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Ruma Bolon-based IPAS instruction for strengthening elementary students' critical thinking skills

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Abstract

This study examines how *Ruma Bolon*-based IPAS instruction can strengthen elementary students' critical thinking skills while sustaining Toba Batak cultural values as learning resources. Using an explanatory mixed-methods design, the study involved 30 fourth-grade students in Medan Helvetia District. Quantitative data were gathered through a validated critical-thinking test, supported by interviews, classroom observations, questionnaires, and documentation. Instrument validation showed strong content validity (CVI = 0.91), valid item coefficients (0.42-0.81), and high reliability for the critical-thinking test (Cronbach's alpha = 0.88) and student perception questionnaire (Cronbach's alpha = 0.86). The quantitative findings showed increases in analytical skills from 40% to 70%, synthesis skills from 50% to 75%, and evaluation skills from 60% to 80%; the average score rose from approximately 65% to 85%. A paired-sample t-test confirmed the improvement, $t(29) = 16.84$, $p < 0.001$, with a large effect size (Cohen's $d = 1.92$) and a normalized gain of approximately 0.60. Qualitative findings indicated that *Ruma Bolon* symbols, spatial organization, and values such as cooperation and social harmony helped students relate IPAS concepts to familiar cultural experiences. The integration of local culture made classroom discussion, project work, and evaluation tasks more meaningful. These findings suggest that culturally grounded IPAS instruction can support critical thinking, creativity, and cultural appreciation when it is designed through clear learning indicators and valid assessment procedures.

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1. Introduction

Natural and Social Sciences (IPAS) in elementary school is intended to help students read natural and social phenomena as connected experiences rather than as separate bodies of factual knowledge. In practice, however, IPAS learning often still privileges explanation, note-taking, and short-answer recall. Such instruction may support basic comprehension, yet it gives students limited space to compare evidence, question assumptions, test explanations, and justify conclusions. This tension is central to the present study because critical thinking in IPAS depends on repeated opportunities to analyze relationships between concepts, synthesize information from different sources, and evaluate decisions in contexts that students can recognize.

Evidence from elementary schools in Medan Helvetia indicates that students' initial critical-thinking performance remained below the expected threshold for higher-order thinking. Preliminary classroom data showed pretest averages in the range of 53-58, while evaluative reasoning and argumentation were still difficult for more than 65% of students. These findings are consistent with studies reporting that teacher-centered learning, limited inquiry media, and weak links between school concepts and local contexts reduce students' participation in analytical discussion (Lumbanbatu et al., 2024; Viqri et al., 2024). The issue, then, is not simply low achievement. It concerns the mismatch between the contextual nature of IPAS and instructional practices that do not yet fully use students' cultural and environmental experiences as resources for reasoning.

Ruma Bolon, the traditional house of the Toba Batak community, offers a culturally rich learning context for addressing this gap. Its architecture, spatial organization, ornaments, and social meanings embody values of cooperation, kinship order, ecological awareness, and collective responsibility. When these values are translated into IPAS tasks, students can observe how cultural artifacts connect with concepts of environment, social interaction, materials, space, and community life. In this sense, local culture does not function as decorative content added to the lesson; it becomes a bridge that helps students move from familiar experience toward scientific and social reasoning.

Previous studies have examined problem-based learning, inquiry learning, and local wisdom-based instruction in elementary education. Fewer studies, however, have mapped a specific Toba Batak cultural artifact into a structured IPAS intervention and then tested its relation to distinct indicators of critical thinking, especially analysis, synthesis, and evaluation. The novelty of this study lies in positioning *Ruma Bolon* as both cultural content and pedagogical scaffold. Accordingly, this study aims to examine whether IPAS instruction integrated with the creative values of *Ruma Bolon* improves fourth-grade students' critical thinking skills and how teachers and students interpret the learning process. The quantitative hypothesis is that students' posttest scores will be higher than their pretest scores after the intervention, while the qualitative strand explains how cultural relevance supports engagement, discussion, and project-based reasoning.

2. Literature Review

2.1 Critical thinking in IPAS learning

Critical thinking in elementary IPAS refers to students' capacity to interpret information, analyze relations among natural and social phenomena, draw reasoned conclusions, evaluate explanations, and communicate arguments with evidence. Facione (2015) describes critical thinking through interpretation, analysis, evaluation, inference, explanation, and self-regulation,

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while Ennis (2018) stresses clarity, evidence, inference, and reflective judgment. In the present study, these broad constructs were operationalized through three observable indicators that match the IPAS tasks: analysis, synthesis, and evaluation. Analysis concerns students' ability to identify relations among concepts; synthesis refers to combining information into a coherent explanation or product; evaluation concerns judging the adequacy of reasons, evidence, and solutions.

Instructional models such as problem-based learning, inquiry learning, discovery learning, and the 5E learning cycle have been associated with stronger critical thinking because they require students to examine problems rather than merely reproduce answers (Haryanti et al., 2022; Arzyana, 2024; Martir, 2024). These models share a common assumption: students learn more deeply when they are asked to make claims, use evidence, collaborate, and revise their thinking. Within IPAS, this assumption is particularly relevant because the subject integrates scientific and social concepts that students encounter in daily life. The weakness in many applications, however, is that inquiry tasks are often detached from students' cultural world. This study addresses that limitation by embedding critical-thinking tasks within a Toba Batak cultural context.

2.2 Culture-based learning and creativity

Culture-based learning treats local knowledge as a source of meaning, not as supplementary illustration. From a constructivist perspective, students build understanding through social interaction and familiar experiences (Vygotsky, 1978). Culturally responsive teaching extends this idea by arguing that students' cultural references can support participation, confidence, and academic reasoning when they are connected carefully to curricular goals. In IPAS, this connection is valuable because students can examine natural and social phenomena through examples close to home, family practices, and community life.

Creativity strengthens this process by encouraging students to generate ideas, design products, and connect prior experience with new concepts. Creativity in learning involves fluency, flexibility, originality, and elaboration; it also requires students to assess the usefulness and relevance of their ideas (López et al., 2024; Mayuni et al., 2024). When local culture becomes a learning resource, creativity is not separated from reasoning. Students must decide which cultural symbols are relevant, how they can explain an IPAS concept, and why a proposed project or solution is reasonable. This is the point at which creativity and critical thinking become mutually reinforcing.

2.3 *Ruma Bolon* as a source of creativity values

Ruma Bolon is not only an architectural object. In *Toba Batak* society, it represents social order, kinship, collective life, and the relationship between humans and their environment. Its raised structure, spatial arrangement, ornaments, and communal functions provide concrete entry points for IPAS learning. For example, the house structure can be linked to materials, environmental adaptation, and spatial reasoning; its communal functions can be linked to social relations, cooperation, and responsibility; and its symbolic meanings can prompt students to compare cultural values with contemporary environmental and social problems.

Values such as *gotong royong*, *dalihan na tolu*, social harmony, and respect for nature can therefore be converted into classroom activities that ask students to observe, classify, explain, design, and evaluate. Students may analyze why the structure of *Ruma Bolon* fits a particular environment, synthesize cultural and scientific information into a miniature model or written explanation, and evaluate how traditional values can inform solutions to present-day community

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issues. This form of learning gives *Ruma Bolon* a clear pedagogical function: it becomes a scaffold for analytical, synthetic, and evaluative thinking rather than an isolated cultural topic (Situmorang et al., 2025; Sinulingga et al., 2025).

2.4 Conceptual framework

The conceptual framework of this study integrates constructivist learning, Bloom's taxonomy (Anderson & Krathwohl, 2001), and culturally responsive teaching. Constructivism explains why students need meaningful social interaction and contextual experience; Bloom's taxonomy (Anderson & Krathwohl, 2001) clarifies the progression from understanding to analysis, evaluation, and creation; and culturally responsive teaching explains how local cultural references can increase relevance and participation. These theoretical foundations are linked to the intervention in the following pathway: *Ruma Bolon*'s creative values are translated into IPAS learning activities that require students to analyze, synthesize, and evaluate; these cognitive processes are expected to improve critical thinking while also strengthening creativity and cultural appreciation. Figure 1 illustrates the framework.

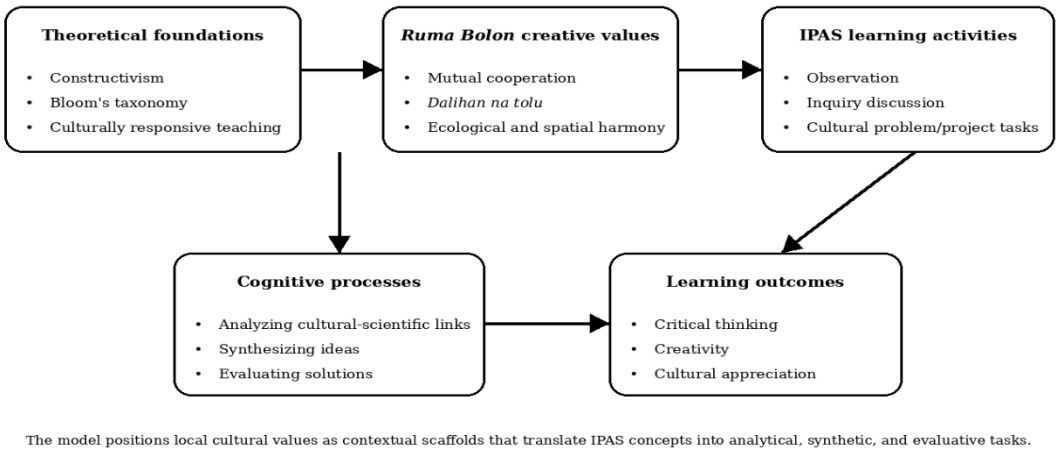

Figure 1. Conceptual framework of *Ruma Bolon*-based IPAS instruction.

3. Method

This study used an explanatory mixed-methods design with a quantitative priority. The quantitative strand employed a one-group pretest-posttest design to examine changes in students' critical thinking after *Ruma Bolon*-based IPAS instruction. The qualitative strand, consisting of interviews, classroom observations, and documentation, was used to explain how students and teachers experienced the intervention and how cultural elements supported classroom reasoning. The two datasets were integrated during interpretation: statistical results identified the pattern of improvement, while qualitative themes explained the classroom mechanisms underlying it.

The research was conducted in elementary schools in Medan Helvetia District, Medan City, North Sumatra, where Toba Batak cultural references are accessible as contextual learning resources. The population consisted of fourth-grade students who studied IPAS in the district. Purposive sampling was used because the intervention required schools that implemented IPAS, permitted culture-based learning activities, and had students with sufficient exposure to Toba

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Batak cultural materials. The final matched quantitative sample comprised 30 fourth-grade students (n = 30) with complete pretest and posttest data. This number was used consistently in the inferential analysis.

The intervention was organized through a series of classroom activities. First, students were introduced to the structure, symbols, and social functions of *Ruma Bolon*. Second, the teacher connected these cultural elements with IPAS topics, including environment, social interaction, materials, and community life. Third, students worked in small groups to discuss problems, design cultural projects, and justify their ideas using IPAS concepts. Fourth, students presented their work and reflected on the reasons behind their conclusions. This sequence was intended to move students from observation to explanation, from explanation to synthesis, and from synthesis to evaluation.

The main quantitative instrument was a critical-thinking test covering three indicators: analysis, synthesis, and evaluation. The scoring rubric assessed the accuracy of concept identification, the coherence of connections among ideas, the quality of evidence, and the reasonableness of conclusions. Qualitative instruments included a semi-structured teacher interview guide, student interview questions, an observation sheet focused on teacher-student interaction and group inquiry, and documentation of learning products. The student perception questionnaire measured engagement, creativity, participation, understanding, and perceived support for critical thinking. Table 1 reports instrument validity and reliability.

Table 1. Validity and reliability of the research instruments

Instrument/procedure	Index	Result	Interpretation
Critical-thinking test	Content Validity Index (CVI)	0.91	Very strong content validity
Critical-thinking test items	Item validity coefficient	0.42-0.81	All items valid
Critical-thinking test	Cronbach's alpha	0.88	High reliability
Student perception questionnaire	Cronbach's alpha	0.86	High reliability
Expert validation	Validator background	IPAS, educational evaluation, and Toba Batak culture experts	Content and cultural relevance confirmed

Instrument quality was examined before data analysis. The critical-thinking test was reviewed by three experts: an IPAS expert, an educational evaluation expert, and a Toba Batak culture expert. The validation results yielded a Content Validity Index (CVI) of 0.91, indicating very strong content agreement. Item validity coefficients ranged from 0.42 to 0.81, so all items were retained. Reliability analysis produced Cronbach's alpha = 0.88 for the critical-thinking test and Cronbach's alpha = 0.86 for the student perception questionnaire, indicating high internal consistency.

Quantitative analysis began with descriptive statistics for pretest and posttest scores, followed by a Shapiro-Wilk normality test. Because the pretest and posttest data met the normality assumption ($p > 0.05$), a paired-sample t-test was used to examine score differences. Cohen's d was calculated to estimate effect size, and normalized gain (N-gain) was used to describe the magnitude of learning improvement relative to the maximum possible score. Qualitative data were analyzed thematically through data familiarization, initial coding, category development, theme refinement, and interpretation. Trustworthiness was supported through source triangulation between interviews, observations, questionnaires, and student products.

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Ethical procedures were applied throughout the study. The researchers obtained school permission before data collection, informed teachers and students about the learning activities, and treated students' responses and scores confidentially. Student identities were not reported in the manuscript, and classroom data were used solely for research and instructional improvement.

4. Results

4.1 Quantitative changes in critical thinking scores

Table 2 presents the descriptive change in students' critical thinking scores before and after the implementation of *Ruma Bolon*-based IPAS instruction. The three indicators are analysis, synthesis, and evaluation, which were aligned with the test rubric used in the study.

Table 2. Changes in critical-thinking test scores

Critical Thinking Skills	Before *Ruma Bolon*-Based Learning (%)	After *Ruma Bolon*-Based Learning (%)	Improvement (%)
Analytical Skills	40%	70%	30%
Synthesis Skills	50%	75%	25%
Evaluation Skills	60%	80%	20%
Total Average Score	**65%**	**85%**	**20%**

The descriptive pattern shows consistent improvement across the three indicators: analysis increased by 30 percentage points, synthesis by 25 percentage points, and evaluation by 20 percentage points. The average score rose from 65% to 85%, indicating stronger ability to examine information, connect ideas, and justify conclusions.

Table 3. Inferential analysis of critical-thinking scores

Analysis	Result	Interpretation
Shapiro-Wilk normality test	Pretest and posttest $p > 0.05$	Normality assumption met
Paired-sample t-test	$t(29) = 16.84$; $p < 0.001$	Posttest scores were higher than pretest scores
Effect size	Cohen's $d = 1.92$	Large effect
Normalized gain	N-gain approx. 0.60	Moderate-to-high gain

As shown in Table 3, the paired-sample result supports the descriptive findings in Table 2. Because the normality assumption was met, the t-test was appropriate for the matched pretest-posttest data. The large effect size suggests that the improvement was not only statistically confirmed but also educationally meaningful for the participating class.

4.2 Visualization of critical thinking score changes

Figure 2 visualizes the pretest-posttest pattern and shows that improvement occurred across all three indicators, rather than being limited to a single aspect of critical thinking.

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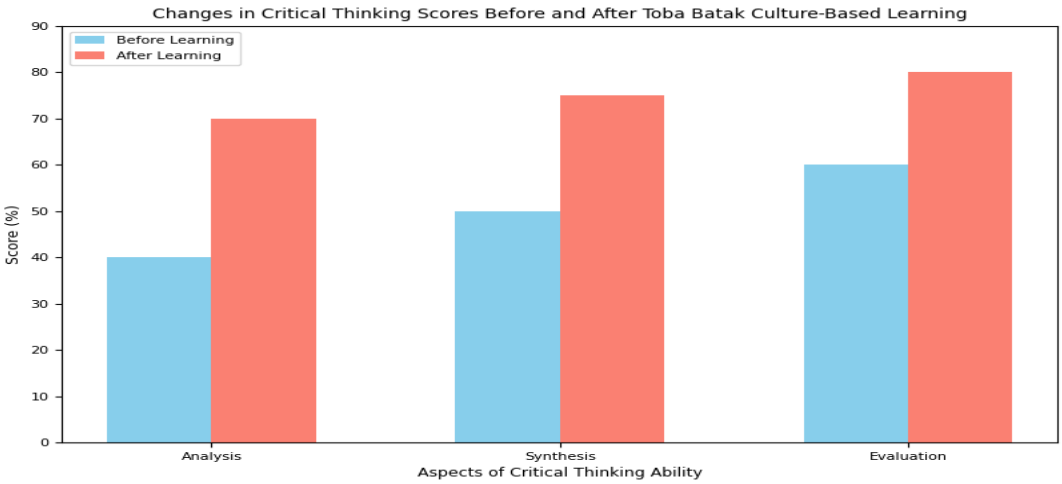

Figure 2. Graph showing changes in critical-thinking test scores

Figure 2 reinforces the pattern shown in Table 2: the largest increase appeared in analysis, while synthesis and evaluation also improved. This distribution is pedagogically plausible because the intervention first asked students to identify and compare cultural-scientific relations before requiring them to synthesize project ideas and evaluate explanations.

4.3 Qualitative findings: teacher and student perceptions

Interviews and observations were used to explain the classroom processes behind the quantitative improvement. Three related themes emerged: cultural familiarity, active participation, and project-based reasoning. Teachers reported that using *Ruma Bolon* helped them explain IPAS concepts with concrete examples. The house's structure, ornaments, and communal values provided students with an accessible context for discussing the environment, social relations, and problem-solving. Teachers also observed that students asked more questions during group discussion and were more willing to justify their answers when the task was connected to cultural objects they recognized. Students' questionnaire responses are summarized in Table 4.

Table 4. Results of the student perception questionnaire

Perceptions of Learning	Percentage of Students Who Agree (%)
Learning is more engaging thanks to the integration of the Toba Batak culture	85%
Culture-based learning enhances my creativity	80%
This lesson helped me understand the material better	75%
I participate more actively in class discussions	70%
Culture-based learning encourages me to think more critically	78%

Students described the lessons as easier to understand because the examples were close to their family and community experiences. Cultural familiarity reduced the distance between textbook concepts and everyday life. Many students also stated that project tasks, such as creating *Ruma Bolon* models or explaining Lake Toba-related environmental issues, helped them express ideas more freely while still using evidence from IPAS materials.

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Table 4 summarizes students' perceptions of the learning experience. The responses support the interview findings because most students agreed that culture-based IPAS learning was engaging, encouraged creativity, and helped them think more critically.

4.4 Classroom observation: teacher-student interaction

Classroom observations showed that the intervention altered the structure of classroom interactions. Instead of receiving cultural information passively, students discussed how cultural values and IPAS concepts could be connected in explanations and projects. Positive interaction: Students discussed cooperation, respect for nature, and social responsibility as entry points for explaining IPAS concepts. Creative projects: Students developed miniature *Ruma Bolon* models and short reports on the Lake Toba ecosystem, then explained the IPAS concepts represented in their products.

Teacher engagement: Teachers used Toba Batak folklore, spatial symbols, and community practices as prompts for questioning, comparison, and reflection. The qualitative data, therefore, explain the quantitative pattern: students' scores increased because the learning tasks required them to work with concrete cultural objects, discuss reasons with peers, and present products that had to be justified through IPAS concepts. These themes are discussed more analytically in the following section. The convergence of test results, questionnaire responses, interviews, observations, and student products indicates that the intervention supported both cognitive and affective dimensions of learning. The results do not warrant broad generalization beyond the participating class, yet they provide empirical support for further development of *Ruma Bolon*-based IPAS learning materials.

5. Discussion

The findings show that *Ruma Bolon*-based IPAS instruction led to a clear improvement in students' critical thinking scores. The improvement was not confined to descriptive averages; it was supported by inferential evidence, $t(29) = 16.84$, $p < 0.001$, with a large effect size (Cohen's $d = 1.92$). This matters because the intervention did more than introduce local culture as lesson content. It reorganized learning around tasks that required students to observe cultural objects, relate them to IPAS concepts, and defend their explanations through discussion and project work.

The largest increase occurred in analytical skills. This pattern is reasonable because the first instructional demand placed on students was to identify relationships: between the physical structure of *Ruma Bolon* and environmental adaptation, between communal space and social organization, and between cultural symbols and everyday community practices. These activities map closely onto the analytical dimension of critical thinking. Synthesis and evaluation also improved, though with smaller gains, because these indicators require more complex forms of reasoning. Students had to combine cultural and scientific information into products and then judge whether their explanations or solutions were coherent.

The qualitative findings clarify why cultural integration supported these outcomes. Teachers reported stronger participation when students worked with familiar cultural references, and students described the tasks as easier to understand because the examples were rooted in their social world. This aligns with Vygotsky's constructivist view that learning develops through mediated interaction and meaningful context (Vygotsky, 1978). It also supports culturally responsive teaching, which holds that students' cultural knowledge can serve as an academic

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resource when connected to rigorous learning goals rather than treated as an ornamental addition.

Compared with previous studies on problem-based learning, guided inquiry, and local wisdom-based instruction (Haryanti et al., 2022; Rosyidah & Setiawan, 2025; Susanti & Sari, 2024), this study adds a more specific cultural mechanism. The use of *Ruma Bolon* provides a concrete artifact through which students can examine space, materials, environment, social relations, and values simultaneously. This specificity distinguishes the present intervention from broader local-culture approaches and explains its contribution to IPAS learning: cultural knowledge becomes a structured route for analysis, synthesis, and evaluation.

At the same time, the findings should be interpreted with caution. The one-group pretest-posttest design cannot fully rule out maturation, teacher influence, repeated testing, or other classroom factors. The sample comprised 30 students with complete paired data, and the intervention took place within a specific cultural and school context. These limitations do not invalidate the improvement observed in this study, but they restrict the strength of causal claims. Future studies with comparison groups, larger samples, and longer intervention periods are needed to test the model's transferability.

6. Conclusion and Implications

6.1 Conclusion

This study concludes that IPAS instruction integrated with the creative values of *Ruma Bolon* can strengthen fourth-grade students' critical thinking skills in the participating class. Students' average critical-thinking score increased from 65% to 85%, and the paired-sample test confirmed a reliable pretest-posttest difference, $t(29) = 16.84$, $p < 0.001$, with a large effect size. Qualitative findings show that the cultural context helped students connect IPAS concepts with familiar experiences, participate more actively in discussions, and produce projects that required analysis, synthesis, and evaluation.

6.2 Theoretical implications

The findings support constructivist and culturally responsive perspectives by demonstrating that local cultural artifacts can serve as cognitive scaffolding. *Ruma Bolon* helped translate abstract IPAS concepts into concrete tasks, while Bloom's taxonomy clarified the progression from understanding to analysis, synthesis, and evaluation. The study, therefore, contributes to culture-based education by identifying a specific pathway through which local wisdom can support critical thinking.

6.3 Practical implications

For elementary teachers, the model can be adapted into IPAS lessons through three practical steps: selecting cultural artifacts that align with the topic, designing inquiry questions that require evidence-based reasoning, and asking students to present products or explanations that can be evaluated using a rubric. For schools, the findings suggest the need for learning resources, teacher collaboration, and project-based activities that connect local culture with curricular outcomes. For education offices, *Ruma Bolon*-based IPAS learning can inform teacher training modules and culturally grounded teaching materials that support the *Merdeka* Curriculum without reducing academic rigor.

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6.4 Limitations and future research

This study was limited by purposive sampling, a single matched quantitative sample of 30 students, the absence of a control group, and the culturally specific setting of Medan Helvetia. These conditions limit the generalizability of the findings. Future studies should involve larger samples, comparison classes, multiple schools, and longer intervention periods. Further research may also examine how *Ruma Bolon*-based learning affects creativity, problem-solving, character development, and achievement across different IPAS topics and other elementary grade levels.

Declaration of Statements

The authors did not provide information or include statements concerning the CRediT Authorship Contribution Statement, Declaration of Competing Interest, Data Availability Statement, Ethical Declaration, and Declaration of AI Statement in the submitted manuscript.

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