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Differences in the Effects of Learning Styles Visual, Auditory, and Kinesthetic on Students' Collaboration Skills in Biology

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Abstract

Collaborative skills are considered 21st-century competencies in biology education, and differences in students' learning styles are believed to influence these skills. This study aims to examine the effect of three learning styles visual, auditory, and kinesthetic on students' collaboration skills in biology education. This study employs a quantitative approach with a correlational design. The research sample consisted of 168 11th-grade students majoring in natural sciences, selected through purposive sampling. Data were collected via a Likert-scale questionnaire and analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The results indicate that visual learning styles (0.088 > sig. 0.05) and auditory learning styles (0.063 > sig. 0.05) do not have a significant effect on collaborative skills. Conversely, kinesthetic learning style had a significant influence (0.021 < sig. 0.05) with a positive path coefficient (0.268) and a small F-square value of 0.044. These findings indicate that kinesthetic learning style is effective in enhancing student collaboration. The coefficient of determination indicates that learning styles as a whole explain 34% of the variation in collaboration skills, while the remaining 66% is influenced by other factors outside the research model. This study contributes to the development of learning strategies that are more oriented toward physical activities, hands-on practice, and active student engagement, which need to be further optimized as a means to improve collaboration skills.

Keywords: *Collaborative Skills, Learning Styles, and SEM-PLS*

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INTRODUCTION

In this era, students are required to master 21st-century skills, one of which is collaboration. Collaboration is the involvement of individuals in problem solving to achieve common goals (Marita et al., 2023). Through collaboration, students can interact with one another, share knowledge or ideas, and work together cohesively and help one another to solve problems (Adi et al., 2019). When students collaborate, they share their ideas, backgrounds, expertise, and different perspectives with each other. This interaction opens up opportunities for new combinations of ideas that might not have emerged if someone had worked alone (Watson, 2007). One subject that requires student collaboration is biology. Based on interviews with biology teachers at State High School 5 in Jambi City, students' collaborative skills are evident in the biology learning process that takes place in the classroom instruction needs to include activities that encourage teamwork, such as laboratory activities designed to develop students' collaborative skills (Wilson et al., 2024). In these activities, students

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generally were able to work together by dividing roles, discussing to solve problems, and exchanging opinions within groups influenced by their different learning styles.

Improving collaboration is challenging and requires a deep understanding of the factors that influence it. Some factors that influence collaboration include teacher encouragement, classroom conditions, and group dynamics (Muammar et al., 2024). Enhancing collaboration requires a comprehensive strategy, and this is in line with Asnawi et al. (2023) each student has different learning needs, so teachers need to provide a variety of learning strategies that accommodate learning styles to enable students to engage through collaboration. Several studies show that learning styles play an important role in the development of students' abilities Rahmadani et al. (2025) found that learning styles are significantly related to 21st-century skills, including critical thinking and collaboration. The findings confirm that understanding learning styles contributes to optimizing students' collaborative abilities.

Learning style is a combination of ways to process and absorb information so that the learning process can take place more easily and effectively (DePorter and Hernacki, 2010). In general, learning styles are divided into three types, commonly known as VAK (Visual, Auditory, and Kinesthetic) (Solihah et al., 2020). The concept of learning styles cannot be understood in a rigid and singular manner. This is in line with the opinion that Bruyckere et al. (2015), who state that most individuals do not fully fit into a specific learning style, and the diversity of learning style categories makes attempts to associate students with a specific style less accurate. Based on the information gathered, in biology instruction at SMAN 5 Kota Jambi, teachers stated that varying teaching methods can elicit different learning style tendencies among students.This finding aligns with the opinion of Sembiring *et al*. (2024), who state that differentiated instruction is a key strategy in accommodating the diversity of students' learning needs in biology education.

Differences in learning style preferences can influence how students interact and contribute in group work, making learning style a relevant factor in students' ability to collaborate. Unlike previous studies, which generally only found a significant relationship between learning styles and collaboration, this study not only examines the relationship between variables but also identifies the extent to which visual, auditory, and kinesthetic learning styles directly influence students' collaboration skills in biology learning through data analysis using the -Partial Least Squares (SEM-PLS). These findings are expected to provide insight into which learning styles demonstrate a statistically significant contribution to collaboration skills in biology learning.

METHOD

This study employs a correlational design with a quantitative approach. The research flowchart as shown in Figure 1, the research was conducted through several stages, starting with problem identification and literature review, followed by interviews, instrument development and validation, data collection, data analysis, discussion, and drawing conclusions. The population in this study is all grade XI students who chose the science specialization class at SMAN 5 Kota Jambi in the 2025/2026 academic year. The sample used in this study consists of students from classes XI AI, A2, A3, D2, and E1 at SMAN 5 Kota Jambi in the 2025/2026 academic year, selected based on the suitability of the research time, the willingness of the respondents, and the availability of facilities or infrastructure. The sampling technique used in this study was purposive sampling. The sample consisted of 168 students selected based on specific considerations related to the study's objectives, including respondent availability, the timing of the study, and the participants' alignment with the characteristics required for this study.

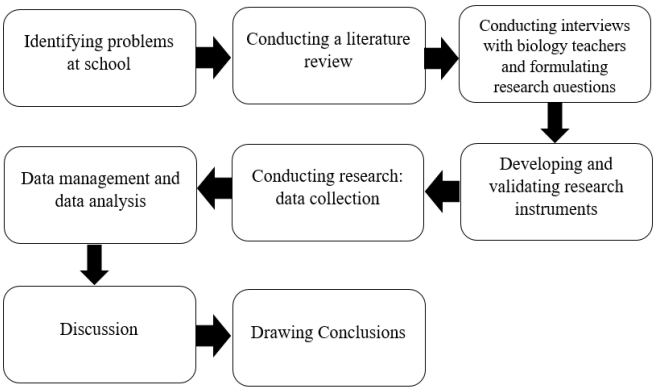


Figure 1. Research Flowchart

The data collection method used in this study was a survey. The questionnaire was distributed to students via Google Forms. The questionnaire was used to measure the variables involved in the path analysis, namely learning style as the independent variable and collaboration skills as the dependent variable. Learning style consists of visual, auditory, and kinesthetic dimensions. The instrument used in this study was a questionnaire with a Likert scale (1–6) (Taherdoost, 2019). The learning style questionnaire was developed to meet the researchers' needs and validated using Confirmatory Factor Analysis (CFA), with Cronbach's Alpha values ranging from 0.837 to 0.903. The instruments measuring student collaboration were adopted from previous research Danni et al. (2024) which has a reliable value with Cronbach's Alpha ranging from 0.740 to 0.817.

Researchers used non-parametric path analysis analyzed using the Structural Equation Modeling–Partial Least Squares (SEM-PLS) model. There were two evaluations of the testing process model conducted in stages, starting from measurement model evaluation (Outer Model) In the outer model, convergent validity, reliability, and discriminant validity tests were conducted to ensure that the indicators consistently represented the constructs and that each construct measured a different concept. Structural model (Inner Model) In the inner model, multicollinearity tests were conducted to ensure that there were no problems with the relationships between variables. Hypothesis testing was conducted through bootstrapping to assess the significance of the influence. Next, the R-square and f-square values were calculated to determine the ability of the independent variables to explain the variance of the dependent variables and the magnitude of the influence of each variable.

The authors declare that this study was classified as low or negligible risk and did not require formal Ethical Clearance under the applicable institutional requirements. Permission to conduct the research was obtained from the relevant school/institution, and appropriate ethical safeguards, including voluntary participation, consent where applicable, and protection of participant confidentiality, were implemented.

RESULTS AND DISCUSSION

The evaluation of the measurement model (Outer Model) aims to determine whether each indicator is related to its latent variable. Data analysis was performed using smartPLS 4.0 software. The following are the results of the convergent validity test based on the factor loading values presented in Figure 2.

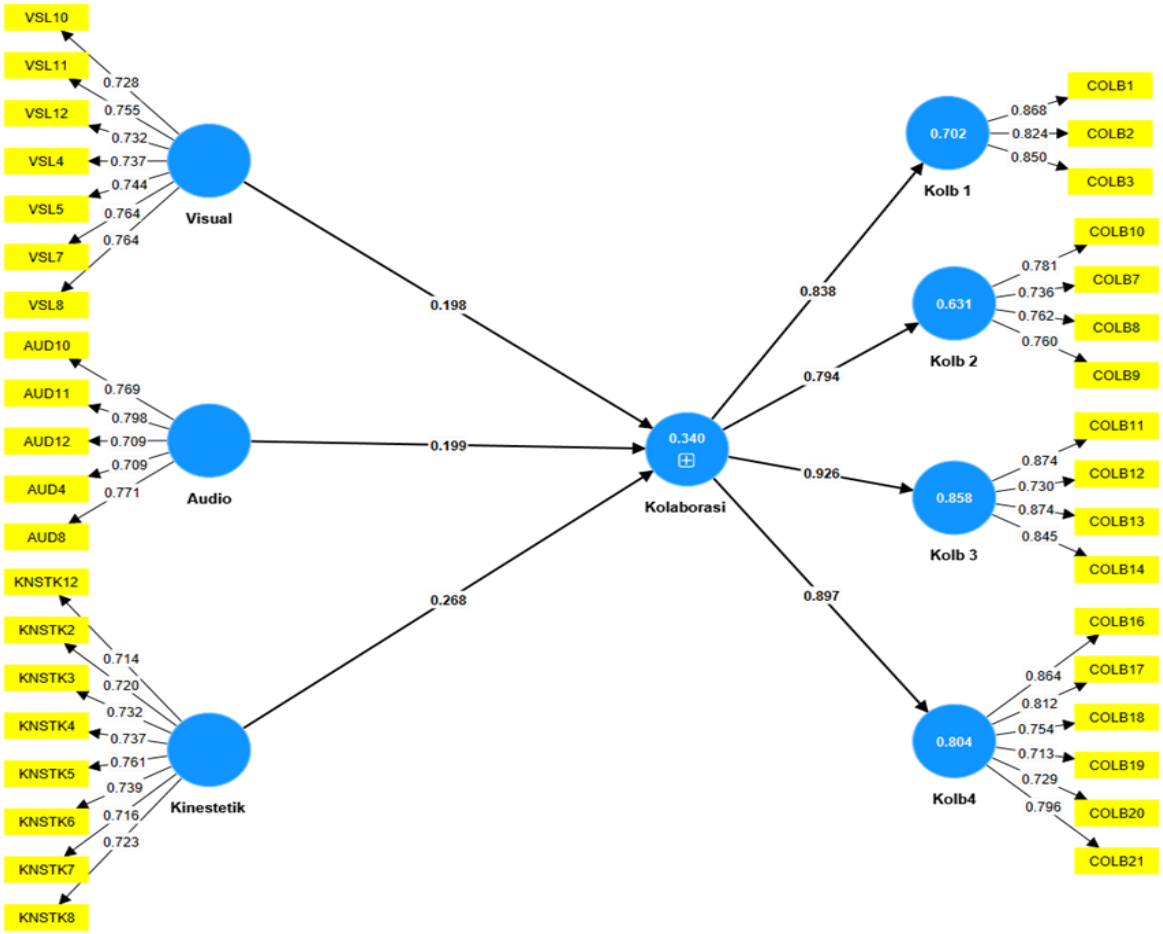


Figure 2. Model Diagram

Figure 2 presents the structural model of the study, showing the relationships between visual, auditory, and kinesthetic learning styles and students' collaboration skills. Each learning style construct is measured by several indicators, with their respective loading factor values presented to assess the validity of the measurement model. The loading factor, VIF, and AVE values for each item of the research variables are presented in Table 1.

Table 1. Results for Outer Lodiang, VIF, and AVE

Variable	Item code	*Outer Loading*	VIF	AVE
Visual	VSL4	0.737	1.832	0.557
	VSL5	0.744	1.696	
	VSL7	0.764	1.889	
	VSL8	0.764	1.828	
	VSL10	0.728	1.801	
	VSL11	0.755	1.837	
	VSL12	0.732	1.840	
Auditory	AUD4	0.709	1.607	0.566
	AUD8	0.771	1.498	
	AUD10	0.769	1.796	
	AUD11	0.798	1.633	
	AUD12	0.709	1.674	
Kinesthetic	KNSTK2	0.720	1.770	0.533
	KNSTK3	0.732	1.663	
	KNSTK4	0.737	1.939	
	KNSTK5	0.761	2.066	
	KNSTK6	0.739	1.723	
	KNSTK7	0.716	1.623	
	KNSTK8	0.723	1.732	
	KNSTK12	0.714	1.676	
Collaboration	COLB1	0.868	1.839	0.610
	COLB2	0.824	1.541	
	COLB3	0.850	1.897	
	COLB7	0.736	1.454	
	COLB8	0.762	1.915	
	COLB9	0.760	1.764	
	COLB10	0.781	1.331	
	COLB11	0.874	2.391	
	COLB12	0.730	1.556	
	COLB13	0.874	2.775	
	COLB14	0.845	2.096	
	COLB16	0.864	2.673	
	COLB17	0.812	2.071	
	COLB18	0.754	1.902	
	COLB19	0.713	1.961	
	COLB20	0.729	2.022	
	COLB21	0.796	1.933	

Table 1 shows the SEMPLS output calculation results, indicating that all indicators of each variable, such as visual, audio, and kinesthetic learning styles, as well as collaboration skills, have a factor loading value > 0.7, VIF < 5.00, and > 0.50. These results not only confirm good convergent validity but also indicate that each indicator consistently represents its construct without overlap. This consistency reinforces the credibility of the measurement model, as reliable constructs in educational research generally meet these validity thresholds (Hair et al., 2014).

Table 2. Results of the Cronbach's Alpha and Composite Reliability Tests

Variable	*Cronbach's alpha*	*Composite reliability*	Description
Visual	0.868	0.898	Reliable
Auditory	0.813	0.867	Reliable
Kinesthetic	0.875	0.901	Reliable
Collaboration	0.920	0.934	Reliable

Table 2 shows Cronbach's alpha values ranging from 0.813 to 0.920 and composite reliability between 0.867 and 0.934. According to Hair et al. (2014) Cronbach's alpha and composite reliability values greater than 0.70 indicate good reliability. Therefore, all constructs in this study meet the recommended reliability criteria, indicating that the measurement instruments demonstrate satisfactory internal consistency.

Table 3. Results of the *Heterotrait-Monotrait Ratio* (HTMT) Discriminant Validity Test

	Auditory	Kinesthetic	Collaboration	Visual
Auditory				
Kinesthetic	0.694			
Collaboration	0.524	0.588		
Visual	0.699	0.843	0.566	

Table 3 shows the results of the Heterotrait-Monotrait Ratio (HTMT) According to Henseler et al. (2015) and Hair et al. (2017) an HTMT value < 0.90 indicates that discriminant validity is fulfilled. Thus, each latent variable measures a different concept and there is no overlap in measurement between constructs. Evaluation of the structural model (inner model) was performed using R-square (coefficient of determination) for the dependent variable and F-square (effect size test).

Table 4. R-square Coefficient of Determination

	R-square
Collaboration	0.340

Table 4 shows that the R-square value of the collaboration variable is 0.340, which is categorized as small. According to Hair et al. (2014) an R-square value of 0.75 is categorized as large, 0.50 as moderate, and 0.25 as small. This indicates that the audio, kinesthetic, and visual variables are able to explain 34% of the collaboration variance, while the remainder is explained by other variables outside the research model. Next, an effect size test and hypothesis were conducted, as presented in Figure 3 and Table 5.

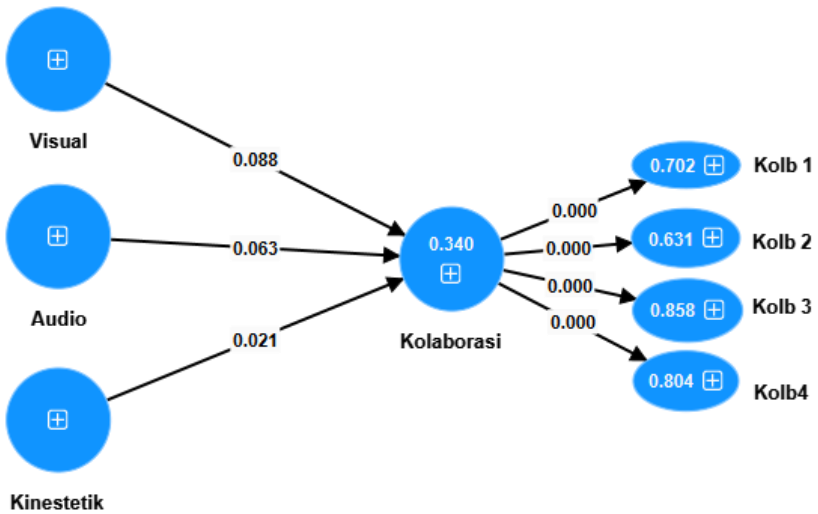


Figure 3. Bootstrapping Results

Figure 3 presents the structural model bootstrapping results, illustrating the relationships between the independent and dependent variables. Hypothesis testing results are presented based on path coefficients, T-statistics, and p-values to determine the significance of the relationships between the variables. Additionally,

Table 5 presents the effect size values (f-square) for each relationship between variables, which indicate the magnitude of the contribution of each independent variable to the dependent variable.

Table 5. Hypothesis Test Results

	Original sample (O)	*T statistics (|O/STDEV|)*	*P values*	*f-square*
Visual -> Collaboration	0.198	1.705	0.088	0.025
Auditory -> Collaboration	0.199	1.863	0.063	0.035
Kinesthetic -> Collaboration	0.268	2.314	0.021	0.044

Path coefficients are estimated values that indicate the strength and direction of the relationship between constructs. If the path coefficient is close to +1, it indicates a strong positive relationship, and vice versa for negative values (Hair et al., 2014). Hypothesis testing, where the hypothesis is considered significant if the T-statistics > 1.96 and P-values < 0.05 at a significance level of 5% (Hair et al., 2014). With the f-square value categorized into three levels of effect size, namely 0.02 small, 0.15 medium, and 0.35 large (Hair et al., 2014).

Hypothesis testing on visual learning style on collaboration did not have a significant effect with a path coefficient of 0.198, t-statistics of 1.705, and a p-value of 0.088 > sig. 0.05. Although the path coefficient shows a positive relationship, the effect is not statistically strong enough to be considered significant. In addition, the f-square value of 0.025 is relatively small, indicating that the contribution of visual learning style to collaboration skills does not have a significant impact. These findings show that students' tendency to receive and understand information visually does not directly improve their ability to work together in groups.

Theoretically, students with visual learning styles understand information through observation of images, diagrams, colors, and text, and tend to process information independently and in a structured manner (Suprapto et al., 2024). This characteristic supports a systematic understanding of concepts, but is more oriented towards individual processing. This condition has the potential to limit active involvement in interactions that are at the core of collaboration.The finding that visual learning styles do not significantly affect collaboration indicates that biology teachers need to integrate visual media. Media not only facilitates student learning, but also aims to provide various facilities for learning methods. Therefore, it is necessary to explore combinations of visual strategies with the support of visual feedback-based technology, such as visual learning analytics or generative AI, in order to improve the quality of student collaboration (Yin et al., 2025). Thus, AI supported tools can foster collaboration if designed to encourage meaningful group interaction (Suraworachet et al., 2025; Wicaksana et al., 2025)

Hypothesis testing on audio learning style did not have a significant effect on collaboration skills (path coefficient = 0.199; t-statistics = 1.863; p-value = 0.063 > sig. 0.05). Although the path coefficient shows a positive relationship, statistically the effect does not meet the significance criteria. The f-square value of 0.0345 is classified as small, indicating that the contribution of audio learning style to collaboration skills is very limited or does not have a significant impact. These findings suggest that students' tendency to receive and understand information through audio does not directly improve their collaboration skills.

This finding can be explained by the characteristics of the auditory learning style, which emphasizes listening, verbal discussion, and lectures (Kurniawan et al., 2022). Although auditory learners excel in verbal communication, this advantage does not necessarily lead to active participation in group work. This is because collaboration requires not only speaking skills, but also the ability to adapt, shared responsibility, flexibility in working together, commitment to group goals, and active contribution to task completion (Danni et al., 2024; Sugiharto and Hidayati, 2022). Therefore, biology learning needs to involve more activities that encourage teamwork, such as group projects and joint experiments, to develop students' collaboration skills (Suciati et al., 2025). Assemblr Edu is a media tool that combines materials, 3D images, audio, and text into a single unit that suits the learning styles of students (Tika et al., 2024).

Hypothesis testing regarding the kinesthetic learning style indicates that the kinesthetic learning style has a significant effect on collaboration skills (path coefficient = 0.268; t-statistic = 2.314; p-value = 0.021 < sig. 0.05). A positive path coefficient indicates that the higher the tendency toward a kinesthetic learning style, the higher the students' collaboration skills, and this effect meets the significance criteria. Although the F-square value of 0.044 is relatively small, meaning its contribution to the variation in collaboration skills is relatively low, it remains significant.

Conceptually, the kinesthetic learning style involves learning through physical activity, hands-on practice, and active engagement (Syafei, 2025). These characteristics are in line with indicators of collaboration such as working effectively, adapting, taking responsibility, and contributing to the team (Danni et al., 2024). In the

context of biology learning, collaboration encompasses various activities that involve active interaction between students, such as laboratory practices that require direct involvement in observation, group discussions that encourage students to solve problems collectively, and projects that integrate real-life situations so that the entire series emphasizes the ability to work together in a team (Sari et al., 2024). These activities can provide opportunities for students to engage directly through practice and physical activity, encouraging adaptation, contribution, and cooperation within the group (Darling et al., 2025).

This study has limitations in terms of its sample scope, as it involved only 11th-grade students; therefore, the results cannot yet be broadly generalized. Consequently, it is recommended that future research include 10th-, 11th-, and 12th-grade students to obtain more representative results. This study was limited to 11th-grade students at SMAN 5 Kota Jambi, so the findings cannot be broadly generalized to other grade levels or schools with different characteristics. In addition, the study examined only three learning style dimensions visual, auditory, and kinesthetic and their influence on students' collaboration skills, while other factors that may contribute to collaboration were not included in the research model. Future research is recommended to involve students from different grade levels and broader school contexts, as well as incorporate other relevant variables, to obtain more representative and comprehensive findings

Furthermore, these findings differ from previous studies, which generally only demonstrated a relationship between learning styles and collaboration. This study confirms that the kinesthetic learning style is more evident in practice-based biology learning, where students' direct physical engagement shapes their collaborative behavior. These results indicate that laboratory and project-based activities not only support conceptual understanding but also strengthen student collaboration. Therefore, educators need to design student-centered learning by integrating practical activities and projects, as well as combining various learning strategies to accommodate students' diverse characteristics and effectively enhance their collaborative skills.

CONCLUSION

Based on the results of the study, it can be concluded that visual and auditory learning styles do not have a significant effect on students' collaboration skills in biology learning. In contrast, the kinesthetic learning style has a significant positive effect on students' collaboration skills. These findings indicate that learning activities involving direct experience, physical involvement, practical work, and active participation are more supportive of developing students' collaboration skills. Overall, learning styles contribute to students' collaboration skills, although other factors outside the research model also play a role. Therefore, biology learning can optimize kinesthetic-oriented activities while still integrating visual and auditory approaches to accommodate students' diverse learning needs. Future research should involve broader samples and additional variables to provide a more comprehensive understanding of the factors influencing students' collaboration skills.

AUTHOR CONTRIBUTIONS

Rira Ramadhani: Conceptualization, Investigation, Resources, Data Curation, Writing - Original Draft, Project Administration, and Funding Acquisition; **Ervan Johan Wicaksana**: Validation, Resources, Writing - Review and Editing, and Supervision; **Dian Arisandy Eka Putra**: Methodology, Validation, Writing - Review and Editing, Supervision, and Project Administration; and **Muhammad Faruq Aljasry**: Writing - Review and Editing, Visualization, and Project Administration. All authors have read and approved the final version of this manuscript.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the authors upon reasonable request, subject to ethical approval and applicable institutional regulations.

DECLARATION OF COMPETING INTEREST

The authors declare no known financial conflicts of interest or personal relationships that could have influenced the work reported in this manuscript.

DECLARATION OF ETHICS

The authors declare that the research and writing of this manuscript adhere to ethical standards of research and publication, in accordance with scientific principles, and are free from plagiarism.

DECLARATION OF ASSISTIVE TECHNOLOGIES IN THE WRITING PROCESS

The authors state that Generative Artificial Intelligence (Generative AI) and other assistive technologies were used as supporting tools during the writing process of this manuscript. Specifically, ChatGPT and Grok were used during the drafting and revision stages to brainstorm ideas, refine sentence structure and academic language, improve the clarity and coherence of the manuscript, and address conceptual questions related to the research; and DeepL was used during the language translation and proofreading stages to assist with English-language translation and refinement. The authors independently reviewed, verified, and edited all AI-assisted content to ensure its accuracy, completeness, and adherence to ethical and scientific standards. The author team takes full responsibility for the content and final version of the manuscript.

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