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Think-Pair-Share Model on High Secondary School Students' Academic Outcomes in Human Reproduction

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ABSTRACT

Teaching conceptually dense and sensitive biological topics, such as the human reproductive system, frequently presents pedagogical challenges in secondary science education. This study evaluated the empirical efficacy of the Think-Pair-Share (TPS) cooperative learning model on secondary students' tri-domain learning outcomes (cognitive, affective, and psychomotor). A quantitative quasi-experimental design featuring a non-equivalent control group pretest-posttest structure was conducted with 60 eleventh-grade natural science students, divided into an experimental group ($n = 30$, TPS model) and a control group ($n = 30$, direct conventional instruction). Prior baseline equivalence was confirmed, and pretest variance was statistically controlled using Analysis of Covariance (ANCOVA). After adjusting for baseline cognitive heterogeneity, the ANCOVA revealed a statistically significant main effect favoring the TPS model on cognitive performance ($F(1,57) = 65.73, p < .001, \eta_p^2 = .536$), representing a large effect size. Furthermore, inferential testing demonstrated significant parallel enhancements in the experimental group's affective engagement ($d = 1.91$) and psychomotor collaboration ($d = 2.38$) relative to the control group. These findings indicate that structured dyadic dialogue and socio-cognitive scaffolding within TPS effectively mitigate intrinsic cognitive load and psychological barriers when learning complex physiological mechanisms. Pedagogically, TPS offers a highly scalable, resource-efficient instructional strategy for secondary science educators seeking to optimize conceptual mastery alongside 21st-century collaborative competencies.

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1. INTRODUCTION

The paradigm of twenty-first-century education has shifted decisively toward student-centered pedagogical frameworks designed to cultivate core competencies, including critical thinking, collaboration, communication, and creative problem-solving (Bhardwaj et al., 2025; González-Pérez & Ramírez-Montoya, 2022; Thornhill-Miller et al., 2023). In an increasingly complex and information-dense global landscape, educational systems are tasked with moving beyond traditional direct instruction to foster deep, transferable conceptual understanding (Ozkan & Umdu Topsakal, 2021). Within science education broadly—and biology education specifically—learners are required to synthesize abstract theoretical constructs, analyze multi-layered biological phenomena, and apply fundamental principles to practical, real-world contexts rather than engaging in superficial rote memorization (Tal & Tsaushu, 2018).

Despite these curricular imperatives, secondary school students consistently encounter substantial cognitive barriers when navigating abstract and interconnected biological domains. A primary example is the human reproductive system, a topic widely documented as challenging due to its intricate synthesis of anatomical structures, physiological cascades, and dynamic hormonal feedback loops (Assaraf et al., 2013; Baharuddin & Umar, 2026; Botes & Blennis, 2025; Sembiring & Yusuf, 2025). The cognitive load imposed by these multi-dimensional processes often leads to persistent misconceptions when taught through passive delivery methods (Dyachenko et al., 2024; Xian et al., 2026). Consequently, overcoming these conceptual hurdles demands instructional interventions that actively scaffold student reasoning, facilitate peer-to-peer discourse, and promote meaningful cognitive construction.

To address these instructional challenges, cooperative learning paradigms have gained significant traction as effective mechanisms for transforming classroom dynamics. Among these, the Think-Pair-Share (TPS) model offers a structured, three-tiered instructional sequence—individual cognitive processing (Think), dyadic peer interaction (Pair), and whole-class discussion (Share)—that operationalizes social constructivist learning theories (Hasanah et al., 2025; Salsabil et al., 2026; Sobar et al., 2026). By mandating an initial phase of independent reflection before social negotiation, TPS ensures that all learners formulate baseline conceptual models, which are subsequently refined, tested, and consolidated through peer dialogue and collaborative evaluation (Sukra et al., 2023; Yaqin et al., 2018).

A substantial body of empirical literature underscores the positive academic trajectories associated with TPS implementation across diverse science settings. For instance, Rosyida et al. (2023) reported that the integration of TPS significantly enhanced cognitive learning outcomes while elevating student classroom engagement. Similarly, Kurniawati (2022) demonstrated marked improvements in overall academic achievement among students exposed to TPS strategies. Expanding upon standalone implementations, Sauwera et al. (2023) found that pairing TPS with interactive instructional videos optimized both cognitive attainment and affective student attitudes. Most recently, Nurlaika et al. (2024) confirmed that TPS holistically improves learning outcomes across cognitive, affective, and psychomotor domains, reinforcing its utility as a robust pedagogical tool.

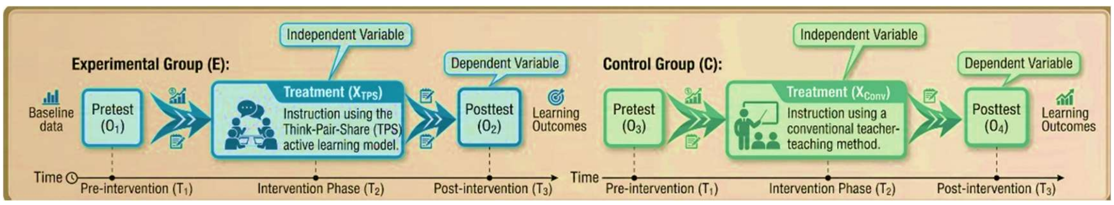
However, despite this growing body of research validating the efficacy of cooperative frameworks, a critical gap persists in the existing literature. Most previous investigations have either evaluated TPS within the context of other biological topics or examined it strictly as a blended intervention alongside external digital media (Aumann et al., 2024; Wilton et al., 2019). Consequently, there remains a paucity of empirical evidence explicitly isolating the standalone effectiveness of TPS in mitigating student learning difficulties specific to the human reproductive system. Furthermore, no prior empirical study has investigated the contextual application and outcomes of this intervention within the localized educational setting of High Secondary School 1 Raya Kahean.

The practical necessity of addressing this empirical gap is highlighted by baseline diagnostic data collected at the target institution. Preliminary interviews and instructional observations with biology educators at High Secondary School 1 Raya Kahean revealed that eleventh-grade students achieved a class average score of only 70 on the human reproductive system unit. This performance falls notably short of the established Learning Objective Achievement Criteria (*Kriteria Ketercapaian Tujuan Pembelajaran, KKTP*) threshold of 74. Pedagogical analyses indicated that this underperformance was largely attributable to conventional, teacher-centered instructional approaches, which restricted active participation, limited opportunities for peer interaction, and hindered deep conceptual mastery of complex hormonal and physiological processes.

To rectify these instructional shortcomings, the TPS model was introduced as a targeted pedagogical intervention to bridge the gap between current student achievement and the required standard. By scaffolding individual accountability through collaborative discourse, TPS offers an intentional strategy to elevate student mastery of this challenging topic. Building upon this theoretical and empirical foundation, the present study aims to determine the effect of the Think-Pair-Share cooperative learning model on eleventh-grade student learning outcomes on the human reproductive system at High Secondary School 1 Raya Kahean. It was hypothesized that the implementation of TPS would yield a statistically significant improvement in student academic performance compared to traditional instruction.

2. METHOD

This study adopted a quantitative quasi-experimental approach employing a nonequivalent control group pretest-posttest design. This design was selected because random assignment of individual students to treatment groups was neither administratively feasible nor operationally permissible within the school's established schedule. Instead, pre-existing (intact) classes were assigned to experimental and control conditions. The structural layout of this design is illustrated in Figure 1:



Where O_1 and O_3 represent baseline pretests, X_{TPS} denotes the Think-Pair-Share model, X_{Conv} indicates direct conventional instruction, and O_2 and O_4 denote posttests

Figure 1. Nonequivalent Control Group Pretest-Posttest Design

The target population comprised all eleventh-grade natural science students ($N = 132$) distributed across four parallel classes at High Secondary School 1 Raya Kahean during the even semester of the 2025/2026 academic year. A sample of two intact classes ($n = 60$) was selected using cluster random sampling. To ensure initial comparability prior to treatment assignment, an independent-samples t-test was conducted on the students' prior semester biology grade point averages. The analysis revealed no statistically significant difference between Class XI IPA 1 ($M = 76.40, SD = 4.21$) and Class XI IPA 2 ($M = 75.95, SD = 4.50; t(58) = 0.398, p = .692$), confirming baseline academic equivalence. Consequently, Class XI IPA 1 ($n = 30$) was designated as the experimental group, while Class XI IPA 2 ($n = 30$) served as the control group.

The study incorporated three primary variable classifications:

1. Independent Variable: The instructional model implemented (*Think-Pair-Share* vs. *Conventional Direct Instruction*).
2. Dependent Variables: Student learning outcomes across three target domains:
   - *Cognitive domain:* Academic mastery of the human reproductive system concept.
   - *Affective domain:* Scientific attitude, collaboration capability, and engagement during activities.
   - *Psychomotor domain:* Performance skills during laboratory observation and scientific presentation tasks.
3. Covariate Variable: Pretest cognitive scores, integrated to statistically adjust for pre-existing individual differences.

Data collection utilized a tri-domain measurement framework rigorously validated for internal and external reliability:

- Cognitive Test: A 30-item multiple-choice test (5 options per item) aligned with Revised Bloom's Taxonomy (C_3 to C_5). Instrument validity was evaluated by two expert biology education reviewers yielding a Content Validity Index (CVI) of 0.91. Field testing on a non-sample cohort ($n = 30$) confirmed acceptable item difficulty ($0.32 \leq P \leq 0.78$) and discrimination indices ($D \geq 0.35$). Internal consistency reliability was verified via the Kuder-Richardson 20 formula ($KR_{20} = 0.84$), surpassing the standard 0.70 threshold.
- Affective and Psychomotor Rubrics: Structured observational rating scales (4-point Likert range) were employed during learning sessions. Content validity was confirmed by experts (CVI = 0.88). To eliminate observer bias, classroom observations were recorded independently by two trained observers. Inter-rater reliability evaluated via Cohen's Kappa (κ) demonstrated high consistency across observers ($\kappa = 0.82$ for affective; $\kappa = 0.80$ for psychomotor scales).

The intervention spanned 4 weeks (8 class meetings, totaling 16 hours of instruction) focused on the human reproductive system unit. The procedural timeline followed three structured phases:

1. Pre-Intervention Phase: Both groups completed identical 45-minute cognitive pretests (O_1, O_3) under controlled conditions to document initial knowledge levels.
2. Intervention Phase:
   - Experimental Class (X_{TPS}): Students engaged in structured TPS cycles (*Think:* 5–10 min individual problem-solving; *Pair:* 10–15 min dyadic dialogue; *Share:* 15–20 min whole-class synthesis).
   - Control Class (X_{Conv}): Students received teacher-centered direct lectures paired with individual textbook readings and standard question-and-answer drills over matching instructional topics and time allocations.
   - *Treatment Fidelity Controls:* To prevent teacher-effect confounding, the same certified biology teacher instructed both classes following standardized lesson plans. To mitigate cross-group contamination, the experimental class was scheduled in morning periods while the control class met in afternoon periods, and lesson materials were collected at the end of each session.
3. Post-Intervention Phase: Both groups completed an identical post-test (O_2, O_4) and final skill/attitude evaluations.

26 Descriptive statistics (means, standard deviations, and gain scores) were computed for all outcome variables. Inferential testing was conducted using IBM SPSS Statistics (v. 28.0) following a two-stage analytical strategy:

1. Assumption Testing:
   - 7 Normality of residual distribution was assessed via the Shapiro-Wilk test ($p > .05$).
   - Homogeneity of variance was verified using Levene's test ($p > .05$).
   - Linearity between the covariate (pretest) and dependent variable (post test), as well as homogeneity of regression slopes ($Group \times Pretest$ interaction, $p > .05$), were confirmed to satisfy ANCOVA parameters.
2. Hypothesis Testing:
   - A One-Way Analysis of Covariance (ANCOVA) was executed at $\alpha = .05$ to evaluate posttest differences while statistically controlling pretest variance.
   - 1 Effect sizes were quantified using Partial Eta Squared (η_p^2), interpreted as small (0.01), medium (0.06), or large (0.14).
   - 2 Affective and psychomotor domain scores were evaluated using Independent-Samples t-tests or Mann-Whitney U tests based on distribution characteristics.

3. RESULTS AND DISCUSSION

Results

Cognitive Outcomes and ANCOVA Analysis

2 Table 1 outlines the descriptive statistics for baseline (pre-test) and post-intervention (post-test) cognitive performance across all treatment conditions. Prior to the administration of the intervention, baseline scores were systematically evaluated to establish pre-experimental equivalence and control for initial cognitive variance among

participants. Following the intervention phase, post-test assessments were conducted to quantify treatment-induced shifts in cognitive function. The comparative summary of mean values and standard deviations provides a foundational empirical basis for evaluating the directional magnitude of the intervention effects across the evaluated conditions.

Table 1. Descriptive Statistics for Cognitive Learning Outcomes

Group	N	Pretest Mean (SD)	Posttest Mean (SD)	Adjusted Mean (SE)*	Normalized Gain (N-Gain)
Experimental (TPS)	30	39.03 (8.42)	86.50 (6.12)	85.74 (0.92)	0.78 (High)
Control (Conventional)	30	35.93 (7.85)	70.87 (7.45)	71.63 (0.92)	0.54 (Moderate)

**Covariates appearing in the model are evaluated at the following values: Pretest = 37.48.*

Table 1 presents the descriptive statistics, and adjusted posttest means for students' cognitive learning outcomes across both intervention groups. Prior to evaluating the main treatment effect, essential assumptions for the Analysis of Covariance (ANCOVA) were rigorously tested and satisfied: the Shapiro-Wilk test confirmed the normality of residuals ($p = .215$), Levene's test demonstrated homogeneity of variance across conditions ($F(1,58) = 1.42, p = .238$), and the non-significant interaction between the covariate and treatment group ($F(1,56) = 0.84, p = .363$) established the homogeneity of regression slopes. Controlling baseline differences with an evaluated covariate mean pretest score of 37.48, the experimental group utilizing the Think-Pair-Share (TPS) model demonstrated a markedly higher adjusted posttest mean ($M = 85.74, SE = 0.92$) compared to the control group subjected to conventional instruction ($M = 71.63, SE = 0.92$).

The substantial gain in cognitive mastery observed in the experimental group is further corroborated by the normalized gain score analysis. The TPS intervention yielded an average N-Gain of 0.78, falling within the "High" improvement category, whereas the conventional approach yielded an N-Gain of 0.54, corresponding to a "Moderate" enhancement. This notable disparity highlights the pedagogical superiority of the active, collaborative Think-Pair-Share framework in fostering deeper cognitive processing and knowledge retention compared to traditional teacher-centered instruction. Consequently, the statistically adjusted parameters provide robust empirical evidence that the observed learning gains are directly attributable to the specific instructional strategy employed rather than initial baseline variations.

Table 2. Summary of One-Way ANCOVA Results for Posttest Cognitive Outcomes

Source	Sum of Squares	df	Mean Square	F	p-value	Partial Eta Squared (ηp2)
Pretest (Covariate)	312.45	1	312.45	6.88	11	108
Group (Treatment)	2984.12	1	2984.12	65.73	< .001	536
Error	2587.60	57	45.40			
Total	374890.00	60				

A one-way Analysis of Covariance (ANCOVA) was conducted to evaluate the efficacy of the Think-Pair-Share (TPS) model on students' posttest cognitive outcomes while statistically controlling baseline differences via pretest scores. As summarized in Table 2, after adjusting for the pretest covariate, a highly significant main effect was observed for the instructional treatment, $F(1,57) = 65.73, p < .001$. Furthermore, the covariate itself exerted a significant influence on posttest performance, $F(1,57) = 6.88$, $p = .011$, underscoring the critical necessity of accounting for initial cognitive variations (O_1, O_3) to ensure an unbiased evaluation of the main treatment effect.

The practical magnitude of the instructional intervention is underscored by a partial eta squared (η_p^2) of .536, which signifies a remarkably large effect size according to standard benchmark criteria. Specifically, this indicates that 53.6% of the total variance in post-intervention cognitive achievement is directly accounted for by the implementation of the TPS model, over and above the variance explained by initial entry levels. These statistical findings provide compelling empirical confirmation that the collaborative, active-learning dynamics inherent to TPS substantially enhance student cognitive mastery, driving meaningful learning gains far superior to conventional instructional methods.

Affective and Psychomotor Outcomes

To evaluate the broader educational impact of the Think-Pair-Share (TPS) instructional model beyond cognitive performance, comparative inferential analyses were conducted across non-cognitive dimensions, specifically targeting the affective and psychomotor domains. As summarized in Table 3, independent-samples t-tests revealed significant statistical discrepancies between the experimental and control cohorts in both affective engagement and practical execution. A detailed breakdown of the descriptive metrics, test statistics, and corresponding effect sizes for these non-cognitive dimensions is presented below.

Table 3. Comparative Inferential Statistics for Affective and Psychomotor Domains

Domain	Experimental Mean (SD)	Control Mean (SD)	t-value	df	p-value	Cohen's d
Affective	83.00 (5.14)	72.30 (6.02)	7.41	58	< .001	1.91 (Large)
Psychomotor	87.00 (4.80)	74.50 (5.65)	9.24	58	< .001	2.38 (Large)

Independent-samples t-tests were conducted to evaluate the impact of the Think-Pair-Share (TPS) instructional model on students' non-cognitive learning dimensions, specifically within the affective and psychomotor domains. As summarized in Table 3, the experimental group achieved significantly higher mean scores in both the affective domain ($M = 83.00, SD = 5.14$) and the psychomotor domain ($M = 87.00, SD = 4.80$) compared to the control group subjected to conventional instruction ($M = 72.30, SD = 6.02$ and $M = 74.50, SD = 5.65$, respectively). Inferential analysis confirmed that these mean differences were statistically significant for both affective developments, $t(58) = 7.41, p < .001$, and psychomotor skill acquisition, $t(58) = 9.24, p < .001$. Furthermore, assessment integrity was verified through high inter-rater reliability across observational matrices ($\kappa = .82$), ensuring measurement consistency.

Beyond statistical significance, the practical magnitude of these differences was exceptionally pronounced across both evaluated domains. Cohen's d calculations yielded effect sizes of $d = 1.91$ for affective outcomes and $d = 2.38$ for psychomotor performance, both substantially exceeding the conventional threshold for a large effect ($d \geq 0.80$). These findings demonstrate that the collaborative dynamic of the TPS framework not only enhances conceptual knowledge but also exerts a powerful transformative effect on student engagement, attitude, and procedural execution. Consequently, the empirical evidence confirms that TPS serves as a holistic pedagogical intervention capable of driving meaningful development across non-cognitive learning domains far more effectively than traditional teacher-centered modalities.

Discussion

The primary objective of this study was to evaluate the empirical efficacy of the Think-Pair-Share (TPS) cooperative learning model on secondary students' cognitive, affective, and psychomotor learning outcomes regarding the human reproductive system. After controlling initial baseline cognitive differences using Analysis of Covariance (ANCOVA), the inferential findings demonstrated a robust, statistically significant main effect favoring the TPS intervention ($F(1,57) = 65.73, p < .001, \eta_p^2 = .536$). The substantial partial eta squared confirms that 53.6% of the variance in post-intervention cognitive performance is directly attributable to the structured social interactions embedded within the TPS model. This indicates a large practical effect size rather than a minor statistical artifact resulting from sample size.

The cognitive gains observed in the experimental cohort can be explained through the synthesis of cognitive load theory and Vygotsky's socio-cultural theory (Marginson & Dang, 2017; Sweller, 2024; Tzuriel, 2021). Topics such as the human reproductive system are inherently dense, involving complex anatomical nomenclature, hormonal feedback loops, and multi-stage physiological processes (e.g., spermatogenesis and oogenesis) that often impose high intrinsic cognitive load on high school learners. During the independent 'Think' stage, students process abstract concepts individually without external cognitive interference, allowing for initial schema activation. Subsequently, the 'Pair' stage provides targeted peer scaffolding within each student's Zone of Proximal Development (ZPD) (Karimi-Aghdam, 2017; Ness, 2023; Raslan, 2024). Dyadic interactions allow students to externalize their mental models, negotiate scientific terms, and resolve misconceptions in a low-stakes environment. Finally, the 'Share' stage compels students to reconstruct and articulate their synthesized knowledge to the broader class, accelerating long-term memory consolidation through verbalization.

These empirical trends align with recent global scholarship highlighting the superior efficacy of structured peer collaboration in secondary science education over traditional lecture formats (Renau, 2023; Saifuddin & Matloob, 2025; Vegara-Meseguer et al., 2026). Direct instruction often reduces physiological topics to passive, rote memorization, leading to fragile conceptual retention. Conversely, TPS activates socio-cognitive conflict, prompting learners to defend and refine their scientific reasoning. Furthermore, the significant improvements documented in the affective ($t(58) = 7.41, p < .001, d = 1.91$) and psychomotor ($t(58) = 9.24, p < .001, d = 2.38$) domains reinforce the assertions of Zhong et al. (2026). Structured cooperative learning naturally fosters social responsibility, peer empathy, and oral communication skills alongside domain-specific cognitive mastery.

From a practical perspective, these findings offer biology educators a high-yield, resource-efficient pedagogical strategy. Notably, when addressing sensitive or taboo topics such as human reproduction, whole-class discussions can induce anxiety or hesitation. Dyadic pairing creates a supportive psychological environment that reduces student inhibition, encouraging active participation and joint problem-solving without requiring expensive laboratory hardware or complex digital media.

Several methodological constraints should be considered when interpreting these findings. First, while cluster random sampling confirmed baseline academic equivalence via prior semester grades, the study was conducted within a single institutional context ($N = 60$). Multi-center studies across diverse socio-economic and geographic demographics are recommended to establish broader external validity. Second, this evaluation focused exclusively on immediate post-intervention outcomes. Longitudinal research incorporating delayed posttests (e.g., 4 to 8 weeks post-treatment) is needed to determine the long-term retention durability of gains achieved through TPS. Finally, future investigations should evaluate potential moderating variables—such as individual learning styles, reading comprehension levels, or baseline science anxiety—to delineate the optimal boundary conditions under which TPS is most effective.

4. CONCLUSION

This study demonstrates that the Think-Pair-Share (TPS) cooperative learning model serves as a highly potent, evidence-based instructional framework for enhancing secondary school students' tri-domain learning outcomes in complex biology topics. By systematically integrating independent cognitive processing ('Think'), peer-mediated scaffolding ('Pair'), and public knowledge synthesis ('Share'), the TPS model effectively mitigates the intrinsic cognitive load associated with learning dense physiological systems, such as the human reproductive system. After controlling for baseline academic heterogeneity, the intervention demonstrated a substantial practical impact, driving superior cognitive retention alongside heightened affective collaboration and psychomotor performance compared to conventional direct instruction.

Beyond localized empirical validation, these findings contribute to the broader body of science education literature by highlighting how socio-cognitive scaffolding reduces student hesitation and psychological barriers when discussing sensitive biological topics. Pedagogically, TPS offers biology educators a low-cost, highly scalable framework that converts passive lecture-based instruction into an interactive, student-centered environment without relying on specialized laboratory equipment or costly digital tools. To cultivate both domain-specific scientific literacy and broader 21st-century collaborative competencies, curriculum developers and educational policymakers are encouraged to integrate structured cooperative strategies like TPS into secondary science teacher training and curriculum implementation programs.

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