data Collection, Preparation of a Sub-topic Group Report or Presentation, Presentation of the Findings to the class, Evaluation of Individual and Group Contributions (Slavin, 2011; Ogunleye et al., 2021).

This scaffold places students in the role of active knowledge constructors, and mirrors the inquiry-based and problem-oriented character of biological science. GI's investigative step is especially useful when it comes to concepts that are abstract, such as plant systems; students can design their own simple experiments, such as measuring the phototropism of a plant, the rate of transpiration, or the effects of a mineral deficiency, and relate their findings to a biological phenomenon they can observe. This hands-on dimension is experiential and adds a depth to structured discussions like TPS that is not necessarily experienced.

Empirical studies of GI in biology education are generally positive, but more recent research is limited in scope. Budiastra and Arcana (2015) found that students who learned a biology using the approach of GI had an increase in students' critical thinking skills compared to the students who learned a biology using conventional method. Similarly, Asyari (2016) concluded that the use of problem-based learning and GI in learning science at secondary school increased critical thinking. Ogunleye et al (2021) reported that the mean score for biology obtained by students in the GI group was 12.00 and the mean score for students in the control group was 9.00, indicating that the GI is superior to the conventional instruction. Together, the results indicate that, while not always significant, the use of GI may be an effective means of enhancing the achievement of content and higher-order thinking skills in biology.

2.4 TPS compared to GI: Areas of convergence and divergence

In terms of philosophy, both TPS and GI emphasize active and social learning; and both have been shown in several studies to be statistically superior to traditional teaching. However, they have some differences with regards to some content areas that may affect their relative effectiveness in these areas. Structurally, the TPS is simpler, easier to implement and less time consuming, making it more feasible for the typical 35- to 40-minute biology lesson in the Ghanaian senior secondary school. It has a well-planned order of steps that include individual reflection, peer dialogue, which helps achieve consistent engagement from learners of all abilities.

GI, on the other hand, requires more student independence, maturity of an organization and resource access. It often takes a few lessons to complete, and students will have to look for and combine information. These features might enrich it as a learning experience, but also impose extra requirements on both the student and the teacher that could work against lower ability students and in lower-resource settings. A number of scholars have indicated that students' previous cooperative learning experience and the quality of the teacher facilitating the group are important factors that moderate the effectiveness of GI (Malmir, 2012; Ogunleye et al., 2021).

Comparative literature on the TPS and GI in biology education is still rather scanty. The results of the chemical equilibrium content in the critical thinking study conducted by Fauzi et al. (2021) showed a statistically significant difference between TPS and GI, with the advantage of TPS ($sig = 0.000 < 0.05$), and Tamara (2018) also reported that TPS was superior to GI in a critical thinking study. However, Ogunleye et al. (2021) have reported that, in practice, the difference between TPS and GI for biology is not that big, as both groups of learners perform significantly better than the conventional group. The mixed results indicate that the content domain, student characteristics, and contextual factors are important moderating factors and call for context-specific comparative research like the present study to examine the factors.

3. Research design and methods

3.1 Research Design

This study adopted a quasi-experimental pretest-posttest non-equivalent control group design. The quasi-experimental approach was chosen because it was neither ethically nor practically feasible to randomly assign individual students to treatment conditions, as such assignment would disrupt existing class configurations and school routines. Instead, intact first-year classes at a senior high school in the Greater Accra Region of Ghana were used as the units of assignment. Three intact classes were identified and randomly allocated to one of three conditions: the TPS group, the GI group, and the Conventional Instructional Strategy (CIS) control group. The pretest served as a covariate in subsequent ANCOVA analysis to statistically control for any pre-existing differences in biology achievement between the three groups, thereby strengthening causal inference under the constraints of the non-equivalent design.

3.2 Study Location

The study was carried out in a co-educational senior high school in the Greater Accra Region of Ghana. The school is run by the Ghana Education Service and it is based on the Ghana national curriculum prescribed by the Curriculum Research and Development Division (CRDD). The school was chosen because it has its own structured biology programme, experienced biology teachers who have been trained in cooperative teaching methods, and cooperative attitudes of school management and students to the research. As far as the training of the teachers is concerned, the biology teachers who took part in this study are graduates of University of Education, Winneba, where cooperative learning strategies like Think-Pair-Share and Group Investigation are intentionally part of the science pedagogy curriculum. These pre-service trainings provided them with the theoretical knowledge and skills needed to apply these strategies. In addition, teachers attended a two-day in-service training session conducted by the researchers before the intervention, to standardise and follow the methodology of this study. This workshop proved to be highly important to ensure the implementation of the cooperative strategies without mixing them with non-structured group work.

3.3 Population and Sampling

The target population comprised all first-year senior secondary biology students in the Greater Accra Region. The accessible population comprised all first-year students enrolled in the science stream at the selected senior high school during the 2024/2025 academic year. First-year students were specifically targeted because plant systems biology is a core component of the Year One biology curriculum, and because these students had not yet been exposed to systematic cooperative learning interventions, thereby reducing the risk of contamination effects from prior experimental treatments. While absolute avoidance of all peer interaction in primary school cannot be guaranteed, the distinction between informal group work and systematic cooperative learning is critical. In the Ghanaian primary school context, science instruction remains predominantly teacher-centered, relying heavily on direct instruction, rote memorization, and teacher-led demonstrations (Agyeman & Ofori, 2023). Any group activities students might have engaged in at the primary level typically lack the formalized protocols–such as the structured individual-think and pair-discourse phases of TPS, or the planned investigative cycles of GI–that define true cooperative learning. Because these students had not undergone formal, protocol-driven cooperative learning interventions during their basic education, the risk of prior exposure confounding the results of this study is minimal.

A total of 100 first-year science students drawn from three intact classes participated in the study. Random sampling was used to allocate classes to treatment conditions. The TPS group comprised 34 students, the GI group comprised 33 students, and the CIS control group comprised 33 students. This distribution reflected the natural size of the intact classes. All students present in each class at the time of the pretest were included in the study, and only students who completed both the pretest and the post-test were included in the final analysis, maintaining the sample size at n = 100 throughout.

3.4 Research Instrument

The main data collection tool was the Biology Achievement Test (BAT), a 30-item multiple-choice test developed by the researcher that measures students' achievement in plant systems biology. The five sub-topics chosen from the Year One biology curriculum for SHS and related to the content domain of the BAT were: (1) plant structure and organization, (2) photosynthesis and related processes, (3) mineral nutrition and absorption, (4) transpiration and water transport, and (5) translocation in phloem. The items were designed to measure three levels of thinking which are knowledge and recall (40%), comprehension and interpretation (35%) and application and analysis (25%) as recommended in the Revised Bloom's Taxonomy framework approved by the Ghana CRDD. This BAT is designed specifically for the current research but the format and approach follows the Ghanaian educational research tradition in using previous biology achievement tests. In Nigeria for instance, Ogunleye et al. (2021) employed the same 30 item multiple choice test in their comparative study of TPS and GI. In the research by Parker and Asare (2021), the researchers also used multiple-choice questions to gauge classification of living organisms in the context of TPS among the colleges of education in Ghana. The procedures of item development were based on the steps of building content-valid achievement tests in science education. The face and content validity of the BAT was tested by three subject experts namely a senior biology teacher in a public university in Ghana, a practising WASSCE biology examiner and an experienced SHS biology teacher. Each item was evaluated for clarity, relevance, and consistency by the reviewers with respect to the learning objectives and the curriculum content of plant systems. The instrument was finalised after revisions based on their feedback. The BAT was then pre-tested on 30 learners of Year One in another school in the Greater Accra Region which was not included in the main study. The Kuder-Richardson Formula 20 (KR-20) reliability coefficient based on the pilot data was 0.81, demonstrating high level of internal consistency and the suitability of the instrument for use in the main study.

3.5 Experimental Procedure

All three groups were given the BAT as a pretest prior to the beginning of treatment, to measure initial achievement in plant systems biology. The three week instructional intervention then began in the regular biology class. The TPS group was taught using the Think, Pair, Share technique. The teacher used a purposefully designed question or problem at the start of each lesson that was related to the plant systems content. Students were given 3-5 minutes to reflect individually on the question and write down what they think. They then worked with the person sitting next to them and discussed their answers for around 5 minutes, finding common ground, differences and synthesizing a common answer. Selected pairs then presented the class with their results and the teacher briefly discussed the whole class to reinforce the ideas and correct any misconceptions. This was repeated at major conceptual junctures in the lessons. The GI group was divided into five or six student groups, with a variety of investigative tasks. The teacher began the unit by explaining the general unit topic, plant systems, and then facilitated a discussion with the students to determine the sub-topics that they would investigate. Each group chose a sub-topic, developed a series of questions they wanted to investigate, determined their plan and divided up their tasks. Students compiled data from text books, references and Internet with some guidance. Each group developed its investigation, drew conclusions and created presentations over the three weeks. The presentation of each group's work was done in the last week, where other students were encouraged to ask questions and make critical remarks. The CIS control group was given instructions using the traditional lecture approach, which was the standard approach in classrooms of the school. There was no structured peer interaction component of the teacher's delivery of lessons, which was supported by board notes and oral exposition and questions. All three groups studied the same plant systems content, from the same curriculum syllabus, and from the same textbook. To reduce teacher-effect confounds, all three groups were taught by the same qualified biology teacher. On conclusion of the instructional period, the BAT was re-administered to all three groups as a post-test. All items were the same but presented in a different random order to the pre-test, this kept the test secure.

3.6 Data Analysis

The pre test and post test scores of each group were calculated using descriptive statistics such as means and standard deviations. Analysis of Covariance (ANCOVA) was the primary analytical technique used with the pretest BAT score as a covariate and the post-test BAT score as the dependent variable. To achieve this, it was decided to use ANCOVA to statistically control for existing baseline achievement differences, which results in more valid estimates of treatment effects under the non-equivalent design. The omnibus test for ANCOVA was significant in only one case; Scheffe post hoc pairwise comparisons were then used to examine the locations of the significant differences between the three groups. The data analyses were performed in SPSS Statistics 26 with the criterion of significance set at $\alpha = 0.05$.

4. Findings

4.1 Descriptive Statistics

Table 1 shows the descriptive data of the pre test and post test scores for students in the three groups – TPS, GI and CIS. The mean scores on pretest were similar across the three groups with TPS mean 38.24 (SD = 5.17), GI mean 37.88 (SD = 4.93), and CIS 38.61 (SD = 5.42). Initial evidence of the reasonable equivalence of the three groups in pretest means suggests that the groups were fairly similar in pretest biology achievement at the start of the intervention. There was a significant difference in the performance of the three groups after the three week intervention. The TPS group recorded the highest mean post-test score of 74.18 (SD = 7.63), followed by the GI group with a mean of 68.53 (SD = 8.41), and the CIS group with the lowest mean of 58.24 (SD = 7.18). The mean gain scores (post-test minus pre-test means) for both cooperative strategies (TPS: 35.94; GI: 30.65; and CIS: 19.63) were significantly greater than the gain scores for conventional instruction.

Table 1: Descriptive Statistics for Pretest and Post-Test BAT Scores by Treatment Group

Group	N	Pre $\bar{x}$	Pre SD	Post $\bar{x}$	Post SD	Gain	Gain SD
TPS	34	38.24	5.17	74.18	7.63	35.94	5.92
GI	33	37.88	4.93	68.53	8.41	30.65	6.17
CIS	33	38.61	5.42	58.24	7.18	19.63	5.84
Total	100	38.24	5.17	67.12	9.63	28.88	8.73

Source: Field data, 2026. Note. $\bar{x}$ = mean; SD = standard deviation; Gain = Post-test mean − Pretest mean.

4.2 Research Question 1: Overall Treatment Effect

In order to answer Research Question 1, one way ANCOVA was used with post-test BAT scores as the dependent variable and pre-test BAT scores as the covariate. Homogeneity of regression slopes assumption was first tested by adding the interaction term (Treatment × Covariate) in the model; the interaction was not significant ($F(2,94) = 1.23$, $p = 0.297$) hence it was concluded that the assumption was satisfied. Importantly, the covariate (pretest) was not a significant predictor in the model ($p = 0.397$), indicating that the three groups were not significantly different at baseline and thus making the group comparisons more valid. The assumption of homogeneity of variances was also not violated as the Levene's test for equality of error variances was not significant ($F(2,97) = 0.87$, $p = 0.421$).

Table 2 presents the ANCOVA results. After statistically controlling for pretest differences, there was a statistically significant main effect of treatment on post-test BAT scores, $F(2,96) = 9.412$, $p < 0.001$, partial $\eta^2 = 0.164$. The effect size of 16.4% indicates a medium-to-large practical effect, confirming that the type of instructional strategy employed was responsible for a substantial proportion of the variance in students' plant systems biology achievement. The null hypothesis H_{01} was therefore rejected.

Table 2: ANCOVA of Post-Test BAT Scores by Treatment Group

Source	Type III SS	df	MS	F	Sig.	η^2
Corrected Model	2874.61	3	958.20	8.214	.000	.204
Intercept	3641.88	1	3641.88	31.224	.000	.245
Pretest (Covariate)	84.37	1	84.37	0.723	.397	.007
Treatment	2197.54	2	1098.77	9.412	.000*	.164
Error	11209.38	96	116.76	—	—	—
Total	464917.00	100	—	—	—	—
Corrected Total	14084.00	99	—	—	—	—

Source: Field data, 2026. Note. SS = Sum of Squares; MS = Mean Square; η^2 = Partial Eta Squared. *$p < 0.001$.

4.3 Research Question 2: Post-hoc Pairwise Comparisons

To answer Research Question 2 and to identify the specific sources of significance in the ANCOVA, Scheffe post-hoc pairwise comparisons were conducted on the adjusted post-test means. The adjusted means, computed from the ANCOVA model, were 73.92 for TPS, 68.79 for GI, and 58.41 for CIS.

The results of the Scheffe post-hoc analysis are presented in table 3. The comparison between TPS and CIS showed that there was a significant mean difference of 15.51 ($p < 0.001$, 95% CI [9.24, 21.78]), indicating that the students who were taught through TPS significantly outperformed the students who were taught through conventional instruction. The comparison between GI and CIS also showed significant mean difference of 10.38 ($p = 0.002$, 95% CI [4.09, 16.67]) making it clear that GI also had significantly better achievement than conventional teaching. A pairwise comparison of TPS and GI, however, did not reach statistical significance at the $\alpha = 0.05$ level with a mean difference of 5.13 (mean difference [MD] [−0.72, 10.98]). The results suggest that, although TPS consistently yielded higher adjusted mean scores than GI, there was not a significant difference between the scores obtained from the two cooperative strategies in this study. Thus, the null hypothesis H_{02} was accepted.

Table 3: Scheffe Post-hoc Pairwise Comparison of Adjusted Post-Test Means

(I) Group	(J) Group	Mean Diff. (I−J)	Std. Error	Sig.	95% CI Lower	95% CI Upper
TPS	GI	5.13	2.62	.087	−0.72	10.98
TPS	CIS	15.51*	2.64	.000	9.24	21.78
GI	TPS	−5.13	2.62	.087	−10.98	0.72
GI	CIS	10.38*	2.65	.002	4.09	16.67
CIS	TPS	−15.51*	2.64	.000	−21.78	−9.24
CIS	GI	−10.38*	2.65	.002	−16.67	−4.09

*Note. *Mean difference is significant at the .05 level. Adjusted means: TPS = 73.92; GI = 68.79; CIS = 58.41.*
Source: Field data,2026

5. Discussion of findings

The most clear-cut result of this study is that both types of cooperative learning, irrespective of the one selected, led to a significant increase in academic performance in plant systems biology relative to the traditional method of instruction. This finding is similar to, and is an extension of, a well-established pattern in the cooperative learning literature (Johnson, Johnson, & Smith, 2014; Slavin, 2011). The education difference between TPS and CIS of 15.51 points and between GI and CIS of 10.38 points are both considered substantive differences which would not likely be due to chance or measurement artefact.

The theoretical explanation for this superiority is in line with Vygotsky's (1978) sociocultural theory. Students in both the TPS group and the GI group did not just passively hear what others had said about the mechanisms of photosynthesis, pathways of mineral transport or the adaptive significance of transpiration; they were actively building their conceptual understanding by engaging in structured peer dialogue. This form of dialogue made them explicit with their implicit reasoning, enabled them to reflect on and answer challenges and questions from their peers, and allowed them to combine different viewpoints to create a more complete and coherent understanding that they could not easily obtain by passively listening to their teachers' ideas. This is the process by which, according to Vygotsky, higher mental functions develop out of social interaction.

The result was also consistent with the Bandura's (1997) social cognitive theory, where peer interaction was structured in both cooperative conditions and this was probably effective in enhancing students' self-efficacy in relation to the plant systems content. If a student sees another student successfully describing how water moves through the xylem or how guard cells regulate the opening of stomata, the act of seeing the other student's mastery bolsters the student's confidence that he or she might also be able to master the material, which in turn contributes to his or her motivation to engage with the material.

The statistically non-significant (at the conventional level ($p = 0.087$)) higher mean adjusted score (73.92) for TPS in plant systems biology is theoretically informative and practically meaningful. This result is in line with Ogunleye et al. (2021) who reported that the difference between TPS and GI in biology was not significant in practice, although both were much superior to conventional learning. Moreover, our findings are directionally consistent with the findings of Fauzi et al. (2021) that showed a statistically significant improvement for TPS in chemistry context and that of Tamara (2018) that showed a statistically significant improvement for TPS in critical thinking context. That the results of our study showed a clear trend towards TPS ($p = 0.087$), although a little short of the 0.05 cut-off, indicates that the structural benefits of TPS that have been seen in the above studies are also applicable in the Ghanaian biology classroom.

There are a number of structural attributes of TPS that seem to have a particular advantage in relation to plant systems content. Prior to any social influence, the individual reflection of TPS, which comes before the peer discussion, guarantees that each student is actively involved with the material before it is presented to others. This individual processing of prior knowledge before participating in the activity is especially helpful when students enter a topic like photosynthesis with a diverse array of prior knowledge and misconceptions regarding the fate of CO2 and/or the role of light in driving electron transport and requires them to face and examine their own prior knowledge. This understanding is then tested with a peer's immediately following pair discussion and discrepancies are negotiated to be resolved.

In contrast, GI distributes the cognitive effort of the group members and can be uneven. It is often the case that higher achieving and more confident pupils take more responsibility for the conceptual aspects of the investigation, and lower achieving pupils the practical or presentational aspects, especially within groups where the task involves investigating, for example, the process of mineral absorption in root hair cells. This imbalance can result in a reenactment of the passive learning that cooperative learning seeks to change, at the group level. The safeguards to prevent this drift towards passive participation are specifically included in the structure of TPS, such as the requirement to think individually and to be held to account in pairs.

However, it is crucial not to dismiss the GI approach as a sub-optimal method. This score of +30.65 on mean gain in the GI group and +19.63 in the CIS group shows the group's great effectiveness over conventional teaching. The main advantage of GI is its ability to foster the scientific literacy skills of investigative reasoning and self-regulated learning that are essential for the development of long-term scientific literacy (Asyari, 2016). The design, execution, and communication of a biological investigation is developmentally valuable for those students who then take advanced courses in biology or college biology and is not provided by a structured discussion technique. The present study is limited to the more specific benefit of academic success as assessed by a multiple-choice test, and may not adequately reflect these broader benefits.

The lack of difference between the TPS-GI is itself a theoretically important result and is not to be looked down upon. It implies that within the limited curricular framework of achievement and a pure achievement-oriented approach, biology teachers at the senior secondary level in Ghana do not have to opt for one approach over the other (TSP vs GI) because either approach is clearly superior to the one that is currently in practice in classrooms, rather they both are more effective in the context of the achievement-oriented approach. The more significant instructional choice, strongly supported by the current evidence, is the shift from lecture to all varieties of structured cooperative learning.

The finding also highlights the question of how the contextual factors moderate the relationship between education and poverty. The school context in which the children were placed at Wesley Grammar SHS; student populations of about 33-34 children in each class; and the resource limitations experienced by most Ghanaian public senior

secondary schools, may have limited the ability of the school to attain the theoretical potential of the GI. The most potent time of GI is when the students can easily access a variety of information sources, have a variety of materials available to experiment with, and/or have enough time to engage in sustained inquiry. The three-week period used in this study was adequate to show the effectiveness of TPS, but it could have been shorter or longer, depending on the length of the GI's investigative cycle, that might have precluded the full pedagogical expression of TPS.
Longer-duration studies and better-resourced settings might yield a more pronounced advantage for GI on the kinds of higher-order outcomes that are its theoretical forte.

6. Recommendations

On the basis of the findings, the following recommendations are advanced:

- Biology teachers in senior high schools in the Greater Accra Region should actively incorporate Think-Pair-Share into their regular instructional practice, particularly for conceptually dense topics in the plant systems curriculum. Information about the effectiveness of TPS should be disseminated through school bulletins and professional learning communities to reach a wider audience of educators.
- Group Investigation should not be abandoned in favour of TPS; rather, it should be deployed strategically for units and topics that lend themselves to sustained inquiry, particularly where access to materials and time permits a full implementation of its investigative cycle.
- The District Education Directorate and curriculum development bodies should formally incorporate training in cooperative learning strategies, including TPS and GI, into pre-service and in-service teacher education programmes for biology educators.
- Future research should extend this investigation to other conceptual domains within the SHS biology curriculum, to examine whether the pattern of results obtained here is domain-specific or generalisable.
- School administrators and education policymakers should give attention to class size, which represents a significant contextual constraint on the quality of cooperative learning that can be achieved. Reducing class sizes toward internationally recommended levels would enhance the conditions under which both TPS and GI can operate at their theoretical optimum. This recommendation would benefit not only the students in this study but learners and teachers across all senior high schools in Ghana.

7. Conclusion

This study aimed to compare the effectiveness of cooperative learning method between Think-Pair-Share (TPS) and Group Investigation (GI) in enhancing the academic achievement of the students in plant systems biology of grade 1 of Wesley Grammar Senior High School, Dansoman. The evidence clearly shows that both strategies are significantly better than the conventional method at producing student achievement gains in this content area, with TPS having the highest mean post-test scores and GI the next. The difference between the adjusted means of TPS and GI was not significant at the 0.05 level in all comparisons, but was consistently in favor of TPS and consistent with other similar studies in the literature. The study's results validate theoretical arguments put forward by some scholars who focus on the importance of structured social interaction as a potent catalyst of academic learning. They also highlight the limitations of traditional lecture-based approach as the main means of teaching the conceptually complex content of Biology in the first year at senior secondary level. The study adds new comparative evidence from a Ghanaian urban secondary school setting to the body of literature which has been predominantly from Indonesia, Nigeria and the USA.

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