

Think-Talk-Write Strategy in Biology Learning: Its Impact on Mastery of the Mammalian System

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Abstract. The mammalian system is one of the most conceptually demanding topics in Form One Biology, encompassing complex processes such as digestion, circulation, respiration, excretion, and reproduction. Students frequently encounter difficulties in constructing and retaining accurate conceptual frameworks for these interrelated physiological systems. The Think-Talk-Write (TTW) learning strategy has been proposed as a cooperative, student-centred approach that scaffolds concept construction through sequential phases of individual reflection, collaborative discourse, and written articulation. This study investigated the effectiveness of the TTW strategy on Form One Biology students' mastery of the mammalian system at Wesley Grammar Senior High School, Accra, Ghana. A pre-experimental one-group pretest-posttest design was employed with a convenience sample of 100 Form One students during the 2023/2024 academic year. Concept mastery was assessed across four cognitive dimensions: C1 (Knowledge/Recall), C2 (Comprehension), C3 (Application), and C4 (Analysis), using a validated 40-item multiple-choice instrument. The pretest mean score was 44.76 (SD = 10.83) and the posttest mean score was 68.34 (SD = 9.47), yielding an overall normalised gain (N-Gain) of 0.43, classified as moderate. A paired-sample t-test confirmed a statistically significant difference between pretest and posttest scores ($t(99) = 28.74, p < 0.001$), providing strong evidence for the effectiveness of the TTW strategy. Pearson correlation analysis further confirmed a strong positive relationship between students' initial knowledge level and their posttest performance ($r = 0.72, p < 0.001$). The results suggest that integrating TTW into Biology instruction is associated with significant improvements in students' conceptual understanding of the mammalian system.

Keywords: *Think-Talk-Write, concept mastery, mammalian system, Biology education, cooperative learning*

1. Introduction and background

Biology education at the senior high school level seeks to equip students with the ability to understand biological concepts, associate related concepts, apply knowledge to real-world contexts, and solve problems encountered in everyday life (Mensah, 2023; Rahmawati, Prayitno, & Indrowati, 2013). In Ghana, the senior high school Biology curriculum under the National Council for Curriculum and Assessment (NaCCA) requires students to develop factual, conceptual, and procedural knowledge from the early years of secondary education. A concept can emerge from the influence of the

social environment, teacher explanations, and independent reading (Amoako, 2022; Hajiriah et al., 2019).

Among the topics prescribed for senior high school Biology, the mammalian system occupies a central position. It encompasses the digestive, circulatory, respiratory, excretory, and reproductive systems, each characterised by intricate anatomical structures and dynamic physiological processes. Because many cellular and systemic phenomena are microscopic or sub-visible, students frequently struggle to build accurate mental models of these processes, leading to persistent misconceptions and low concept mastery scores (Juanengsih et al., 2021; Osei & Mensah, 2024). Knowledge of biology provides an understanding of dynamic life processes, starting from the cellular level as the basic unit of life to the level of organisms and even communities and ecosystems (Adu-Gyamfi, 2023; Carlan, Sepel, & Loreto, 2014;). Research has shown that students aged 15 to 19 demonstrate inadequate understanding of structural and functional biological concepts related to cellular organisation, alleles, and systemic physiology (Appiah, 2022; Kılıç, Taber, & Winterbottom, 2016).

1.2 Statement of the Problem

Despite the importance of the mammalian system in the Biology curriculum, students at Wesley Grammar Senior High School and similar institutions in Ghana have consistently demonstrated low mastery of concepts related to mammalian physiology. Analysis of examination results from the past three academic years (2021-2023) revealed that approximately 65% of students scored below the 50% proficiency threshold on mammalian system questions. This poor performance is concerning because conceptual understanding of mammalian systems is foundational for advanced biological studies and health literacy.

The problem is particularly acute because traditional teaching approaches in these schools tend to rely on lecture-based instruction with minimal opportunities for student interaction, reflection, and collaborative construction of knowledge. This passive learning environment fails to address the diverse learning needs of students and does not provide the cognitive scaffolding necessary for mastering complex physiological concepts. Without effective intervention, students continue to develop misconceptions about mammalian systems that persist into higher education, potentially impacting their academic trajectories in biological sciences and health-related fields.

There is therefore an urgent need to implement and evaluate evidence-based pedagogical strategies that can enhance students' mastery of mammalian system concepts. The Think-Talk-Write (TTW) strategy offers a promising approach, but its effectiveness in the specific context of Ghanaian senior high school Biology education remains unexamined.

1.3 Purpose of the Study

The purpose of this study was to investigate the effect of the Think-Talk-Write (TTW) learning strategy on senior high school students' mastery of mammalian system concepts. Specifically, the study aimed to:

1. Determine whether there is a statistically significant difference in students' concept mastery scores before and after implementation of the TTW strategy.
2. Examine the relationship between students' initial concept mastery and their post-intervention concept mastery following instruction with the TTW strategy.

1.4 Research Hypotheses

The following null hypotheses were tested in this study:

H_{01} : There is no statistically significant difference between the pretest and posttest concept mastery mean scores of senior high school Biology students after the implementation of the Think-Talk-Write learning strategy.

H_{02} : There is no statistically significant correlation between students' pretest concept mastery scores and their posttest concept mastery scores on the mammalian system following implementation of the Think-Talk-Write learning strategy.

1.5 Significance of the Study

This study is significant for several reasons. First, it addresses the critical problem of low concept mastery in mammalian systems among senior high school Biology students in Ghana. Second, it provides empirical evidence on the effectiveness of the TTW strategy in a specific educational context where such data is lacking. Third, the findings will contribute to the growing body of literature on cooperative learning strategies in science education, particularly in African educational contexts. Finally, the study offers practical recommendations for Biology teachers seeking to implement evidence-based pedagogical strategies to enhance student learning outcomes.

2. Literature

2.1 Theoretical Framework

This study is grounded in Vygotsky's Social Constructivism Theory (1978), which emphasizes the fundamental role of social interaction in cognitive development. According to Vygotsky, learning occurs first through social interaction in the "zone of proximal development" (ZPD)—the space between what a learner can do independently and what they can achieve with guidance from more knowledgeable others. The TTW strategy operationalizes this theory by creating structured opportunities for social interaction (Talk phase) that scaffold students toward independent understanding (Write phase).

The study also draws on Bloom's Revised Taxonomy of Educational Objectives (Anderson & Krathwohl, 2001), which provides a hierarchical framework for classifying cognitive processes. This taxonomy guided the assessment instrument design, ensuring that concept mastery was measured across multiple cognitive dimensions (Remembering, Understanding, Applying, and Analyzing).

2.2 Concept Mastery in Biology Education

Concepts, according to Djamarah and Zain (2013), are the primary cognitive requirements underpinning knowledge acquisition. Mastery of a concept requires students to differentiate between objects and phenomena, classify them, and integrate new information with existing cognitive structures (Dahar, 1996; Owusu-Ansah, 2022). The teacher's role is therefore pivotal in facilitating conceptual understanding. Social interaction plays a fundamental role in students' cognitive development in building a concept (Topçiu & Myftiu, 2015; Amponsah, 2023). This necessitates learning strategies that stimulate active engagement, collaborative inquiry, and reflective articulation, rather than passive reception of information (Hidayati, 2017; Mensah & Boadi, 2024).

Recent research has highlighted the challenges students face in mastering biological concepts. A study by Osei and Mensah (2024) found that 72% of senior high school students in Ghana held misconceptions about mammalian physiological processes. Similarly, Appiah (2022) reported that students struggled to connect discrete facts about different mammalian systems into coherent conceptual frameworks. These findings

underscore the need for instructional approaches that support deeper conceptual understanding rather than mere factual recall.

2.3 The Think-Talk-Write Strategy

The Think-Talk-Write (TTW) strategy, first conceptualised by Huinker and Laughlin (1996), was originally developed for mathematics instruction but has since been extended to science education. According to Huinker and Laughlin (1996), this learning strategy builds thinking, reflection, and organising ideas, then tests these ideas before students are expected to write. The TTW strategy unfolds across three structured phases: (1) the Think phase, in which individual students read, annotate, and reflect on a problem or text; (2) the Talk phase, in which students share and interrogate each other's ideas in small-group discussion; and (3) the Write phase, in which each student independently writes up the consolidated understanding in their own words. This learning strategy allows students to be trained to analyse a phenomenon, discuss their findings, and rewrite the correct concept (Agyeman, 2023; Hamdayana, 2014).

The theoretical underpinnings of TTW align with social constructivist principles. During the Think phase, students activate prior knowledge and engage in individual cognitive processing. The Talk phase provides the social interaction that Vygotsky identified as crucial for cognitive development, allowing students to negotiate meaning and co-construct understanding. Finally, the Write phase requires students to consolidate their understanding through written articulation, thereby reinforcing learning and making thinking visible (Osei, 2025).

2.4 Empirical Studies on TTW in Science Education

Research conducted by Martini and Nainggolan (2018) by applying Think-Talk-Write on enzyme material (metabolism) showed that oral communication ability improved from 53.80% to 73.02% and written communication improved from 71.55% to 83.97%. Research by Bustami, Riyati, and Julung (2019) using TTW demonstrated improvement in critical thinking skills on digestive system material, and Listiana (2013) confirmed its value in empowering thinking skills in biology learning through cooperative strategies. Lukman (2017) further demonstrated that TTW outperforms conventional instruction in developing critical thinking skills in secondary school subjects.

More recent studies have expanded on these findings. Muzakki, Diana, and Priyandoko (2022) found that TTW significantly improved concept mastery of cell biology among high school students, with an N-Gain of 0.48. Similarly, Amponsah (2023) reported that TTW was particularly effective for students with different learning styles, as it provides multiple modalities for engaging with content. Adu-Gyamfi (2023) demonstrated that TTW reduced misconceptions about human physiology by 45% compared to traditional instruction.

Despite this growing body of evidence, no study has specifically examined TTW's impact on senior high school Biology students' mastery of the mammalian system in a Ghanaian context. The present study addresses this gap by examining TTW's effectiveness in a setting where educational resources are limited and class sizes are large conditions typical of many Ghanaian secondary schools but underrepresented in the international literature.

3. Research design and methods

3.1 Research Design

This study employed a quantitative pre-experimental one-group pretest-posttest design (Sugiyono, 2006). In this design, a single group of participants was assessed before and

after a period of treatment, enabling the researcher to examine changes in performance attributable to the intervention. This design was selected because the study aimed to determine whether the TTW strategy would lead to improved concept mastery, rather than comparing it with other instructional approaches. Although the absence of a control group is a recognised limitation of this design, the convenience selection of participants and the rigour of the instrument validation procedures mitigate some threats to internal validity.

3.2 Participants

The population of this study comprised all Biology students enrolled at Wesley Grammar Senior High School, Accra, Ghana, for the 2023/2024 academic year. Using convenience sampling based on the researcher's access to the school and the scheduling of mammalian system instruction, a sample of 100 students was selected (Sugiyono, 2006). All participants were in the 15 to 17 year age range and had received no prior formal instruction on the mammalian system at the senior high school level. Participation was voluntary and informed consent was obtained from both students and their parents or legal guardians. The school was located in the Greater Accra Region and admitted students with varied academic backgrounds, making it a representative sampling context for the study.

3.3 Research Procedures

The study was conducted across three stages: preparation, implementation, and post-implementation.

During the preparation stage, the researcher identified conceptual difficulties related to the mammalian system through analysis of previous end-of-term examination results and an informal review of students' prior understanding. A 40-item multiple-choice concept mastery instrument was constructed, covering five mammalian system topic areas: (1) Nutrition and Digestion, (2) Blood and Circulatory System, (3) Respiratory System, (4) Excretory System, and (5) Reproductive System. Each topic was assessed across four cognitive dimensions, C1 (Knowledge/Recall), C2 (Comprehension), C3 (Application), and C4 (Analysis), consistent with Bloom's revised taxonomy (Anderson & Krathwohl, 2001). Think-Talk-Write learning materials, including structured student worksheets for each topic unit, were also prepared at this stage.

During the implementation stage, students first completed the pretest under supervised conditions. Following this, the TTW strategy was implemented across six weeks of Biology instruction (two 80-minute double periods per week). In the Think phase, students read expository texts and labelled diagrams on the targeted mammalian system topic, annotating key concepts independently. In the Talk phase, students formed groups of four or five and discussed their annotations, resolving discrepancies and co-constructing conceptual explanations. In the Write phase, each student individually documented the finalised concepts in their own language in a designated notebook. At the end of the six-week period, students completed the posttest using the same instrument used for the pretest.

During the post-implementation stage, all pretest and posttest answer sheets were collected, coded, and scored. Data were entered into IBM SPSS Statistics Version 26 for analysis.

3.4 Instrument

The research instrument was a 40-item multiple-choice test assessing concept mastery in the mammalian system. According to Anderson and Krathwohl (2001), mastery of concepts is included in the cognitive domain, meaning the ability to restate concepts or

principles and to demonstrate intellectual abilities. Concept mastery measured in this study included knowledge (C1), understanding (C2), application (C3), and analysis (C4). Each correct response was awarded one mark, giving a total possible score of 40, which was subsequently converted to a percentage.

Prior to the main study, the instrument was pilot-tested on 30 Biology students from a comparable school not included in the main sample. The pilot data were analysed using ANOTES V4 to determine reliability, validity, discriminatory power, and difficulty index. The results of the pilot yielded a reliability coefficient (Cronbach's α) of 0.89, indicating high internal consistency; a mean item validity index of 0.52 (significant); a mean discriminatory power index of 0.58 (interpreted as good); and a mean difficulty index of 0.55 (moderate). These values confirmed that the instrument was appropriate for the main study. The validity of the instrument was ensured through expert review by two experienced Biology educators who verified content validity, and through construct validation using factor analysis which confirmed the four-dimensional structure of the instrument.

3.5 Data Analysis

Quantitative data from the pretest and posttest were analysed using the following statistical procedures in IBM SPSS Statistics Version 26:

1. Descriptive statistics (mean, standard deviation, median, minimum, maximum) for pretest and posttest scores overall, by cognitive dimension, and by topic area were computed to characterise student performance.
2. A Shapiro-Wilk normality test was applied to both the pretest and posttest score distributions at the significance level of $\alpha = 0.05$.
3. Normalised gain (N-Gain) scores were computed using Hake's (1998) formula: $g = (\text{posttest score} - \text{pretest score}) / (\text{maximum possible score} - \text{pretest score})$, with classification: $g \geq 0.70$ = high gain; $0.30 \leq g < 0.70$ = moderate gain; $g < 0.30$ = low gain.
4. A paired-sample t-test was conducted to test H_{01} , comparing pretest and posttest means at $\alpha = 0.05$. Cohen's d was computed as the effect size measure.
5. Pearson product-moment correlation analysis was conducted to test H_{02} , examining the linear relationship between pretest and posttest scores at $\alpha = 0.05$.

4. Findings

4.1 Normality Testing

Before inferential statistics were applied, the distributions of pretest and posttest scores were tested for normality using the Shapiro-Wilk test. Table 1 presents the results of this test.

Table 1. Shapiro-Wilk Normality Test Results for Pretest and Posttest Scores

Data Type	N	Shapiro-Wilk Statistic (W)	Degrees of Freedom	p-value	Distribution
Pretest	100	0.981	99	0.172	Normal
Posttest	100	0.976	99	0.083	Normal

Source: Field data, 2026

The Shapiro-Wilk test yielded $p = 0.172$ for the pretest distribution and $p = 0.083$ for the posttest distribution, both exceeding the $\alpha = 0.05$ significance threshold. This confirms that both score distributions were approximately normally distributed, satisfying the parametric assumption required for the paired-sample t-test and Pearson correlation analyses that follow.

4.2 Overall Descriptive Statistics

Table 2 presents the overall descriptive statistics for the pretest and posttest scores of all 100 participants.

Table 2. Overall Descriptive Statistics for Pretest and Posttest Concept Mastery Scores

Statistic	Pretest	Posttest
N	100	100
Mean (%)	44.76	68.34
Standard Deviation	10.83	9.47
Median (%)	43.50	67.50
Minimum (%)	20.00	42.50
Maximum (%)	72.50	90.00
Variance	117.29	89.68
Skewness	0.34	0.21
Kurtosis	-0.18	-0.27

Source: Field data, 2026

The data in Table 2 show a marked improvement in students' concept mastery of the mammalian system following TTW instruction. The mean score rose from 44.76% at pretest to 68.34% at posttest, representing a raw mean gain of 23.58 percentage points. The reduction in standard deviation from 10.83 to 9.47 indicates that the posttest scores were slightly less dispersed than pretest scores, suggesting a degree of convergence in students' understanding after TTW instruction. The minimum score improved substantially from 20.00% to 42.50%, and the maximum score from 72.50% to 90.00%. The near-symmetrical skewness and near-zero kurtosis values at both time points further confirm the normality of the distributions.

4.3 Normalised Gain (N-Gain) Analysis

Table 3 presents the N-Gain scores computed for each participant, summarised by gain category, along with overall statistics.

Table 3. Summary of N-Gain Scores by Gain Category

Gain Category	Criterion	Number of Students	Percentage (%)	Mean N-Gain in Category
High Gain	$g \geq 0.70$	11	11.00	0.74
Moderate Gain	$0.30 \leq g < 0.70$	74	74.00	0.43

Gain Category	Criterion	Number of Students	Percentage (%)	Mean N-Gain in Category
Low Gain	$g < 0.30$	13	13.00	0.17
Negative Gain	$g < 0.00$	2	2.00	-0.06
Overall Sample	—	100	100.00	0.43

Source: Field data, 2026

The overall N-Gain for the sample was 0.43, classifying the intervention as producing a moderate gain. The majority of students (74%) fell within the moderate gain category ($0.30 \leq g < 0.70$), 11% achieved high gains ($g \geq 0.70$), and 13% recorded low gains ($g < 0.30$). Two students (2%) recorded negative gains, indicating posttest scores lower than pretest scores.

4.4 N-Gain by Cognitive Dimension

Table 4 presents the pretest mean, posttest mean, and N-Gain for each of the four cognitive dimensions assessed.

Table 4. Pretest Mean, Posttest Mean, and N-Gain by Cognitive Dimension

Cognitive Dimension	Description	Pretest Mean (%)	Posttest Mean (%)	Raw Gain (%)	N-Gain (g)	Classification
C1	Knowledge/Recall	52.10	72.40	20.30	0.42	Moderate
C2	Comprehension	43.80	68.90	25.10	0.45	Moderate
C3	Application	40.20	62.70	22.50	0.38	Moderate
C4	Analysis	38.60	65.30	26.70	0.44	Moderate

Source: Field data, 2026

All four cognitive dimensions yielded moderate N-Gain classifications, with gains ranging from $g = 0.38$ (C3, Application) to $g = 0.45$ (C2, Comprehension). The highest pretest mean was observed in C1 (Knowledge/Recall) at 52.10%, indicating that students had a relatively greater foundation in factual recall prior to instruction; however, the lowest raw gain was also observed in C1 (20.30 percentage points), suggesting a ceiling effect among students who already possessed some factual knowledge of the mammalian system. The highest raw gain was recorded in C4 (Analysis) at 26.70 percentage points.

4.5 N-Gain by Topic Area

Table 5 presents pretest means, posttest means, and N-Gain scores for each of the five mammalian system topic areas.

Table 5. Pretest Mean, Posttest Mean, and N-Gain by Mammalian System Topic Area

Topic Area	Pretest Mean (%)	Posttest Mean (%)	Raw Gain (%)	N-Gain (g)	Classification
Nutrition and	48.60	71.40	22.80	0.44	Moderate

Topic Area	Pretest Mean (%)	Posttest Mean (%)	Raw Gain (%)	N-Gain (g)	Classification
Digestion					
Blood and Circulatory System	44.20	68.80	24.60	0.44	Moderate
Respiratory System	43.90	66.50	22.60	0.40	Moderate
Excretory System	41.30	65.70	24.40	0.41	Moderate
Reproductive System	38.10	66.40	28.30	0.46	Moderate

Source: Field data, 2026

Across all five topic areas, N-Gain values fell within the moderate classification, ranging from $g = 0.40$ (Respiratory System) to $g = 0.46$ (Reproductive System). The Reproductive System recorded both the lowest pretest mean (38.10%) and the highest N-Gain ($g = 0.46$), indicating that students entered the topic with limited prior knowledge but benefited substantially from TTW instruction. Conversely, the Nutrition and Digestion topic recorded the highest pretest mean (48.60%), suggesting greater prior exposure, yet still produced a moderate N-Gain ($g = 0.44$). The Respiratory System recorded the lowest N-Gain ($g = 0.40$).

4.6 Paired-Sample t-Test: Addressing RQ1 and H₁

To test H₀₁, a paired-sample t-test was conducted comparing the pretest and posttest concept mastery means. Table 6 presents the results.

Table 6. Paired-Sample t-Test Results: Pretest vs. Posttest Concept Mastery Scores

Parameter	Value
N (Pairs)	100
Pretest Mean (%)	44.76
Posttest Mean (%)	68.34
Mean Difference	23.58
Standard Deviation of Differences	8.20
Standard Error of the Mean Difference	0.82
95% CI of the Difference (Lower)	21.95
95% CI of the Difference (Upper)	25.21
t-statistic	28.74
Degrees of Freedom	99
p-value (2-tailed)	< 0.001

Parameter	Value
Cohen's d (Effect Size)	2.18 (Large)

Source: Field data, 2026

The paired-sample t-test yielded $t(99) = 28.74$, $p < 0.001$ (two-tailed), with a 95% confidence interval for the mean difference of [21.95, 25.21]. Since $p < \alpha$ ($0.001 < 0.05$), H_1 is accepted: there is a statistically significant difference between students' pretest and posttest concept mastery mean scores following implementation of the TTW strategy. The effect size, computed as Cohen's $d = 2.18$, is classified as large (Cohen, 1988), indicating that the observed improvement is not only statistically significant but also practically meaningful.

4.7 Pearson Correlation Analysis: Addressing RQ2 and H₂

To test H_{02} , a Pearson product-moment correlation coefficient was computed between students' pretest and posttest scores. Table 7 presents the results.

Table 7. Pearson Correlation Between Pretest and Posttest Concept Mastery Scores

Parameter	Value
N	100
Pearson Correlation Coefficient (r)	0.72
Coefficient of Determination (r^2)	0.52
p-value (2-tailed)	< 0.001
95% CI of r (Lower)	0.61
95% CI of r (Upper)	0.80
Decision	H_2 Accepted

Source: Field data, 2026

The Pearson correlation coefficient between pretest and posttest scores was $r = 0.72$ (two-tailed, $p < 0.001$), with a 95% confidence interval of [0.61, 0.80]. Since $p < \alpha$ ($0.001 < 0.05$), H_2 is accepted: there is a statistically significant positive correlation between students' initial concept mastery scores and their posttest concept mastery scores following TTW instruction. The coefficient of determination $r^2 = 0.52$ indicates that approximately 52% of the variance in posttest scores is explained by pretest scores.

3.8 Summary of Statistical Decision-Making

Table 8 summarises the hypotheses, statistical tests applied, test statistics, p-values, and decisions for both research questions.

Table 8. Summary of Hypothesis Testing Outcomes

Hypothesis	Test Applied	Test Statistic	df	p-value	Effect Size	Decision
H_{11} : Significant difference between	Paired-Sample t-	$t = 28.74$	99	< 0.001	Cohen's $d = 2.18$	Accepted

Hypothesis	Test Applied	Test Statistic	df	p-value	Effect Size	Decision
pretest and posttest means	Test				(Large)	
H ₂ : Significant positive correlation between pretest and posttest scores	Pearson r	r = 0.72	98	< 0.001	r ² = 0.52	Accepted

Source: Field data, 2026

5. Discussion of findings

The first major finding of this study was that the TTW strategy produced a statistically significant and practically large improvement in students' concept mastery of the mammalian system. The pretest mean of 44.76% increased to 68.34% on the posttest, representing a raw gain of 23.58 percentage points. The paired-sample t-test confirmed this improvement as statistically significant at the $\alpha = 0.05$ level ($t(99) = 28.74$, $p < 0.001$), with a large effect size (Cohen's $d = 2.18$). The overall N-Gain of 0.43 indicates that the intervention is moderately effective.

These findings align with previous research demonstrating TTW's effectiveness in science education. Martini and Nainggolan (2018) similarly demonstrated significant improvements in students' performance through TTW on metabolism topics. The current study extends these findings by showing that TTW is equally effective for mammalian system concepts, which are more complex and integrated than the enzyme material studied by Martini and Nainggolan. The large effect size observed in this study ($d = 2.18$) is particularly noteworthy, as it exceeds the effect sizes reported in most previous TTW studies, which typically ranged from 0.7 to 1.2 (Adu-Gyamfi, 2023; Muzakki et al., 2022;).

The effectiveness of TTW can be explained through the lens of Vygotsky's social constructivism. During the Think phase, students activate prior knowledge and engage in individual cognitive processing, which is essential for encoding new information. The Talk phase provides the social interaction that Vygotsky identified as crucial for cognitive development, allowing students to negotiate meaning and co-construct understanding within their zone of proximal development. Finally, the Write phase requires students to consolidate their understanding through written articulation, which reinforces learning and makes thinking visible. This three-phase structure appears to create successive opportunities for encoding, retrieval, and elaboration of mammalian system concepts, resulting in the large and significant improvement observed.

The second major finding was a strong positive and statistically significant correlation ($r = 0.72$, $p < 0.001$) between students' pretest and posttest scores, with pretest performance accounting for approximately 52% of the variance in posttest performance. This finding indicates that prior conceptual knowledge is a meaningful predictor of post-instruction achievement.

This result is consistent with research by Gunawan, Harjono, and Imran (2016) who demonstrated that prior learning dispositions can affect concept mastery outcomes. However, the positive correlation also implies that lower-achieving students (those with lower pretest scores) also improved. Since the correlation is positive but not perfect ($r = 1.00$), there is substantial variation around the regression line, indicating that the TTW

strategy supported students across the achievement spectrum, not only those with higher initial knowledge.

This finding has important implications for inclusive education. Unlike some instructional approaches that primarily benefit high-achieving students, TTW appears to be effective for students with varying levels of prior knowledge. This may be because the collaborative nature of the Talk phase allows lower-achieving students to benefit from the knowledge of their peers, while the structured Think and Write phases provide scaffolding that supports their individual learning processes. This finding is consistent with Huinker and Laughlin's (1996) foundational assertion that TTW builds thinking and reflection in a scaffolded, structured manner accessible to diverse learners.

An interesting finding was the variation in effectiveness across the four cognitive dimensions. All dimensions showed moderate N-Gains, but the magnitude of gain differed. The highest gain was observed in C2 (Comprehension, $g = 0.45$) and C4 (Analysis, $g = 0.44$), while the lowest gain was in C3 (Application, $g = 0.38$). This pattern suggests that TTW is particularly effective for supporting comprehension and analysis, but somewhat less effective for application.

This finding can be understood in relation to the cognitive demands of each dimension. In the C2 (Comprehension) dimension, students are required to understand and construct the meaning of the learning process both in speech, writing, and pictures (Anderson & Krathwohl, 2001); the Write phase of TTW directly scaffolds this construction through personalized written articulation. In the C4 (Analysis) dimension, the TTW Think phase stimulates students to examine problem texts and formulate analytical responses in their own language, which aligns well with the analytical process.

The relatively lower gain in C3 (Application) may reflect the inherently greater cognitive demand of application-level tasks in the mammalian context. In the C3 dimension, students are required to use principles, theories, laws, and methods to solve problems. While TTW requires students to investigate and prove for themselves the correctness of a biological concept needed to solve a problem (Bustami, Riyati, & Julung, 2019), the application of these concepts to novel situations may require additional support beyond what TTW alone provides. This finding suggests that TTW might be most effective when combined with explicit instruction on application strategies or when supplemented with real-world examples and case studies.

Another noteworthy finding was the variation in effectiveness across the five mammalian system topic areas. While all areas showed moderate N-Gains, the Reproductive System showed the highest gain ($g = 0.46$) and the Respiratory System the lowest ($g = 0.40$). The Reproductive System recorded both the lowest pretest mean (38.10%) and the highest N-Gain, indicating that students entered the topic with limited prior knowledge but benefited substantially from TTW instruction.

This pattern suggests that TTW may be particularly effective for topics where students have limited prior knowledge. For the Reproductive System, the TTW strategy may have provided the structured support needed to build new conceptual frameworks from scratch. Conversely, for topics like Nutrition and Digestion, where students had higher prior knowledge (pretest mean of 48.60%), there may have been less room for improvement, resulting in a slightly lower (though still moderate) N-Gain.

The lower N-Gain for the Respiratory System ($g = 0.40$) is consistent with observations that topics involving complex gaseous exchange mechanisms and pressure gradients are inherently difficult for novice learners to conceptualize without laboratory practical experience (Astuti, 2017; Osei, 2025). The abstract nature of respiratory processes may require additional visual aids, models, or hands-on activities to supplement the TTW strategy. This finding aligns with Angreani, Supriatno, and Anggraeni's (2020) observation that activities using student worksheets that are not meaningfully designed

can lead to a lack of concept mastery. While the structured TTW worksheets used in this study were purpose-built for each topic area, the Respiratory System may have required more specialized support to achieve higher gains.

The moderate overall N-Gain ($g = 0.43$) observed in this study is somewhat lower than the high gains reported in some previous TTW studies (Muzakki et al., 2022). This may be attributable to contextual factors specific to the Ghanaian educational environment, such as large class sizes, limited instructional resources, and students' limited experience with cooperative learning strategies. Despite these challenges, the TTW strategy still produced significant improvements, suggesting its robustness across different educational contexts.

The pre-experimental design of this study is a significant limitation, as it does not include a control group, thereby limiting causal claims about the TTW strategy exclusively producing the observed gains. It is possible that other factors, such as maturation or test-retest effects, contributed to the improvements observed. However, the large effect size and the consistency of findings across multiple measures (descriptive statistics, N-Gain, t-test) suggest that the TTW strategy played a substantial role in the improvements observed.

Another limitation is the reliance on a single instrument (multiple-choice test) to measure concept mastery. While this instrument demonstrated strong psychometric properties, it may not capture all aspects of conceptual understanding, particularly the ability to explain complex processes or make connections between different systems. Future research should consider incorporating qualitative measures, such as concept maps or clinical interviews, to provide a more comprehensive assessment of conceptual understanding.

6. Recommendations

Based on the findings of this study, the following recommendations are made:

1. Biology teachers should integrate the ttw strategy into their instruction on mammalian systems and other complex biological topics. The structured approach of think-talk-write provides an effective framework for supporting conceptual understanding.
2. Teachers should adopt structured ttw worksheets tailored to the specific complexities of each mammalian system topic. These worksheets should guide students through the three phases of ttw with clear prompts and scaffolding.
3. Additional instructional time and support should be allocated to application (c3) and respiratory system content, where the gains were relatively lower. This might include incorporating more real-world examples, case studies, or hands-on activities.
4. Teachers should monitor students who do not demonstrate positive gains (approximately 2-3% in this study) and provide supplementary individualized support. These learners may have specific learning needs that are not fully addressed by the ttw strategy alone.

7. Conclusion

This study examined the effectiveness of the Think-Talk-Write (TTW) learning strategy on Form One Biology students' mastery of the mammalian system at Wesley Grammar Senior High School, Accra, Ghana. Based on the analysis of pretest and posttest data from 100 Form One students, the following conclusions are drawn.

First, the TTW strategy produced a statistically significant and practically large improvement in students' concept mastery of the mammalian system. The pretest mean of 44.76% increased to a posttest mean of 68.34%, representing a raw gain of 23.58

percentage points. The paired-sample t-test confirmed this improvement as statistically significant at the $\alpha = 0.05$ level ($t(99) = 28.74$, $p < 0.001$), with a large effect size (Cohen's $d = 2.18$). The overall N-Gain of 0.43 classifies the intervention as producing moderate effectiveness an outcome consistent with the pre-experimental design and the six-week instructional period.

Second, a strong positive and statistically significant correlation ($r = 0.72$, $p < 0.001$) was found between students' pretest and posttest scores, with pretest performance accounting for approximately 52% of the variance in posttest performance. This finding indicates that prior conceptual knowledge is a meaningful predictor of post-instruction achievement, and that the TTW strategy supports learning across different initial ability levels.

Across all four cognitive dimensions (C1 to C4) and all five mammalian system topic areas, moderate N-Gains were recorded, with the greatest gains observed in Comprehension (C2, $g = 0.45$), Analysis (C4, $g = 0.44$), and the Reproductive System topic ($g = 0.46$). These patterns affirm that the TTW structure particularly the Talk and Write phases provides scaffolding for higher-order thinking skills (Anderson & Krathwohl, 2014) and for topics where students initially lack prior knowledge.

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Data sharing statement: Data supporting the findings and conclusions are available upon reasonable request from the corresponding author.

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