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# Comparative Effects of Concept Mapping and Student-Team Achievement Division on Secondary School Students' Achievement in Photosynthesis

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## Abstract

Academic achievement in science, particularly in some Biology, perceived difficulty and abstract topics, such as Photosynthesis, is a global challenge, particularly for educators in most nations with low incomes. As a result, researchers in science education have kept looking for efficient methods of instruction that might raise students' academic achievement in such topics. This study examined the effects of Concept Mapping (CM) and the Student-Team Achievement Division (STAD) on students' achievement in Photosynthesis among secondary school students in Nyamagabe and Gicumbi districts, Rwanda. A quasi-experimental pre-and post-test non-equivalent control group research design was used in the study. Data were obtained from 70 students who were taught using CM, 66 who were taught using STAD, and 65 who taught using the Conventional Teaching methods (CTM ). The Photosynthesis Achievement Test (PAT), which served as pre-and post-test, was the instrument used to gather the data before and after interventions in the study groups. The mean, standard deviation, and Analysis of Covariance were used to analyze data. The results showed that the CM and STAD groups outperformed the CTM group in academic achievement in Photosynthesis. There was a statistically significant difference between the experimental groups in favor of the CM. Female students performed statistically higher than male students in STAD, while males and females performed equally in the CM group. Additionally, there was a statistically significant interaction effect of gender and instructional strategies on students' achievement in Photosynthesis. The study concluded that the CM and STAD improved students' photosynthesis achievement better than the CTM. Thus, biology teachers should implement the CM and STAD to help students better grasp Photosynthesis-related content.

**Keywords:** Biology, achievement, concept mapping, Student-Team Achievement Division, Photosynthesis

## Article information

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## Introduction

It is commonly acknowledged that science has contributed to the nation's overall progress. This is because industrialized nations have progressed rapidly due to their emphasis on teaching scientific literacy (Kyle, 2020). In this context, Joda (2019) contended that without people with a scientific education, it is impossible to expect a nation to make sane socioeconomic and political decisions. This demonstrates how important excellent science education is to the social and economic advancement of the nation. One of the fundamental science subjects for advancing science is biology, which underscores the significance of science. According to Ahmed and Lawal (2020), biology is the study of living entities and how they interact with one another and their surroundings. Among other things, the content of biology prepares students for careers in pharmacy, agriculture, and medicine, making it one of the most important school subjects (Ameyaw & Okyer, 2018; Uitto, 2014). Students in biology education also learn how to strike a balance between the needs of society and the preservation of the environment and natural systems (Mutanen & Uitto, 2020; Tsevreni, 2021).

Nevertheless, research conducted globally indicates that students' performance in biology is subpar over time despite the subject's relevance. For example, due to students' poor performance in science-related disciplines, the United States of America (USA) is losing its competitive advantage (Matheny et al.,2022). According to Chong (2019), Malaysian students did not achieve the minimal international criteria in the Trends in International Mathematics and Science Study. The academic performance of biology students has continuously lagged across Africa, for instance, in Ghana, Kenya, Rwanda, Tanzania, and Zambia (Annan et al., 2019; Bizimana et al., 2022; Cherono et al., 2021; Kambaila & George Kasali, 2019; Mwaura et al., 2019).

Due to their subpar performance, the students have become depressed and have finally given up on studying biology (Adejimi et al., 2022; Byukusenge et al., 2022; Cimer, 2012; Etobro & Fabinu, 2017). According to Etobro and Fabinu (2017) and Hadiprayitno et al. (2019), student's poor performance in biology is primarily caused by their lack of a thorough understanding of the concepts covered in the subject, which they also perceive as being difficult for biology teachers to teach (Byukusenge et al., 2022; Wan Nasriha et al., 2021). These difficult and abstract concepts include, among others, genetics, respiration and Photosynthesis, protein synthesis, DNA replication, cell division, and genetics (Byukusenge et al., 2022; Etobro & Fabinu, 2017; Wan Nasriha et al., 2021).

According to Aboho et al.(2013) and Johnson (2016), Photosynthesis is the process through which carbohydrates or sugars interact with water (H2O) to generate carbon dioxide (CO2) with the help of sunlight energy, creating oxygen (O2) as a byproduct that is primarily released into the atmosphere. Photosynthesis keeps The atmospheric layer cleaner, which puts oxygen into the atmosphere and absorbs carbon dioxide exhaled by animals. Therefore, a conceptual grasp of Photosynthesis is essential to understanding numerous aspects of biological systems.

Even though Photosynthesis is necessary for human survival, students still have difficulty comprehending it (Hadiprayitno et al., 2019; Ojo et al., 2024). Additionally, Nasution (2018) discovered that students have many misconceptions regarding Photosynthesis. Some of the arguments put forth for this include the absence of hands-on activities and visual aids for instruction, the lack of subject-matter expertise among teachers, the overload of the curriculum, and the abstract nature of the subjects (Byukusenge et al., 2022), the absence of a supportive learning environment, and the inadequate science laboratory (Ndihokubwayo, 2017). Moreover, Rubagiza et al. (2016) emphasized inexperienced and disheartened teachers as well as a dearth of suitable instructional resources, whereas Ojo et al. (2024) noted that students had trouble visualizing the steps and experimental procedures involved in Photosynthesis.

However, according to Gorowara and Lynch (2019), Nsengimana (2021), and Samsudin et al.( 2020), the most glaring aspect of the issue is the absence of an effective teaching technique for specific biology topics. The authors went on to say that the majority of biology teachers use traditional teaching strategies like lectures, where students are heavily expected to retain the material and frequently take notes. Students are, therefore, viewed as the passive recipients of knowledge.

These teacher-centered methods of instruction rarely encourage students to take the initiative or be creative (Ugwu et al., 2020). The outcomes of teacher-centered teaching methods are lower comprehension and an inability to apply knowledge outside of the classroom (Samsudin et al., 2020). Thus, low skill levels and subpar academic accomplishment in the field have primarily been caused by the didactic method of teaching and learning biology topics.

According to Bahar and Aksüt (2020), the modern educational system is moving toward an activity-based curriculum that allows students to participate actively in their science education. Thus, to improve achievement in scientific classes, it is critical to give priority to instructional strategies that challenge students' preconceptions and clarify concepts. Accordingly, research on how science-related concepts should be taught to students has led to the discovery of innovative and successful teaching methods. Problem-based learning, guided inquiry, idea mapping, and cooperative learning techniques like Student-Team Achievement Division (STAD) are a few of these innovative teaching methods (Adiyiah et al., 2023; Sor et al., 2018). STAD and concept mapping were employed in this investigation.

The concept mapping (CM) approach visualizes concepts that show relationships between concepts through linking words (Abamba & Esiekpe, 2021). The assimilation theory of cognitive learning by Ausubel (1963) is the source of the CM. Using concept maps, concepts are arranged to demonstrate how they relate to one another, from more inclusive to more specific notions (Huang et al., 2017). Concept maps are schematic representations of concept meanings incorporated into a propositional framework (Novak & Gowin, 1994). As per Hsieh et al.. (2016), this map exhibits a noteworthy conceptual association with keywords through a hierarchical graphic organization.

According to Cañas et al. (2017), concepts must be arranged hierarchically to build a concept map, with basic concepts positioned at the top and more specialized, less general concepts positioned at the bottom. In the end, concept maps will enhance meaningful learning since students will become more involved and able to differentiate concepts by gradually seeing them depicted hierarchically (Cañas & Novak, 2008). Concept maps are, therefore, useful for organizing and structuring knowledge.

The literature has shown an abundance of advantages for concept map implementation in the classroom. The development of critical and creative thinking, for example, is facilitated by the CM (de Ries et al.., 2022; Hu & Hwang, 2024; Turan-Oluk & Ekmekci, 2018). Additionally, the CM helps students develop their ability to apply and synthesize concepts to discover answers to questions and their capacity for problem-solving. Once more, the CM helps learners communicate what they comprehend (Prasetya et al., 2022). Additionally, the CM enhances students' knowledge structures by offering graphical tools that connect freshly learned concepts with previously studied ones (Singh & Moono, 2015). Moreover, the processes involved in creating concept maps aid students in developing their critical thinking abilities (Tseng, 2020). These studies demonstrated that the CM promotes learning more successfully than Conventional Teaching Methods (CTM).

Robert Slavin and associates at Johns Hopkins University created the Student-Team Achievement Division (STAD) cooperative learning concept. Slavin (2014) asserts that STAD is among the most basic methods of cooperative learning. When using the STAD for cooperative learning, students are placed in groups based on their academic standing; some groups have high, medium, and low achievement levels and different genders. To fulfill the required learning outcomes, the students collaborate in their groups. The STAD was founded on group learning exercises that fostered a social exchange of knowledge among students. To get the best outcomes, students are urged to assist one another in understanding the subject matter (Motwani et al., 2022).

Students in the STAD are placed in learning groups with four or five individuals who are of different genders and abilities. After the instructor presents the lesson, the students work together in groups to ensure that each person understands the assignment. Lastly, each student tests the material individually, and during this exam, they are not allowed to speak with one another. The STAD consists of a variety of student activities, such as seminars, group projects, and conversations, that take place in various group sizes under workplace-based coaching (Guraya & Abdalla, 2020).

Numerous investigations that examined STAD outcomes discovered that it fosters the group's members' cognitive, psychomotor, and emotional development. Additionally, it improves test results for students (Motwani et al., 2022). Beyond test outcomes, STAD has many advantages. The STAD strengthens students' attitudes toward the material being learned, boosts their sense of self-worth, and hones their interpersonal skills based on their positive relationships with one another (Guraya & Abdalla, 2020). Furthermore, it prepares students for the challenges of modern life by teaching them how to collaborate effectively in groups (Odutayo & Fonseca, 2024).

The complementary goals of the CM and STAD are similar in that they include students in the learning process, which promotes higher-order thinking and more practical behavior that are essential for the growth of science and technology. This is consistent with Elmaadaway's (2018) assertion that students' active participation, communication of learning objectives, and feedback on students' performance concerning those objectives are all necessary components of a successful scientific classroom. Thus, this study aimed to examine how students' academic achievement in Photosynthesis in secondary schools is affected by CM and STAD. The intention was to find out if using these strategies could be a substitute for the students' subpar academic achievement on this concept's test questions. This is because photosynthesis-related questions frequently come up in Biology National Examinations, particularly in Rwanda.

According to Susperreguy et al.(2017), academic achievement results from students in the courses they learn in school. It is closely tied to how much knowledge learners acquire and how they progress in an educational setting where teaching and learning occur. According to Neji and Joda (2016), academic achievement is defined as meeting predetermined goals as measured by test scores. A student is considered to have achieved this if they completed a task and reached the intended outcome for that particular learning experience. According to Luck (2015), academic achievement is the sum of a person's accomplishments following participation in a learning program.

In earlier research, Jia et al.(2020) and Stevenson et al.(2021) found that gender and teaching approaches can affect students' biology achievement. Gender is defined as the roles assigned to men and women by society. Okeke (2018) defines gender as the roles and sociocultural conceptions that are applied to men and women in society. Females are recognized to perform less well in science and technology, according to several studies (Ahmed & Lawal, 2020; Ng et al., 2020). A multitude of interrelated sociocultural and educational factors, including interests, enrollment, involvement, and success in science classes at various educational levels, might be linked to the underachievement of females in the field of science and technology.

Of these above-cited variables, gender has the greatest impact (Ahmed & Lawal, 2020; Bizimana et al., 2022). However, other research has yielded contradictory results regarding the nature of this influence; males outperform females, particularly in mathematics and scientific courses (Uchegbue & Amalu, 2020). Other studies found that overall science performance was similar for males and females (Ngozi et al., 2018; Stevenson et al., 2021). These differing views regarding the gender differences in students' science achievement motivated this study, which examined the influence of gender on students' achievement using the CM and STAD instructional strategies and how these strategies interacted with gender to affect students' academic achievement in Photosynthesis.

### Purpose of the Study

This study aimed to investigate the effects of CM and STAD on students' academic achievement in Photosynthesis. Specifically, the study sought to answer the following research questions:

1. What is the difference in the mean achievement scores between students taught Photosynthesis using concept mapping (CM) and those taught using student-team achievement division (STAD)?
2. What is the influence of gender on students taught using concept mapping (CM) and those taught using student-team achievement division (STAD) teaching strategies on students' achievement in Photosynthesis?
3. What are the relative effects of treatments (CM, STAD, and CTM) and gender interaction on students' achievement in Photosynthesis?

## Methodology

The study adopted the quasi-experimental research design, specifically, the pre-test post-test non-equivalent comparison research design (Creswell, 2014), using gender as a moderating variable. The design was deemed appropriate because the students were taught in their already-formed intact classes. According to Creswell (2014), it is unethical to divide students into groups at random or to interfere with already-running classes for experimental purposes. As a result, using intact classes made it feasible to experiment with some of the classes while using the other classes as the comparison group. There were two levels of gender (male and female) in the moderating variable and three levels of independent variables (two experimental and one comparison) in the treatment variable. The dependent variables were the pre-test and post-test results.

Before the treatment, students in both groups (experimental and comparison) were given a pre-test using the Photosynthesis Achievement Test (O1). Students in experimental group 1 (EG1) were exposed to CM (X1), students in experimental group 2 (EG2) were exposed to STAD (X2), and students in the comparison group (CG) were exposed to CTM (X0). After four weeks of intervention, they were given a post-test (O2). The study research design layout is shown in Table 1.

**Table 1: Research Design Layout**

| Groups | Pre-test | Treatment | Post-test |
|---|---|---|---|
| $EG_1$ | $O_1$ | CM ($X_1$) | $O_2$ |
| $EG_2$ | $O_1$ | STAD ($X_2$) | $O_2$ |
| CG | $O_1$ | CTM ($X_0$) | $O_2$ |

The study was conducted in the Nyamagabe and Gicumbi districts, Rwanda, during the 2021/2022 school year. Purposive sampling was used to select six lower co-educational secondary schools in each district. The choice of the schools was made based on the type of school (Boarding), school ownership (public and government-aided), gender composition (mixed school), and student's enrollment in senior two secondary schools (SS2). Based on these sampling criteria, six schools a total of 201 students, were chosen for this study. Using a simple random sampling technique, six schools were assigned to the experimental and comparison groups. All intact classes of senior two secondary school students from each of the selected schools were used in the study. Thus, 70 students in two classes were assigned to the CM group (EG1). Then, 66 students in two classes were assigned to STAD Group (EG2), and 65 students in two classes were assigned to the Comparison Group (CG). Table 2 shows the sample distribution for the study.

**Table 2: Study's Sample Distribution**

| Study Groups | Male | Female | Total |
|---|---|---|---|
| Concept Mapping ($EG_1$) | 33 | 37 | 70 |
| Student-Team Achievement Division ($EG_2$) | 30 | 36 | 66 |
| Comparison Group (CG) | 27 | 38 | 65 |
| **Total** | **90** | **111** | **201** |

The research assistants administered a pre-test to the students before each class's teaching activities, and the results were recorded. The research assistants in each group, who had already received training from the researchers in that group, performed the initial instruction to prevent unneeded variables. The lesson plans created by the researchers in the Photosynthesis Unit were distributed to each experimental group. In the comparison groups, the research assistants used their traditional teaching techniques to instruct on the same concept.

Four weeks were allotted to the teaching activities in all study groups. Following that, a post-test was given, and the results were recorded. The students' achievement in Photosynthesis was assessed using the 40-item Photosynthesis Achievement Test (PAT), which consisted of multiple-choice questions with options A–D. The focus on the unit of Photosynthesis was motivated by the fact that most students perceived the topic of Photosynthesis as difficult to learn and also perceived by teachers as difficult to teach (Etobro and Fabinu, 2017). Besides, many secondary school students have a lot of misconceptions about it (Eziyi, Mumuni, and Nwanekezi, 2016). The PAT had 40 multiple-choice items. The items were selected from the SS2 Biology textbooks and were developed based on the objectives of the unit of Photosynthesis as specified in the Ordinary Level Biology Competence-Based Curriculum (Rwanda Education Board, 2015). Five items were on introduction to Photosynthesis, 11 items on the necessity of Photosynthesis, nine on the necessity of sunlight, eight on the necessity of $CO_2$, five on adaptation of the leaf to and limiting factors to Photosynthesis, and two items on the importance of Photosynthesis. Two experts in measurement and evaluation and two biology teachers with over ten years of experience in secondary schools validated the instrument. They checked if the PAT items were based on the content and specific objectives of the unit of Photosynthesis as specified in the SS2 syllabus, checked if the items were suitable to the level of students, possible grammatical errors in the statements, and suggested answer options. Their corrections and suggestions guided the production of the final draft of PAT. After that, it underwent a pilot test, and the Kuder-Richardson formula 21 (KR-21) was used to determine the reliability coefficient of 0.82.

Collected data were analyzed using the Analysis of Covariance (ANCOVA) and other statistical analyses, such as mean and standard deviation. Besides, the Benferroni post hoc analysis was performed to identify the source of significant differences where they occurred. The use of ANCOVA test was in line with Wang et al.( 2017) 's viewpoint that it lowers experimental error. In particular, the ANCOVA was selected as the statistical method because study participants were not randomly assigned to groups; instead, students in their intact classes were used. The analysis followed a systematic procedure, starting with testing the parametric assumptions before applying the ANCOVA statistic to the data. The test of homogeneity affirmed that the study groups did not significantly differ from each other ($F= .753$; $p= .472> 0.05$). This finding is in line with Bahar and Aksüt's (2020) advice that pre-test results for the experimental and control groups should be as similar as feasible in a quasi-experimental study. The ANOVA test allows for the deduction of treatment effects (Argaw et al., 2017). Having satisfied these assumptions, the one-way ANCOVA statistic was applied to the students' achievement scores in the study groups. In running the ANCOVA test, the post-test scores served as the dependent variable, the teaching methods as the fixed factor, and the pre-test scores as the covariate.

In addition, the Bonferroni post-hoc test was used in cases where the main effect was significant to determine the direction of a significant difference between the group means. This was done to determine which intervention strategies (CM, STAD) had a beneficial influence on students' achievement in Photosynthesis (Creswell, 2014). Furthermore, the effect magnitude was quantified using the Eta squared ($\eta^2$) method. According to Cohen's 1988 analysis, the effect size in the eta squared evaluation was evaluated as follows: $0.01< \eta^2< 0.06$: small; $0.06 \leq \eta^2<0.14$: moderate; and $0.14 > \eta^2$: big.

## Results

**Research question 1:** What is the difference in the mean achievement scores between students taught Photosynthesis using concept mapping (CM) and those taught using student-team achievement division (STAD)? To answer this question, the pre-test and post-test results of the study groups were compared to ascertain the impact of the intervention on students' academic performance (Table 3).

**Table 3: Mean and Standard Deviation Achievement Scores of Students taught Photosynthesis using CM, STAD, and CTM**

| Groups | Pre-test | | | Post-test | | Mean Gain |
|---|---|---|---|---|---|---|
| | N | Mean | SD | Mean | SD | |
| CM | 70 | 15.61 | 3.29 | 35.20 | 4.47 | 19.59 |
| STAD | 66 | 16.12 | 1.66 | 29.52 | 8.38 | 13.4 |
| CTM | 65 | 15.95 | 2.14 | 21.26 | 6.43 | 5.31 |

Table 3 demonstrates that from the pre- to post-PAT, the mean scores of the students in the CM group grew by 19.53 points, those in the STAD group increased by 13.4 points, and those in the CTM increased by 5.31 points. These results demonstrated that while students taught using CTM achieved lower than those taught using STAD, students taught using CM achieved higher than those taught using STAD and CTM.

To determine whether there were any statistically significant variations in achievement across the study groups, the ANCOVA test was used (Table 4).

**Table 4: ANCOVA Showing Significant Difference in the Mean Achievement of Students Taught using CM, STAD, and CTM**

| **Source** | **Type III Sum of Squares** | **df** | **Mean Square** | ***F*** | ***Sig.*** | $\eta^2$ |
|---|---|---|---|---|---|---|
| Corrected Model | 6625.616[a] | 3 | 2208.539 | 50.349 | .000 | .434 |
| Intercept | 3237.514 | 1 | 3237.514 | 73.807 | .000 | .273 |
| Pretest | 30.949 | 1 | 30.949 | .706 | .402 | .004 |
| Groups | 6623.469 | 2 | 3311.735 | 75.499 | .000 | .434 |
| Error | 8641.290 | 197 | 43.864 | | | |
| Total | 182284.000 | 201 | | | | |
| Corrected Total | 15266.905 | 200 | | | | |

a. R Squared = .434 (Adjusted R Squared = .425)

The ANCOVA analysis in Table 4 shows that a significant difference existed in post-test scores among the study groups ($F_{(2, 197)} = 75.499$, $p = 0.000 < 0.05$). Thus, the mean achievement scores in the study groups differed significantly. The index value of eta-squared ($\eta^2$) = 0.434 corresponded to the big effect size, which means that the treatments explain 43.4% of the variance in the post-achievement. Nevertheless, the results in Table 4 did not explain the variations discovered during the ANCOVA test analysis. Thus, paired contrast was analyzed using Sheaffer's test (Table 5).

**Table 5: Benferroni Pair-Wise Comparisons of Students' Scores**

| (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig.[b] |
|---|---|---|---|---|
| CTM | CM | -13.992* | 1.143 | .000 |
| | STAD | -8.226* | 1.158 | .000 |
| CM | CTM | 13.992* | 1.143 | .000 |
| | STAD | 5.767* | 1.140 | .000 |
| STAD | CTM | 8.226* | 1.158 | .000 |
| | CM | -5.767* | 1.140 | .000 |

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

Table 5 demonstrates that compared to the mean difference between the CM and CTM groups (13.992), the mean difference between the CM and STAD groups (8.22) was smaller. This demonstrated how the three strategies varied in raising student achievement, with CM having the greatest impact, STAD, and CTM having the lowest. Consequently, the impacts of CM, STAD, and CTM on students' achievement vary significantly.

**Research question 2:** What is the influence of gender on students taught using concept mapping (CM) and those taught using student-team achievement division (STAD) teaching strategies on students' achievement in Photosynthesis?

The study also examined the influence of gender on students taught using concept mapping (CM) and those taught using student-team achievement division (STAD) teaching strategies on students' achievement in Photosynthesis (Table 6).

**Table 6: Mean and Standard Deviation of Students' Achievement Scores by Study Group and Gender**

| Group | Gender | Pre-test | | | Post-test | | Mean Gain |
|---|---|---|---|---|---|---|---|
| | | N | Mean | SD | Mean | SD | |
| CM | Male | 33 | 14.97 | 3.58 | 35.42 | 3.93 | 20.45 |
| | Female | 37 | 16.18 | 2.95 | 35.00 | 5.12 | 18.82 |
| STAD | Male | 30 | 16.43 | 1.63 | 26.92 | 8.84 | 10.49 |
| | Female | 36 | 15.86 | 1.67 | 31.68 | 7.43 | 15.82 |
| CTM | Male | 27 | 15.85 | 1.93 | 21.46 | 5.06 | 5.61 |
| | Female | 38 | 16.01 | 2.31 | 21.12 | 7.32 | 5.11 |

Gender-specific analysis of the data in Table 6 suggests that males performed better in the CM and CTM groups and that females performed better in the STAD group. Males in the CM group increased their mean by 20.45 points from pre-PAT to post-PAT, while females increased their mean by 18.82 points. In the STAD group, the mean was raised by 10.49 points for men and 15.82 points for women. In the CTM group, the mean for males increased by 5.61 points, while the mean for females improved by 5.11.

The study investigated whether utilizing the CM to teach Photosynthesis resulted in a statistically significant achievement difference between male and female students (Table 7).

**Table 7: ANCOVA Result for Achievement Scores of Male and Female Students Taught Photosynthesis using CM Strategy**

| Source | Type III Sum of Squares | df | Mean Square | *F* | *Sig.* | $\eta^2$ |
|---|---|---|---|---|---|---|
| Corrected Model | 12.122[a] | 2 | 6.061 | .283 | .754 | .008 |
| Intercept | 3211.242 | 1 | 3211.242 | 150.186 | .000 | .692 |
| Pretest | 8.982 | 1 | 8.982 | .420 | .519 | .006 |
| Gender | 5.257 | 1 | 5.257 | .246 | .622 | .004 |
| Error | 1432.578 | 67 | 21.382 | | | |
| Total | 88177.500 | 70 | | | | |
| Corrected Total | 1444.700 | 69 | | | | |

a. R Squared = .008 (Adjusted R Squared = -.021)

According to the results of the ANCOVA (Table 7) test, there was no discernible difference between the male and female students in the CM group ($F(1, 67) = .246$, $p = .622 > 0.05$). This shows that both male and female students' photosynthetic achievement was enhanced equally by the CM.

The study also looked at whether there were significant differences between male and female students who were taught Photosynthesis using the STAD technique (Table 8).

**Table 8: ANCOVA Result for academic achievement of Male and Female Students Taught Photosynthesis using STAD Strategy**

| Source | Type III Sum of Squares | df | Mean Square | *F* | *Sig.* | $\eta^2$ |
|---|---|---|---|---|---|---|
| Corrected Model | 456.664[a] | 2 | 228.332 | 3.494 | .036 | .100 |
| Intercept | 216.209 | 1 | 216.209 | 3.308 | .074 | .050 |
| Pretest | 85.297 | 1 | 85.297 | 1.305 | .258 | .020 |
| Gender | 423.283 | 1 | 423.283 | 6.477 | .013 | .093 |
| Error | 4117.321 | 63 | 65.354 | | | |
| Total | 62069.500 | 66 | | | | |
| Corrected Total | 4573.985 | 65 | | | | |

a. R Squared = .100 (Adjusted R Squared = .071)

The results of the ANCOVA test (Table 8) indicate a statistically significant difference ($F(1, 63) = 6.477$, $p = 0.013 < 0.05$) between the male and female students in the STAD group. This suggests that male and female students' achievement scores in Photosynthesis are improved differentially by the STAD instructional technique, with female students outperforming statistically better than their male counterparts.

**Research question 3:** What are the relative effects of treatments and gender interaction on students' achievement scores in Photosynthesis?

The study looked at whether the interaction effect of gender and the teaching methods on students' mean achievement scores in Photosynthesis differed significantly (Table 9).

**Table 9: ANCOVA Result Showing Interaction Effect of Gender and Teaching Methods on Students' Achievement Scores in Photosynthesis**

| Source | Type III Sum of Squares | df | Mean Square | F | *Sig.* | $\eta^2$ |
|---|---|---|---|---|---|---|
| Corrected Model | 7023.019[a] | 6 | 1170.503 | 27.545 | .000 | .460 |
| Intercept | 2957.746 | 1 | 2957.746 | 69.603 | .000 | .264 |
| Pretest | 51.973 | 1 | 51.973 | 1.223 | .270 | .006 |
| Groups | 6489.533 | 2 | 3244.766 | 76.358 | .000 | .440 |
| Gender | 80.426 | 1 | 80.426 | 1.893 | .170 | .010 |
| Groups * Gender | 317.466 | 2 | 158.733 | 3.735 | .026 | .037 |
| Error | 8243.886 | 194 | 42.494 | | | |
| Total | 182284.000 | 201 | | | | |
| Corrected Total | 15266.905 | 200 | | | | |

a. R Squared = .460 (Adjusted R Squared = .443)

The results, which are displayed in Table 9, indicate that there was a statistically significant interaction between gender and teaching methods (CM, STAD, and CTM) ($F(1,194) = 3.375$, $p = 0.026 < 0.05$). This suggests that gender and teaching methods combined had an impact on students' achievement scores in Photosynthesis. Figure 1 below highlights the interaction effect of gender and teaching methods.

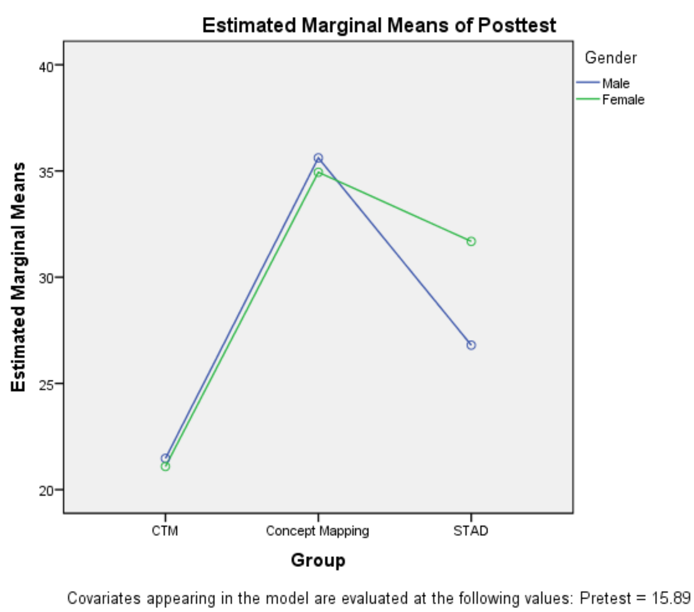


**Figure 1: Interactive Effect of Treatment and Gender on Students' Achievement in Photosynthesis**

Figure 1 above shows that in both the CM and CTM groups, male and female students performed at least equally. However, in the STAD group, Figure 1 showed that female students outperformed male students in PAT scores.

## Discussion

This study examined the effects of concept mapping and Student-Team Achievement Division (STAD) on secondary school students' achievement in Photosynthesis. To achieve this, the study compared the students' scores on the photosynthesis achievement test of students taught the concept using CM, and STAD, and those taught using the conventional teaching methods before and after interventions. The results showed that compared to CTM group students, CM and STAD groups achieved noticeably better in Photosynthesis. This finding is in tandem with previous studies (Abamba & Esiekpe, 2021; Hu & Hwang, 2024; Chang et al., 2017; Hsu, 2019; Motwani et al., 2022), which showed that the CM and STAD instructional strategies were better than the CTM in enhancing students' achievement in science concepts. The superiority of the CM and STAD strategies over the CTM can be attributed to their ability of the CM and STAD to allow students to participate actively in the teaching and learning process. However, students' active participation in the CTM was limited because they were primarily passive listeners most of the time. This is consistent with the opinions of Mokiwa and Agbenyeku (2019) as well as Collins and Nyenhuis (2021), who stated that activity-oriented instructional strategies help students understand the subject being taught. This student's active involvement in learning supports the findings of this study. Likewise, Biamba et al. (2021), and Orji and Ogbuanya (2020) added in supplementing that better achievement also resulted from the structured material and students' active participation in the teaching and learning process.

Additionally, the study's results showed that learners in the CM group outperformed their peers in the CTM group in terms of achievement. These findings are consistent with research results by Ayimbila and Akantagriwon (2021), Dashne and Sinaa (2019), and Woldeamanuel et al. (2020), who discovered, respectively, that students who were taught biology concepts using the CM significantly outperformed those who were taught using CTM in terms of their academic achievement. The results of this study also showed that, in comparison to students in the CTM, the students who were taught Photosynthesis using the STAD had substantially higher mean scores. This result is consistent with the findings of Guraya and Abdalla (2020), Motwani et al.(2022), and Odutayo and Fonseca (2024), who discovered that the STAD was superior to the CTM in raising student achievement.

The application of social constructivism in the STAD may also have contributed to its efficacy. This method enhances students' affective and cognitive abilities, including their involvement, communication and listening abilities, sharing of ideas, and capacity to come to consensus on information or decisions that benefit everyone (Trung and Truong, 2023). These benefits frequently outweigh the ability to make decisions on one's own or create new information, as demonstrated by the teaching and learning process using CTM teaching methods (Prihatnawati et al., 2017).

The study revealed that male students had slightly higher mean achievement scores than their female counterparts when Photosynthesis was taught using the CM. However, there was no significant difference in the mean achievement scores between genders. This indicates that the CM improved the achievement of both male and female students equally. The finding agrees with that of Doris (2018), who reported similar findings. However, the finding contradicts Sor et al. (2018).

Moreover, the findings on gender differences in the STAD group showed a statistically significant difference in mean achievement scores between male and female students in favor of females. This finding is supported by Singh (2018). According to the author, female students are generally better at utilizing the benefits of collaborative learning, such as information sharing, introspection, and mutual evaluation among intelligent peers. In this study, STAD provided female students with an opportunity to discuss and share their views of the issues presented by competent participants through the utilization of cooperative discussion groups. As a result, using STAD helps many more female students understand and retain the concepts covered. However, the finding contradicts that of Gambari and Yusuf (2017), who found that there were no significant differences between the achievement of males and females taught with STAD instructional strategy.

Lastly, the study found that there was a significant interaction effect of treatment and gender on students' achievement in Photosynthesis. This suggests the observed differences in the achievement scores between the study groups were linked to instructional strategies and gender. This result validates the study of Iorzua (2017), which produced comparable outcomes at different points in time. The finding, however, appears to be at odds with Omenka Omenka's (2019) findings, which gave contradictory results.

## Concluding remark

From the results of this study on the comparative effects of the CM and STAD strategies on lower secondary school students' outcomes in Photosynthesis, it was found that students benefit from the use of the CM and STAD than the use of the CTM in learning photosynthesis, with students in the CM group outperforming those in the STAD and CTM. Besides, both males and females achieved significantly equal results when exposed to the CM. However, when exposed to the STAD, females achieved more than their male counterparts. It was revealed that male and female students achieved significantly equal results in Photosynthesis when the CM was used, while females achieved significantly higher results than males when the STAD was used. Thus, it follows that both CM and STAD are effective teaching strategies that can be used to enhance students' conceptual understanding of Photosynthesis and other difficult and abstract biology concepts. In light of the study's findings, an attempt should be made to shift the focus of biology instruction from the conventional approaches to one that is more student-centered. Teachers should be urged to implement CM and cooperative learning techniques such as STAD to effectively teach biology and other science courses in secondary schools. The Ministry of Education and its partners should arrange for in-service training in the form of workshops and seminars to enable teachers to use CM and STAD instructional strategies in science instruction. Curriculum designers should include innovative teaching strategies in their different teacher-education programs, like CM and STAD.

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