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Implementation of STEAM-Based Educational Games and Changes in Elementary School Students' Learning Interest in South Central Timor

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ABSTRACT

Purpose: This study examined changes in elementary school students' interest in learning Mathematics and Science following the implementation of Science, Technology, Engineering, Arts, and Mathematics (STEAM)-based educational games in South Central Timor. **Methods:** This study employed a quantitative pre-experimental one-group pretest–posttest design. The participants comprised 90 students from grades I–VI at SD Inpres Besaloka, selected through total sampling. The intervention was implemented during two learning sessions. Data were collected using a five-point Likert-scale questionnaire measuring attention, interest, enjoyment, involvement, and willingness to participate in learning. Content validity was assessed through expert judgment, while instrument reliability was examined using Cronbach's alpha. Data were analyzed using descriptive statistics, the Shapiro–Wilk normality test, and a paired-samples t-test at a significance level of .05. **Findings:** Students' mean learning-interest score increased from 65.42 (SD = 8.12) before the intervention to 84.78 (SD = 6.45) after the intervention, representing a mean difference of 19.36 points. The paired-samples t-test indicated a statistically significant difference between the pretest and posttest scores, $t(89) = 18.74$, $p < .001$. The magnitude of the difference was large, Cohen's $d_z = 1.98$. These findings indicate that students demonstrated higher learning-interest scores following the implementation of STEAM-based educational games. **Research Implications:** STEAM-based educational games may provide a relevant instructional alternative for supporting students' interest in learning Mathematics and Science, particularly in resource-limited elementary school contexts. However, because this study employed a one-group pretest–posttest design without a control group, the observed changes cannot be attributed exclusively to the intervention. Further research should employ controlled experimental designs, longer intervention periods, and systematic observational measures. **Originality:** This study provides context-specific evidence regarding the implementation of STEAM-based educational games among elementary school students in a resource-limited region of Indonesia.

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INTRODUCTION

Students' interest in learning is an important affective factor in elementary education because it influences their attention, participation, persistence, and willingness to engage in learning activities. Students who demonstrate a strong interest in learning are generally more willing to explore learning materials, participate in classroom discussions, and complete academic tasks. Conversely, low learning interest may lead to passive participation, limited engagement, and difficulty sustaining attention during lessons. This issue is particularly relevant in Mathematics and Science, which are often perceived by elementary school students as abstract, difficult, and less connected to their everyday experiences. Therefore, teachers need instructional strategies that can create enjoyable, contextual, and participatory learning experiences.

One strategy that may support students' learning interest is the use of educational games. Educational games combine learning objectives with play-based activities, challenges, rules, feedback, and interaction. These characteristics can provide students with opportunities to participate actively while learning academic concepts in a less threatening environment. Previous studies have shown that educational games can support students' interest and engagement in Mathematics learning by presenting concepts through interactive and enjoyable activities (Muqoddaroh, 2024; Ni et al., 2026). Digital educational games have also been reported to support elementary school students' interest in learning Mathematics and Science by providing interactive learning experiences and opportunities for active participation (Kamandewi, 2025; Zeng et al., 2020). However, educational games need to be designed according to clear pedagogical principles so that students do not merely play but also construct meaningful conceptual understanding.

The Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach provides an interdisciplinary framework that can strengthen the educational value of learning games. STEAM-based learning integrates scientific concepts, mathematical reasoning, technological applications, engineering design, and artistic creativity in solving contextual problems. Through this approach, students are encouraged to observe phenomena, identify problems, propose ideas, test solutions, collaborate with peers, and communicate their learning outcomes. The integration of STEAM into elementary learning has been associated with the development of creativity, collaboration, and other active learning competencies among elementary school students (Muzaini, 2024; Wilson et al., 2021). In Mathematics education, STEAM-based activities can also help students understand abstract concepts through concrete experiences and contextual tasks (Hidayanthi & Siregar, 2024).

Combining educational games with the STEAM approach may provide a learning environment that is interactive, collaborative, and relevant to students' experiences. In this type of learning, students do not only respond to questions but also participate in challenges that require them to apply Mathematics and Science concepts. Game elements can encourage enjoyment and participation, while STEAM activities can provide opportunities for exploration, design, problem-solving, and collaboration. Previous studies have examined STEAM-based project learning, digital educational games, and interactive learning media separately. For example, Silahuddin et al., (2026) investigated STEAM project-based learning in relation to Mathematics interest and numeracy skills, while Tarigan et al. (2024) examined Scratch-based educational games in Science learning. These studies indicate the potential of both STEAM and educational games to support student engagement.

Nevertheless, several research limitations remain. First, many previous studies have focused on digital games, project-based learning, creativity, numeracy, or learning outcomes rather than specifically examining changes in students' interest in learning both Mathematics and Science. Second, studies integrating educational games with STEAM principles in elementary school settings remain relatively limited. Third, empirical evidence from elementary schools in resource-limited regions, particularly South Central Timor, is still insufficient. Differences in learning facilities, student characteristics, teacher support, and access to instructional media may influence how STEAM-based educational games are implemented (Khairullina et al., 2022; Kostaki & Linardakis, 2026; Susanta et al., 2025). Therefore, context-specific investigation is needed to determine whether students demonstrate changes in learning interest after participating in this type of learning.

This study employed a one-group pretest–posttest design to examine students' learning-interest scores before and after the implementation of STEAM-based educational games. Because the study did not involve a control group, it was not intended to establish a definitive causal relationship between the intervention and changes in learning interest. Instead, it focused on documenting within-group changes following the learning activities. Accordingly, the research question was formulated as follows: Is there a statistically significant difference between elementary school students' learning-interest scores before and after the implementation of STEAM-based educational games in Mathematics and Science learning? Based on this question, the study aimed to examine changes in elementary school students' interest in learning Mathematics and Science following the implementation of STEAM-based educational games at SD Inpres Besaloka, South Central Timor.

METHOD

Research Design

This study employed a quantitative approach using a pre-experimental one-group pretest–posttest design. The design was selected to examine changes in students' interest in learning Mathematics and Science before and after the implementation of STEAM-based educational games. The research design was represented as O_1–X–O_2, where O_1 represented the pretest, X represented the implementation of STEAM-based educational games, and O_2 represented the posttest. Because the study did not include a control group or random assignment, the analysis was limited to identifying within-group changes. Therefore, the findings were not interpreted as definitive evidence that the observed changes were caused exclusively by the intervention. Other factors, including testing effects, maturation, classroom conditions, and students' previous learning experiences, could not be fully controlled.

Research Setting and Participants

The study was conducted at SD Inpres Besaloka, South Central Timor Regency, during the odd semester of the 2025/2026 academic year. The participants consisted of 90 students from Grades I to VI. Total sampling was employed because all students enrolled at the school were included as research participants. No analysis was conducted to compare learning-interest changes across grade levels. Therefore, the participants were analyzed as one group. Considering the differences in reading ability between lower- and upper-grade students, questionnaire administration should be conducted under researcher or teacher supervision. For students who experience reading difficulties, assistance should be limited to reading the instructions and questionnaire statements without directing them toward particular responses.

STEAM-Based Educational Game Intervention

The intervention was implemented during two learning meetings. The learning activities integrated educational game elements with Science, Technology, Engineering, Arts, and Mathematics components. Students participated in group-based challenges that required them to discuss problems, apply Mathematics and Science concepts, propose solutions, and communicate the results of their activities. The intervention followed five main stages. First, the teacher introduced the learning objectives and presented a contextual problem. Second, the teacher explained the educational game procedures and organized students into groups. Third, students participated in the STEAM-based educational game and completed the assigned challenges collaboratively. Fourth, each group discussed and presented its results. Fifth, the teacher facilitated reflection, provided feedback, and guided students in drawing conclusions.

The first meeting included an introduction to the learning activities, administration of the pretest, presentation of the contextual problem, explanation of the game procedures, and initial group activities. The second meeting consisted of continued game activities, group discussion, presentation of results, reflection, conclusion, and administration of the posttest. To improve the replicability of the intervention, the authors should attach the lesson plan, game instructions, materials, student worksheets, and scoring rules as supplementary documents. The current manuscript does not provide sufficient information regarding the specific game format, Mathematics and Science topics, duration of each activity, number of groups, or number of students in each group.

Research Instruments

Learning-Interest Questionnaire

Students' interest in learning Mathematics and Science was measured using a learning-interest questionnaire. The instrument employed a five-point Likert scale and covered five indicators: attention, interest, enjoyment, involvement, and willingness to participate in learning. Higher total scores indicated greater interest in learning Mathematics and Science.

The questionnaire was administered before and after the intervention using the same items and scoring procedures. During questionnaire administration, students were informed that their responses would not affect their academic grades. Assistance for younger students, when necessary, was limited to reading or clarifying the wording of the statements without influencing their responses.

The manuscript states that content validity was examined through expert judgment and that internal consistency was assessed using Cronbach's alpha. However, the number of validators, validation method, number of questionnaire items, and reliability coefficient were not available in the reported data. Therefore, numerical claims regarding validity and reliability cannot be included until the original instrument-validation records are retrieved.

Student Activity Observation

A student activity observation sheet was used to document the implementation of the educational games and students' participation during the learning process. The observation focused on students' attention to instructions, participation in group activities, contribution to discussions, cooperation, communication, and completion of learning tasks.

Because the manuscript did not report a rating scale, observer training, inter-rater agreement, or quantitative observation results, the observation data were treated only as descriptive supporting information. The observation findings were not included in the inferential analysis and were not used to claim that the intervention caused improvements in collaboration, engagement, or meaningful learning. Consequently, statements claiming that student activities became more active, collaborative, interactive, or meaningful should be removed from the abstract and results unless quantitative observation data and a clear scoring procedure are available.

Data Collection Procedure
Data collection was conducted in four stages. First, the researchers prepared the learning materials, STEAM-based educational games, questionnaire, and observation sheet. Second, the learning-interest questionnaire was administered as a pretest before the intervention. Third, students participated in STEAM-based educational game activities during two learning meetings. Fourth, the same questionnaire was administered as a posttest after all learning activities had been completed. The pretest and posttest were administered using equivalent instructions and scoring procedures. Each student's pretest and posttest responses were matched using an identification code to permit paired-data analysis.

Data Analysis
The data were analyzed using descriptive and inferential statistics. Descriptive analysis included the mean, standard deviation, frequency, percentage, and learning-interest category for the pretest and posttest scores. For each participant, a difference score was calculated using the following formula:

$$D_i = Posttest_i - Pretest_i$$

The normality assumption was assessed using the Shapiro–Wilk test on the difference scores rather than by examining the pretest and posttest scores separately. The distribution of the difference scores should also be examined using a histogram and a Q–Q plot. When the difference scores were approximately normally distributed, a paired-samples t-test was used to compare the pretest and posttest scores. If the normality assumption was substantially violated, the Wilcoxon signed-rank test was used. Statistical significance was established at $p < .05$. The paired-samples analysis was reported using the mean difference, standard deviation of the difference scores, 95% confidence interval, t statistic, degrees of freedom, p value, and effect size. Cohen's dz was calculated using:

$$d_z = \frac{t}{\sqrt{n}}$$

All statistical analyses were conducted using IBM SPSS Statistics.

RESULTS

The study involved 90 elementary school students from Grades I to VI at SD Inpres Besaloka, South Central Timor. All participants completed the learning-interest questionnaire before and after participating in two sessions of STEAM-based educational games. Descriptive statistics for the pretest and posttest scores are presented in Table 1.

Table 1. Descriptive Statistics of Learning-Interest Scores

Measurement	*n*	Mean	Standard deviation
Pretest	90	65.42	8.12
Posttest	90	84.78	6.45
Difference score	90	19.36	9.80

The mean learning-interest score was 65.42 (*SD* = 8.12) before the implementation of STEAM-based educational games and 84.78 (*SD* = 6.45) after the implementation. The mean within-participant difference was 19.36 points (*SD*diff = 9.80), indicating that the posttest scores were, on average, higher than the pretest scores. The distributions of students across the learning-interest categories are presented in Table 2.

Table 2. Distribution of Learning-Interest Categories

Category	Pretest, *n* (%)	Posttest, *n* (%)
Very high	5 (5.56%)	33 (36.67%)
High	16 (17.78%)	42 (46.67%)
Moderate	41 (45.56%)	13 (14.44%)
Low	22 (24.44%)	2 (2.22%)
Very low	6 (6.67%)	0 (0.00%)
Total	**90 (100%)**	**90 (100%)**

Descriptively, the proportion of students classified in the high and very high categories increased from 23.34% at the pretest to 83.34% at the posttest. In contrast, the proportion of students in the low and very low categories decreased from 31.11% to 2.22%.

However, these categorical results should be interpreted only after the score intervals used to define the very low, low, moderate, high, and very high categories are clearly described in the Method section. The classification criteria should be supported by the instrument guidelines or an established scoring procedure.

Paired-Samples Analysis

A paired-samples *t*-test was conducted to examine whether students' learning-interest scores differed between the pretest and posttest measurements. The results are presented in Table 3.

Table 3. Paired-Samples *t*-Test Results

Comparison	Mean difference	*SD* of difference	*SE*	95% CI of difference	*t*	*df*	*p*	Cohen's *dz*
Posttest–pretest	19.36	9.80	1.03	[17.31, 21.41]	18.74	89	< .001	1.98

The paired-samples *t*-test showed that the posttest learning-interest scores were significantly higher than the pretest scores, with a mean difference of 19.36 points, 95% CI [17.31, 21.41], $t(89) = 18.74$, $p < .001$. The standardized within-participant difference was large, Cohen's $dz = 1.98$.

These findings indicate a statistically significant change in students' learning-interest scores following the implementation of STEAM-based educational games. Nevertheless, because the study used a one-group pretest–posttest design without a control group, the observed change cannot be attributed exclusively to the intervention.

DISCUSSION

The findings showed that students' mean learning-interest score increased from 65.42 (SD = 8.12) at the pretest to 84.78 (SD = 6.45) at the posttest. The mean difference of 19.36 points was statistically significant, t (89) = 18.74, p < .001, with a large within-participant effect size, Cohen's dz = 1.98. These findings indicate that students reported higher interest in learning Mathematics and Science after participating in two sessions of STEAM-based educational games. Nevertheless, the results represent a within-group change and should not be interpreted as definitive evidence that the intervention was the sole cause of the increased scores.

The increase in students' learning-interest scores is generally consistent with research on game-based learning. Educational games can provide structured challenges, immediate feedback, opportunities for active participation, and clearly defined learning goals. A meta-analysis by Clark et al. (2016) and Tsai & Tsai (2018) showed that digital games can support student learning, although the magnitude of the outcomes depends on the design characteristics of the games and the quality of the comparison conditions. Similarly,Wouters et al. (2013) found that serious games may support cognitive and motivational outcomes, but motivational advantages are not always consistent across studies. Sailer & Homner (2020) and Huang et al. (2019) also reported positive effects of gamification on motivational, cognitive, and behavioral learning outcomes while emphasizing that the effectiveness of game elements depends on their instructional design. Therefore, the positive change observed in the present study may be related to the participatory and challenging nature of the games, but it cannot be assumed that the use of game elements automatically produces sustained learning interest.

This interpretation is reinforced by Dichev & Dicheva (2017) who concluded that empirical evidence regarding gamification in education remains dependent on context, implementation quality, intervention duration, and research design. The use of scores, challenges, rules, competition, or rewards may initially attract students' attention, but these elements must be pedagogically connected to the intended learning content. Consequently, the higher posttest scores in this study should be understood as evidence of students' immediate affective responses following the learning activities rather than proof of a permanent improvement in their interest in Mathematics and Science.

Previous empirical studies at the elementary-school level also support the potential of game-based learning to encourage positive motivational responses. Tüzün et al. (2009) found that computer-game-supported instruction was associated with positive changes in primary school students' achievement and motivation. Partovi & Razavi (2019) similarly reported that elementary students participating in game-based learning demonstrated stronger academic achievement motivation and more positive attitudes toward Science than students receiving conventional instruction. In Mathematics education, the meta-analysis conducted by Tokac et al. (2019) found that game-based learning was generally associated with better achievement than traditional instructional approaches. Although these studies support the educational potential of games, their outcomes cannot be directly equated with the present findings because they involved different subjects, game formats, intervention durations, comparison conditions, and outcome variables.

The integration of game-based learning with STEM or STEAM principles may have made the activities more contextual by connecting Mathematics and Science concepts with challenges, exploration, and problem-solving tasks. A meta-analysis by Fitriyah et al. (2025) showed that digital game-based STEM learning can support achievement, but its outcomes vary according to educational level, disciplinary content, game platform, and intervention duration. Gui et al. (2023) likewise found that the effectiveness of digital educational games in STEM education depends not only on whether a game is used but also on the correspondence between game design and instructional objectives. In the present study, the combination of educational games and STEAM activities may have provided students with an alternative learning experience that differed from their regular classroom instruction. However, because the study did not compare STEAM-based games with non-STEAM games or conventional STEAM instruction, the specific contribution of the STEAM components cannot be isolated.

The findings should also be interpreted in relation to the conceptual diversity of STEAM education. Perignat & Katz-Buonincontro (2019) noted substantial variation in the definitions, disciplinary integration, learning activities, and outcomes associated with STEAM. Quigley et al. (2017) emphasized that effective STEAM teaching requires more than the simultaneous inclusion of Science, Technology, Engineering, Arts, and Mathematics labels; it requires coherent disciplinary integration, problem-based learning, and purposeful instructional facilitation. Kang (2019) review similarly showed that the outcomes of integrated STEM and STEAM education are influenced by curriculum design, teacher competence, school context, and the quality of implementation. Therefore, the present study should explain more explicitly how each STEAM component was represented in the educational games and how the components were connected to the Mathematics and Science learning objectives.

The large within-group effect size found in this study should be interpreted cautiously. A large Cohen's dz indicates that the difference between the two measurement occasions was substantial relative to the variability of the difference scores. However, an effect size calculated from a one-group pretest–posttest design does not separate the intervention effect from testing, maturation, history, regression to the mean, or other external influences. Marsden & Torgerson (2012) emphasized that single-group pretest–posttest designs cannot establish whether observed changes would also have occurred without the intervention. Dimitrov & Rumrill (2003) similarly explained that the measurement of change using pretest and posttest scores requires attention to test reliability, gain-score properties, and the availability of an appropriate comparison condition. Therefore, the large effect size in this study represents the magnitude of the observed within-group difference rather than an unbiased causal treatment effect.

One possible alternative explanation is the testing effect. The same learning-interest questionnaire was administered before and after the intervention. Exposure to the pretest may have sensitized students to the purpose of the research or encouraged them to provide more favorable responses during the posttest. Students may also have remembered the wording or response patterns of the questionnaire items. Because no control group completed the questionnaire without receiving the intervention, the influence of repeated measurement cannot be distinguished from changes associated with the learning activities.

A second possible explanation is the novelty effect. The intervention was implemented during only two meetings, and STEAM-based educational games may have represented a new or unusual classroom experience for the students. The posttest was administered immediately after the activities, meaning that the scores may reflect temporary enjoyment, enthusiasm, or curiosity rather than stable learning interest. Research on gamification indicates that initial motivational responses can decline as learners become familiar with the activity, particularly when game elements are not continuously connected to meaningful instructional goals (Dichev & Dicheva, 2017; Sailer & Homner, 2020). A delayed posttest would therefore be required to determine whether the observed change was maintained after the novelty of the educational games had diminished.

A third consideration concerns the influence of the teacher, researchers, and observation process. During the intervention, students may have received more attention, encouragement, feedback, or assistance than they ordinarily received during Mathematics and Science lessons. Awareness of being observed may also have affected students' participation and questionnaire responses. McCambridge et al. (2014) explained that research participation and observation can produce behavioral responses, although the mechanisms and magnitude of such effects vary across contexts. Because teacher behavior and implementation fidelity were not systematically quantified in the present study, it is difficult to determine whether the change in learning-interest scores was associated primarily with the games, the STEAM structure, increased teacher attention, researcher presence, or a combination of these factors.

Differences among students from Grades I to VI also require consideration. Students at these grade levels differ substantially in reading fluency, cognitive development, prior Mathematics and Science knowledge, attention span, and ability to understand Likert-scale statements. The use of the same questionnaire across all grade levels may have introduced measurement variation, particularly when the instrument's age appropriateness and measurement invariance were not examined. In addition, younger and older students may have responded differently to the complexity of the games, group arrangements, and STEAM tasks. The aggregate analysis of all 90 participants may therefore conceal grade-specific response patterns. Future studies should either analyze lower and upper grades separately or demonstrate that the questionnaire measures learning interest equivalently across the participating age groups.

Claims concerning creativity, communication, collaboration, critical thinking, problem-solving ability, and conceptual understanding should not be made on the basis of the present results. Although these competencies are frequently associated with STEAM and game-based learning, the study measured only students' self-reported learning interest. Perignat & Katz-Buonincontro (2019) cautioned that STEAM studies frequently describe creativity and interdisciplinary competencies as expected outcomes without assessing them through sufficiently defined instruments. Similarly, the conceptual model developed by Quigley et al. (2017) and Herro et al. (2017) indicates that collaboration, inquiry, and problem solving are instructional processes that must be operationalized and investigated rather than assumed to have developed merely because students participated in STEAM activities.

The student activity observation sheet mentioned in the method could potentially provide supporting evidence about participation during the intervention. However, the absence of a clearly defined rating scale, observer agreement, indicator scores, and quantitative observation results prevents the data from supporting claims that students became more collaborative, communicative, active, or meaningfully engaged. Unless the observational results can be reported transparently, classroom behaviors should be presented only as informal observations and not as confirmed research outcomes.

Despite these limitations, the findings provide useful preliminary evidence from an elementary school in South Central Timor. The results indicate that STEAM-based educational games are feasible to implement and that students reported higher learning interest immediately after participating in the activities. This contextual evidence is valuable because the implementation of educational innovations may be influenced by local resources, teacher preparation, school facilities, and student characteristics. Nevertheless, the practical implication should be formulated cautiously: STEAM-based educational games can be considered a promising instructional alternative for supporting students' interest, but their effectiveness has not yet been conclusively established.

Future studies should employ a quasi-experimental or randomized controlled design involving a comparison group, a longer intervention period, and delayed posttests. Researchers should also examine grade-level differences, use age-appropriate and psychometrically validated instruments, report intervention-fidelity data, and systematically analyze classroom observations. Creativity, communication, collaboration, critical thinking, conceptual understanding, and problem-solving skills should be assessed using separate instruments when these constructs are proposed as research outcomes. These methodological improvements would make it possible to determine whether the observed changes are sustained and whether they can be attributed more confidently to STEAM-based educational games.

CONCLUSION

This study identified a statistically significant increase in elementary school students' interest in learning Mathematics and Science following two sessions of STEAM-based educational games at SD Inpres Besaloka, South Central Timor. The mean score increased from 65.42 ($SD = 8.12$) at the pretest to 84.78 ($SD = 6.45$) at the posttest, with a mean difference of 19.36 points, $t(89) = 18.74$, $p < .001$, and a large within-group effect size, Cohen's $dz = 1.98$. These findings indicate that students reported higher learning-interest scores after participating in the learning activities. However, the results should be interpreted as preliminary evidence of change within one group rather than conclusive evidence of a causal effect. Because the study used a one-group pretest–posttest design without a control group, the observed increase cannot be attributed solely to the STEAM-based educational games. Testing effects, the novelty of the activities, teacher support, participant awareness, and differences among students from Grades I to VI may also have influenced the posttest scores. The contribution of this study is therefore limited to providing initial, context-specific evidence regarding the implementation of STEAM-based educational games in one elementary school in South Central Timor. The findings cannot be generalized to other schools, regions, grade levels, or student populations. Nevertheless, they suggest that this instructional approach warrants further investigation as a potentially engaging alternative for Mathematics and Science learning. Future studies should employ control or comparison groups, longer intervention periods, delayed posttests, age-appropriate validated instruments, and grade-level analyses. Systematic observation and implementation-fidelity data should also be included to determine whether changes in learning interest are sustained and can be attributed more confidently to the intervention.

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AUTHOR CONTRIBUTION STATEMENT

BIS and RES contributed to conceptualization, methodology, supervision, validation, writing – original draft, and writing – review & editing. YMC and B contributed to methodology, formal analysis, investigation, resources, and writing – review & editing. AR, K and RL contributed to data curation, investigation, project administration, and writing – original draft. All authors have read and approved the final version of the manuscript.

AI DISCLOSURE STATEMENT

The authors used ChatGPT (OpenAI) during the preparation of this work for limited language editing and grammar improvement. After using the tool, the authors carefully reviewed and revised the manuscript and take full responsibility for the accuracy, integrity, and content of the publication.

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