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

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Abstract

The data presented in this paper is related to Concept Mapping (CM) and Student-Team Achievement Division (STAD) collected from Rwandan secondary schools. This dataset is derived from the study investigating the effects of CM and STAD instructional strategies on lower secondary school students' achievement in photosynthesis. The dataset comprises quantitative data collected through a quasi-experimental pre- and post-test non-equivalent control group study, involving 70 students who were taught using CM, 66 who were taught using STAD, and 65 who were taught using the Conventional Teaching methods (CTM) from Nyamagabe and Gicumbi districts of Rwanda. The Photosynthesis Achievement Test (PAT), which served as a pre- and post-test, was 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 the data. The dataset provides variable insights for biology teachers, policy makers, and researchers seeking to enhance biology education, especially when addressing the challenges faced by students and teachers when learning and teaching, respectively, perceived difficult and abstract biology concepts through innovative and learner-centered teaching strategies. It also facilitates future research on the efficacy of CM and STAD in science-related subjects and provides a basis for comparative studies in different educational settings.

Keywords: data, dataset, concept mapping, biology, photosynthesis, Rwanda

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Introduction

Evidence abounds to show that over the past decades, students in Biology have had consistently low academic achievement. This low achievement in biology, despite its importance in the country's scientific and technological development, has become a source of concern for stakeholders in science education in many countries, especially in Sub-Saharan Africa (Ameyaw and Okyer, 2018; Bizimana, Mutangana, and Mwesigye, 2022). The reasons for such poor academic achievement, as revealed by various research and reports, include, among others, teachers' use of overreliance on conventional teacher-centered methods, especially while teaching concepts that students perceive as difficult (Byukusenge, Nsanganwimana, and Tarmo, 2022). Unfortunately, research has continued to show that science teachers are still using the traditional teaching methods, such as lecturing, which do not allow students to actively participate and engage in their learning, nor interact among themselves for meaningful learning and improved academic achievement (Byusa, Kampire, and Mwesigye, 2020; Ugwu, Jatau & Gwamna, 2020). Therefore, science education researchers advocate adopting innovative teaching strategies with roots in constructivism that allow learners to construct knowledge and understanding since meaningful learning results from learners' active participation (Fernando en Marikar, 2017).

Concept Mapping (CM) and Student-Team Achievement Division (STAD) are among such teaching strategies that actively involve learners in their learning process(Bizimana, Mutangana, and Mwesigye, 2022a; Joda, 2018). The concept mapping (CM) approach is a way of visualizing concepts that shows relationships between concepts through the use of 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.

Student-Team Achievement Division (STAD) is among the most basic co-operative learning methods. When using the STAD for co-operative 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). Despite these strategies being more efficacious in enhancing students' achievement in science education than the CMT, related studies in the Rwandan context are scarce. Besides, the literature does not fully explore the effects of CM and STAD on students' achievement in difficult and abstract biology concepts like photosynthesis. Given this knowledge gap and being a matter of concern for students' academic achievement in biology in Rwanda, there was a need therefore to apply the CM and STAD to biology students' learning and evaluate their effectiveness especially about achievement in photosynthesis when compared with the use of the CTM among lower secondary school students in Nyamagabe and Gicumbi districts. This dataset originates from an empirical study that investigated the comparative effects of CM and STAD instructional strategies on students' academic achievement.

The purpose of presenting this dataset is to provide Biology teachers, researchers, educators, and policymakers with valuable empirical evidence on the effects of CM and STAD on students' academic achievement in Biology education. The dataset enables the development of interventions to enhance student learning outcomes in photosynthesis (Bizimana & Bikorimana, 2025).

Methodology

The study adopted the quasi-experimental research design to collect the data, specifically, the pretest-posttest non-equivalent comparison research design (Creswell, 2014). It was carried out in the two districts of Rwanda, Nyamagabe and Gicumbi, with 201 senior secondary school students from six schools assigned to the experimental and comparison groups using a simple random sampling technique. All intact classes of senior two secondary school students from each of the selected schools were used in the study. Thus, 70 students in their intact classes were assigned to EG1. Then, 66 students were assigned to EG2 and 65 students to CG. Table 2 shows the sample distribution for the study. The dataset related to this data article is free and accessible for reuse in the Figshare repository at the following DOI: https://doi.org/10.6084/m9.figshare.29063147

Intervention

In this study, the instructional strategies (CM, STAD, and CTM) in the study groups served as the independent variables in the study design. One group was assigned to the experimental group (EG), while the other group was assigned to the comparison group (CG). The EG was then divided into two sub-groups, namely EG1 and EG2. Hence, there were three groups altogether in this study. The EG1 was taught using the CM, the EG2 was taught using STAD, while the CG was taught using the CTM. For this study, the concept of photosynthesis was taught during the intervention period, which lasted six weeks of the teaching activities in all study groups. The data collection instrument was the Photosynthesis Achievement Test (PAT), which assessed students' achievement in photosynthesis through pre- and post-tests (**see appendix**).

Data collection procedure and Data analysis

Data were collected over the period of one month and a week in the second term of the school year 2022, from mid-January to the beginning of March 2022. Before the treatment, the Pre-test PATs were administered to both the experimental and comparison groups to establish baseline achievement. The EG1 and EG2 then underwent the CM and STAD interventions, preceded by a week of teacher research assistants' training, respectively, while the comparison groups were taught using the CTM. After the intervention in all study groups, the Post-test PAT was administered subsequently to measure any changes in academic achievement in the concept taught. Data collected through the PAT were classified into pre-test and post-test for both study groups. The analysis was carried out using SPSS Version 20.0. Descriptive statistics of the mean and standard deviation (SD) were used to answer the research questions, and inferential statistics of Analysis of Covariance (ANCOVA) to test the research hypothesis. 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 thorough research methodology guarantees a solid examination of how well CM and STAD teaching

strategies enhance academic achievement in photosynthesis among Rwandan secondary school students.

Data description

In a structured Excel spreadsheet format, the data set is arranged with the header in row 1 revealing the student respondent's number, gender, study group, and pre- and post-test results. The number, study group, pre-test, and post-test scores of each student respondent are displayed in rows 2–202. Each students' number is shown in column B, gender is shown in column C, the study groups is in column D, the pre-test score in column E, and the post-test score in column F.

Ethics statement

In this study, every procedure involving human subjects was carried out strictly in compliance with ethical guidelines. All of the teachers and students participating in this study gave their informed consent before participation. The study's goals, methods, and advantages were fully explained to each participant, guaranteeing their informed and willing participation. Participants' privacy and anonymity were protected at every stage of the study, and the participants' privacy and identities were protected, and data was safely stored, and researchers were the only ones to access it.

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Appendix

Photosynthesis Achievement Test (PAT)

Section A: Identification

Student's Number:. ……

Sex: Male_____Female_____

Section B: Questions on Photosynthesis

INSTRUCTION: Answer all questions on the answer sheet provided. Each question is followed by four options a, b, c, d. Tick the letter corresponding with the correct answer on the answer sheet.

1. Photosynthesis takes place in.…

a) Autotrophic organisms
b) Primary consumers
c) Decomposers
d) Heterotrophic organisms

2. Which of the bellow statements is correct about the structural adaptation of leaf to photosynthesis:

a) The leaf cuticle and epidermis of the leaf are thick and transparent to allow easy penetration of sunlight into the leaf.
b) The leaf cuticle and epidermis are transparent and are made of many layers of cells to allow sunlight to be absorbed easily.
c) The leaf cuticle and epidermis are thin and transparent to allow easy penetration of light.
d) The leaf cuticle and epidermis are transparent and dense to allow easy penetration of the light into the leaf.

3. Photosynthesis is the process in which plants produce:

a) Carbohydrates and oxygen
b) Sugar and carbon dioxide
c) Starch and carbon dioxide
d) chlorophyll and radiant energy

4. One of the following is not a necessary condition for Photosynthesis to take place, which one?

a) Availability of Water.
b) Presence of Sunlight
c) An adequate supply of Oxygen
d) Presence of Chlorophyll

5. Which pair of substances is the raw materials photosynthesis?

a) Oxygen and organic matter
b) Oxygen and water
c) Carbon dioxide and organic matter
d) Carbon dioxide and water

6. The most important benefit to green plants when they photosynthesize is:

a) Removal of carbon dioxide
b) Conversion of light energy to chemical energy

c) Production of energy
d) Production of oxygen

7. What type of energy do plants receive from the sun?

a) Chemical energy
b) Light energy
c) Geothermal energy
d) Electrical energy

8. Which gas is taken by green plants in large amounts when there is no light energy at all?

a) Carbon dioxide gas
b) Oxygen gas
c) Nitrogen gas
d) Neo gas

9. In which part of the plant does photosynthesis take place most?

a) In the whole plant
b) In the roots
c) In the leaves
d) In the stem

10. Which pair of substances are the reactants in photosynthesis and which substances are products of photosynthesis?

a) Reactants are oxygen and water, and products are glucose in oxygen.
b) Reactants are oxygen and water, and products are oxygen and water.
c) Reactants are carbon dioxide and organic matter, and products are glucose in oxygen.
d) Reactants are carbon dioxide and water, and products are glucose and oxygen.

11. Which part of the plant contains chlorophyll and in which part of the plant does photosynthesis take place?

a) Chlorophyll is in the leaves, and photosynthesis takes place in the whole plant.
b) Chlorophyll is in the roots, and photosynthesis takes place in the leaves.
c) Chlorophyll is in the leaves, and photosynthesis takes place in the leaves.
d) Chlorophyll is in green parts of the plant, and photosynthesis takes place in the green parts of the plant.

12. What type of energy do plants receive from the sun and into what type of energy do plants transform sunlight energy?

a) Plants receive chemical energy from the sun and transform it into chemical energy.
b) Plants receive light energy from the sun and transform it into movement.
c) Plants receive light energy from the sun and transform it into chemical energy.
d) Plants receive light energy from the sun and transform it into light energy.

13. Which of the following is the correct photosynthesis equation?

a) $6Co_2+C6H_{12}O_2+\text{light energy} \longrightarrow H_2O+ C_6H_{12}O_6+2H_2O$
b) $6Co_2\ (g) +6H_2O +\text{light energy} \longrightarrow C_6H_{12}O_6 + 6O_2$
c) $6Co_2+ C_6H_{12}O+\text{light energy} \longrightarrow C_6H_{12}O_6+6O_2+6H_2O$
d) $6Co_2+12H_2O+\text{light energy} \longrightarrow H_2O+C_6H_{12}O_6+2H_2O$

14. For photosynthesis to occur, a plant requires...

a) Water, oxygen, light, and chlorophyll.
b) Chlorophyll, light, carbon dioxide, and oxygen.
c) Carbon dioxide, light, chlorophyll, and water.
d) Light, darkness, oxygen, and carbon dioxide.

15. Which of the following atmospheric gases will disappear first if all chlorophyll-containing in plants were to be removed?

a) Nitrogen
b) Carbon dioxide
c) Oxygen
d) Water vapour

16. The net reaction for photosynthesis produces:

a) Water and carbon dioxide.
b) Water and Oxygen.
c) Carbohydrate and carbon dioxide.
d) Carbohydrate and Oxygen.

17. A well-watered potted green plant is kept in a brightly lighted area for 48 hours. What will most likely occur if the light intensity is then reduced slightly during the next 48 hours?

a) Photosynthesis will stop completely.
b) The rate at which nitrogen is used by the plant will increase.
c) The rate at which Oxygen is released from the plant will decrease.
d) Glucose production inside each plant cell will increase.

18. A plant with pink leaves and stem is capable of photosynthesizing because of it

a) has special cells that can photosynthesize.
b) has chlorophyll which has been masked.
c) uses the pink pigment to photosynthesize.
d) possesses carotene which is efficient in photosynthesizing.

19. The deficiency of nitrate ions results to:

a) Poor synthesis of chlorophyll.
b) Yellowing of the leaf.
c) Stunted growth.
d) All the above.

20. Variegated leaf is used in an experiment to show that:

a) Water is essential for photosynthesis.
b) Sunlight is necessary for photosynthesis.
c) Chlorophyll is necessary for photosynthesis.
d) Carbon dioxide is essential for photosynthesis.

21. The type of cells which absorb most carbon dioxide during the day are:

a) Palisade mesophyll cells.
b) Guard cells.
c) Epidermal cells.
d) Mitochondria cells.

22. The entrance where gas exchange occurs into and out of the leave is called:

a) Guard cell.
b) Palisade cell.
c) Stomata.
d) Mesophyll cell.

23. One of the mineral ions required for the synthesis of Chlorophyll is:

a) Magnesium ions.
b) Sodium ions.
c) Potassium ions.

d) Calcium ions.

24. The cells which are responsible for the control of the entrance of air into and out of leaf is:

a) Guard cells.
b) Epidermal cells.
c) Mesophyll cells.
d) Palisade cells.

25. What causes plants to be usually green in colour?

a) Photosynthesis.
b) Chlorophyll.
c) Starch.
d) Glucose.

26. The two major raw materials of photosynthesis are:

a) Water and carbon dioxide.
b) Carbon dioxide and sugar.
c) Oxygen and carbon dioxide.
d) Water and oxygen.

27. Which of the following cells of the leaf lack chloroplasts?

a) Guard cells.
b) Epidermal cells.
c) Palisade mesophyll cells.
d) Spongy mesophyll cells.

28. An inorganic molecule required by green plants for the process of photosynthesis is:

a) Oxygen molecule.
b) Starch.
c) Carbon dioxide.
d) Glucose.

29. Carbon dioxide is removed from the atmosphere through:

a) Respiration.
b) Photosynthesis.
c) Decomposition.
d) Breathing.

30. The principal transport vessel for the transport of water in plants is

a) Phloem.
b) Lenticels.
c) Xylem.
d) Midrib.

31. The role of vascular bundles in photosynthesis is to:

a) Trap sunlight energy.
b) Allow sunlight to penetrate the leaf.
c) Transport manufactured food and water.
d) Absorb carbon dioxide.

32. Which could be used to monitor the rate of photosynthesis in a plant:

a) Carbon dioxide.
b) Water production.
c) Oxygen production.
d) Hydrogen production.

33. Which words are missing from the equation for photosynthesis?

Carbon dioxide (CO_2) + _____ + sunlight ---> sugar + _____

a) Sugar, nitrogen.
b) Energy, water.
c) Water, oxygen.
d) Oxygen, carbon dioxide.

34. Which of the following does not affect the rate of photosynthesis

a) Carbon dioxide concentration.
b) Light intensity.
c) Oxygen concentration.
d) Temperature.

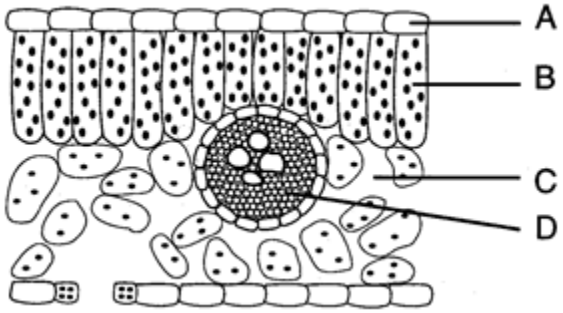
35. As a result of photosynthesis,

a) our atmosphere is now rich in oxygen gas.
b) animals can get energy directly from the sun.
c) plants convert chlorophyll into water.
d) Abundant quantities of carbon dioxide are produced.

36. The principal transport vessel responsible for the transporting of the end product of photosynthesis is:

a) Phloem.
b) Xylem.
c) Midrib.
d) Lenticels.

37. The diagram represents a cross-section of a leaf.



Which cell type absorbs most carbon dioxide during the day?

a) A
b) B
c) C
d) D

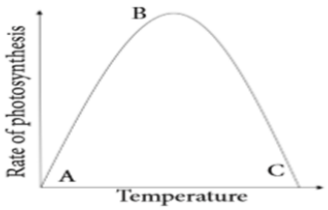
38. For photosynthesis green plants require:

a) Chlorophyll only.
b) Light.
c) Carbon dioxide and water.
d) All of the above.

39. The name of the pigment which is responsible for the absorption of light in plants is:

a) Stroma.
b) Chlorophyll.
c) Xylem.
d) Phloem.

40. The following diagram shows the effect of light intensity on the rate of photosynthesis



In the above diagram, the rate of Photosynthesis started to decrease from point B to C.

Which of the statements below best describe the main cause of the above decrease:

a) The increase of temperature above the optimum point causes the breakdown of some biological catalysts which in turn led to a decrease in the rate of photosynthesis.
b) The increase in temperature above the optimum point has caused a shortage of water through evaporation, which in turn leads to a decrease in the rate of photosynthesis.
c) The temperature above the optimum point has caused the breakdown of chemical bonds in chlorophyll which in turn led to a decrease in the rate of photosynthesis.
d) All above.