

Real Math Interactive Learning Design Integrated with Mathematical Connection Ability at the Junior High School Level

Sirwanti¹, Rusli^{2*}, Arif Tiro³, Ahmad Zaki⁴, Hastuty⁵

¹Mathematics Education Study Program, Faculty of Teacher Training and Education,
Universitas Muhammadiyah Bone

^{2,3,4}Doctoral Program in Mathematics Education, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Makassar

⁵Mathematics Education Study Program, Faculty of Teacher Training and Education,
Universitas Muhammadiyah Pare Pare

*Corresponding author: rusli.siman@unm.ac.id

Email: sirwanti@unimbone.ac.id , rusli.siman@unm.ac.id , arif.tiro@unim.ac.id , ahmadzaki@unm.ac.id ,
hastuty.rusli@gmail.com

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ABSTRACT:

This study developed a Real Math Interactive (RMI) learning design integrated with mathematical connection ability for junior high school students. Educational Design Research comprised preliminary research, prototyping, and assessment. The product included a design guidebook, teaching modules, student books, worksheets, and research instruments. RMI comprised six phases: Meaningful Context, Analyze Situation, Connection, Concept Construction, Application, and Highlighting. Expert judgments classified the guidebook and learning materials as valid to highly valid; research instruments obtained a mean validation score of 3.51. Two trials informed iterative revisions, with the mean learning achievement increasing from 70.33 to 77.94. In the implementation stage, the experimental and control groups each included 30 students. The implementation analysis reported mean normalized gains of 76.16% and 69.90%, respectively. An independent-samples t-test indicated a difference favoring the experimental group, $t(58) = 4.350$, $p < .001$, mean difference = 6.256, 95% CI [3.377, 9.135]. The findings support the validity, practicality, and local effectiveness of RMI for developing mathematical connections. Broader implementation requires replication and clearer reporting of measurement and allocation procedures.

Keywords: Real Math Interactive, mathematical connections, educational design research, realistic mathematics education, junior high school

1. Introduction

Mathematical connections enable students to understand mathematics as a coherent body of knowledge and to use it in unfamiliar situations. The National Council of Teachers of Mathematics (NCTM, 2000) identifies connections among mathematical ideas, across disciplines, and with everyday contexts as essential learning goals. Mathematical proficiency also requires conceptual understanding, strategic competence, and reasoning, rather than isolated procedural performance (Kilpatrick et al., 2001). For junior high school geometry, these goals involve relating properties, diagrams, measurement, perimeter, and area to contextual problems.

1.1 Research context and learning needs

Indonesia's mathematics learning challenges provide a wider context for investigating connection-oriented instruction. The OECD (2023) documents substantial difficulties in mathematical proficiency in PISA 2022. These national patterns do not directly measure the connection ability investigated here, but they reinforce the need for classroom designs that support interpretation, reasoning, and application. The present study therefore focuses on a specific instructional problem: students can sometimes recall geometric formulas without explaining how the concepts and representations are related.

An initial observation on October 11, 2025, at SMP Negeri 6 Watampone identified difficulties with triangles and quadrilaterals. Students struggled to connect geometric properties, choose representations, and relate geometry to land area, space design, and building shapes. Among 32 students, 28% established correct conceptual connections, while fewer than 20% solved contextual geometry problems. Existing materials lacked an explicit connection trajectory and largely emphasized procedures.

The initial observations should be distinguished from the indicator analysis subsequently reported in Table 1. The observation involved 32 students, while the design trials and final implementation

used other reported group sizes. The different percentages describe different diagnostic summaries and are not interchangeable. Together, they motivated closer examination of how instruction helped students recognize relationships within mathematics and between mathematics and familiar situations.

Mathematical connections involve more than recalling two concepts at the same time. They require students to identify, explain, and use relationships that emerge through classroom mathematical activity (de Gamboa et al., 2023). Rafiepour and Faramarzpour (2023) investigated connection ability among ninth-grade students, offering a useful comparison for the difficulties encountered here. In geometry, translating a realistic situation into a diagram and a symbolic expression can impose additional demands because students must coordinate different representations (Duval, 2006).

Realistic Mathematics Education (RME) offers a conceptual basis for addressing these demands. It treats mathematics as a human activity and uses meaningful situations to support guided reinvention (Freudenthal, 1991). The role of the teacher is to organize a trajectory through which informal strategies develop toward increasingly formal mathematical reasoning. Gravemeijer (1994) describes the design of such trajectories, while Van den Heuvel-Panhuizen and Drijvers (2020) explain the central principles of RME. A context is pedagogically useful when it supports mathematical organization and progression, rather than merely introducing a topic.

Evidence from Indonesian classrooms further highlights the importance of instructional materials and teacher involvement in implementing RME (Sembiring et al., 2008). Armianti et al. (2022) developed local instructional theory for probability, illustrating how realistic activities can be organized around a specific content domain. Fredriksen (2021) examined RME in a flipped classroom at the tertiary level. These studies differ in topic and educational setting, but each informs the need to connect theoretical principles with explicit classroom activities.

1.2 Related research and the design contribution

Prior work provides evidence for combining realistic contexts with structured learning resources. Alim et al. (2021) developed an RME-based mathematics textbook oriented toward learning motivation. Lestari et al. (2024) developed electronic worksheets aimed at mathematical connections. Pambudi et al. (2022) examined collaborative RME in indoor and outdoor classrooms, while Sukmaningthias et al. (2022) developed RME worksheets supported by Cabri 3D. Zuhendri et al. (2025) investigated a GeoGebra-supported local learning design for connections in linear programming. These contributions support the value of coordinated contextual activities, although their populations, topics, and interventions differ from the present study.

Digital resources also require a clear instructional purpose. Ainsworth (2006) explains how multiple representations can complement each other and support deeper understanding when their relationships are made explicit. Mayer (2009) provides principles for coordinating verbal and visual information in multimedia learning. A review by Saat et al. (2024) examines digital technology in mathematics education, and the meta-analysis by Schoenherr et al. (2024) supports the educational potential of visualization interventions. Such evidence does not imply that adding digital media alone guarantees mathematical connections; task design and teacher guidance remain central.

Additional evidence relates representation and realistic instruction to mathematical learning. Yuanita et al. (2018) investigated mathematical representation as a mediator between mathematical belief and problem solving. Uyen et al. (2021) examined RME in Grade VII statistics, and Siswantari et al. (2025) linked RME principles with mathematical communication. These studies inform the present design by emphasizing interpretation, expression, and the use of mathematical ideas, while leaving open the question of how a geometry-specific RMI design performs in the local setting.

The development approach follows Educational Design Research, in which interventions are refined through empirical examination rather than assumed to work after initial construction (McKenney & Reeves, 2012; Plomp, 2013). Design-based research also connects the development of usable interventions with understanding learning processes (Design-Based Research Collective, 2003). The present study evaluates the quality of RMI through validity, practicality, and effectiveness, while documenting how initial needs, prototype structure, and trial results inform successive revisions.

1.3 Research objective

The objective was to develop and evaluate an RMI learning design integrated with mathematical connection ability for Grade VII triangles and quadrilaterals. The study addressed three linked questions: whether experts judged the design and its resources valid; whether teachers and students could use the design practically; and whether the implementation was associated with greater improvement in mathematical connection ability than the comparison condition. The scope is a local development and implementation study, rather than a national evaluation of mathematics instruction.

2. Methodology

2.1 Research design and setting

The study used Educational Design Research to develop an RMI learning design for Grade VII triangles and quadrilaterals at SMP Negeri 6 Watampone. Plomp's framework comprised preliminary research, prototyping, and assessment. Each phase informed the next through needs analysis, expert review, implementation, and revision.

The reported stages involved an initial diagnostic observation with 32 students, Trial I with 15 students as shown by Table 7, Trial II with 18 students as shown by Table 9, and final implementation with two groups of 30 students. These sample sizes refer to different stages of development. The final comparison involved an experimental class using RMI and a control class

receiving the comparison instruction. Random allocation was not documented, so the comparison is interpreted as a local classroom implementation rather than a randomized experiment.

2.2 Instruments and procedures

Instruments comprised observation sheets, interview guidelines, expert validation sheets, teacher and student questionnaires, and mathematical connection tests. Observation, interviews, and documentation informed the needs analysis. Expert review examined the guidebook and resources; questionnaires assessed user responses; and pretests and posttests measured connection ability.

Preliminary research analyzed curriculum requirements, student characteristics, learning obstacles, and teachers' needs. Prototyping produced the design guidebook and supporting resources, followed by expert review and formative revision. Assessment included Trial I, evaluation and focus group discussion, revision, Trial II, and the final classroom comparison. This sequence follows the use of prototypes to improve product quality (Nieveen, 1999) and formative evaluation to identify weaknesses before wider implementation (Nieveen & Folmer, 2013).

2.3 Data analysis

Qualitative analysis described learning obstacles, development decisions, feedback, and revisions. Quantitative analysis summarized expert scores, implementation, observer agreement, teacher and student responses, activity, achievement, and

pretest-posttest improvement. The minimum achievement criterion was 75.

Normalized gain was used to summarize improvement relative to the available improvement from the pretest score. For a maximum score of 100, the individual gain is $g = (\text{posttest} - \text{pretest}) / (100 - \text{pretest})$; percentages are obtained by multiplying g by 100 (Hake, 1998). Group mean gains must be distinguished from gains calculated from group mean scores. The implementation analysis used a Shapiro–Wilk normality test, Levene's test of variance homogeneity, and an independent-samples t-test at $\alpha = .05$. Test results, confidence limits, and categorical labels are reported from the study.

The validity, practicality, and effectiveness categories follow the reported criteria. Validation scores describe expert assessments; they do not establish test reliability. Questionnaire responses describe user acceptance, while achievement and gain measures describe learning outcomes. These forms of evidence are considered together, but they are not treated as interchangeable measures of design quality.

3. Results

3.1 Preliminary research

The Preliminary Research phase was conducted to identify the initial conditions and learning needs as the basis for developing the RMI learning design. The analysis covered students' initial abilities, teachers' needs, characteristics of the learning materials, literature review, and the development of the conceptual framework of the learning design.

Table 1 Results of the Initial Analysis of Students' Mathematical Connection Ability

Indicator of Mathematical Connection Ability	Percentage	Category
Connecting topics within mathematics	42%	Low
Connecting mathematics with other disciplines	27%	Low
Connecting mathematics with everyday life	21%	Low

Research data (2026).

Table 1 shows that the ability to connect topics within mathematics reached 42%, while the

ability to connect mathematics with other disciplines reached 27%. The lowest percentage

was found in the ability to connect mathematics with everyday life, at 21%. These findings indicate that the main difficulty is not limited to establishing relationships among mathematical concepts, but becomes more apparent when students are required to apply mathematical concepts in contexts beyond mathematics and in everyday situations.

The analysis of teachers' needs further showed that classroom instruction remained largely teacher-centered and had not yet specifically organized learning activities to facilitate students' mathematical connection ability. Teachers also faced time constraints in developing learning materials that could integrate mathematical concepts, representations, and everyday-life situations. Based on the content analysis,

quadrilaterals and triangles were selected as the focus of the development because these topics include concepts related to properties of geometric figures, perimeter, area, and various contextual problems that provide opportunities for students to establish connections among mathematical concepts.

3.2 Prototype structure

Based on the results of the Preliminary Research, the next stage focused on developing the learning design prototype. The products developed included an RMI learning design guidebook, learning materials, and research instruments. The development of the design was carried out through four main procedures, as presented in Table 2.

Table 2 Development Procedures of the Real Math Interactive Learning Design

No	Design Procedure
1	Formulating learning outcomes
2	Mapping and organizing learning materials
3	Designing Real Math Interactive learning steps and activities
4	Designing assessment strategies

Research data (2026).

Table 3 Phases of Real Math Interactive Learning

No.	Stage	Focus of Activities
1	Meaningful Context	Presenting contextual problems and connecting them with students' prior knowledge
2	Analyze Situation	Analyzing information, solution requirements, and relationships among elements of the problem
3	Connection	Connecting mathematical concepts with previously learned concepts, other disciplines, and everyday life
4	Concept Construction	Organizing information, comparing strategies, and constructing concepts
5	Application	Applying connections among concepts to solve new problems

No.	Stage	Focus of Activities
6	Highlighting	Presenting, clarifying, drawing conclusions, and reflecting on mathematical connections

Research data (2026).

The prototype included a guidebook, teaching modules, student books, worksheets, and research instruments. The Connection phase made relationships among concepts, disciplines, and everyday situations an explicit learning activity. The remaining phases supported progression from interpreting a problem to applying and reflecting on mathematical relationships.

3.3 Expert validation and product revision

Expert validation was first conducted to determine the conceptual and structural feasibility of the RMI learning design guidebook. The validation results are presented in Table 4.

Table 4 Validation Results of the RMI Learning Design Guidebook

Aspect Assessed	Mean Score	Category
Supporting theories	3.50	Highly valid
Design procedures	3.63	Highly valid
Formulation of learning outcomes	3.25	Valid
Mapping and organization of learning materials	3.50	Highly valid
Design of RMI learning steps and activities	3.17	Valid
Design of assessment strategies	3.25	Valid
Design format	3.50	Highly valid

Research data (2026).

Scores for the guidebook ranged from 3.17 to 3.63, with all aspects rated valid or highly valid. The design procedures received the highest score, whereas the design of RMI steps and activities received the lowest. These ratings supported continuation to empirical trials while identifying aspects that could benefit from refinement.

Table 5 Validation Results of the Learning Materials

Learning Material	Content	Construct	Language
Teaching Module	3.44	3.50	3.50
Student Book	3.55	3.80	3.33
Student Worksheet	3.75	3.50	3.50

Research data (2026).

The results show that the teaching module, student book, and student worksheet were rated from valid to highly valid in terms of content, construct, and language. The research instruments developed in this study also obtained an average validation score of 3.51, which was categorized as highly valid. Therefore, both the learning design and its supporting materials met the validity requirements before being implemented in the trial stage.

3.4 Formative assessment sequence

The Assessment Phase was conducted to determine the quality of the developed design in terms of validity, practicality, and effectiveness.

3.5 Trial I and Trial II

This phase included expert validation, prototype revision, Trial I, further revision, Trial II, as well as the implementation and effectiveness testing of the RMI learning design.

The first trial tested implementation and user responses alongside student activity and achievement. Its findings informed evaluation, focus group discussion, and further revision. The second trial then examined the revised prototype before final classroom implementation. Across stages, the design was evaluated as a set of linked instructional resources, rather than as a single digital learning aid.

Table 6 Summary of Trial I Results

Indicator	Result	Category/Criteria
Learning implementation	1.70	Fully implemented
Inter-observer agreement	95.45%	High
Teacher response	95.00%	Highly positive
Student response	88.20%	Highly positive
Student activity	73.93%	Good
Mean learning achievement	70.33	Did not reach the minimum mastery criterion of 75
N-Gain	0.60	Moderate
N-Gain (%)	64.00%	Moderately effective

Research data (2026).

Table 7 Distribution of Mathematical Connection Ability in Trial I

Category	Number of Students	Percentage
High	8	53.33%
Moderate	6	40.00%
Low	1	6.67%

Note. Research data (2026).

Trial I was implemented successfully and received positive responses. However, mean achievement was 70.33, below the mastery criterion of 75. One of the 15 students remained in the low connection category. The prototype therefore required further revision before the next trial.

Table 8 Summary of Trial II Results

Indicator	Result	Category/Criteria
Learning implementation	1.76	Fully implemented
Inter-observer agreement	98.18%	High
Teacher response	92.13%	Highly positive
Student response	90.59%	Highly positive
Student activity	73.26%	Good
Mean learning achievement	77.94	Exceeded the minimum mastery criterion of 75
N-Gain	0.70	Moderate
N-Gain (%)	70.04%	Moderately effective

Research data (2026).

Table 9 Distribution of Mathematical Connection Ability in Trial II

Category	Number of Students	Percentage
High	15	83.33%
Moderate	3	16.67%
Low	0	0%

Research data (2026).

In Trial II, mean achievement reached 77.94, above the mastery criterion. Fifteen of 18 students (83.33%) were in the high category; none were in the low category. Implementation and observer agreement increased, while teacher responses and student activity were slightly lower than in Trial I. Improvements across stages therefore did not occur uniformly on every indicator.

3.6 Final implementation and effectiveness testing

Table 10 Description of Mathematical Connection Ability at the Implementation Stage

Group	N	Mean Pretest Score	Mean Posttest Score	Posttest Mastery
Experimental	30	25.50	78.50	90.00%
Control	30	24.00	76.33	76.67%

Research data (2026).

Both groups improved from pretest to posttest. The experimental mean increased from 25.50 to 78.50; the control mean increased from 24.00 to 76.33. Posttest mastery was 90.00% and 76.67%, respectively. The gain analysis and inferential comparison are reported below.

Table 11 Comparison of N-Gain between the Experimental and Control Classes

Group	N-Gain (%)	Category
Experimental	76.16	Effective
Control	69.90	Moderately effective

Research data (2026).

Table 12 Results of the N-Gain Normality Test

Group	Shapiro-Wilk Statistic	df	Sig.	Interpretation
Experimental	0.950	30	0.164	Normally distributed
Control	0.963	30	0.362	Normally distributed

Note. Research data (2026).

Table 13 Results of the Homogeneity Test and Independent Samples t-Test for N-Gain

Test Statistic	Value
Levene's Test F	0.005
Levene's Test Sig.	0.946
T	4.350
Df	58
Sig. (2-tailed)	< 0.001
Mean Difference	6.256
Std. Error Difference	1.438
95% CI Lower	3.377
95% CI Upper	9.135

Research data (2026).

Shapiro-Wilk p-values were .164 and .362. Levene's test yielded $F = 0.005$, $p = .946$. The

equal-variances t-test yielded $t(58) = 4.350$, $p < .001$, with a mean gain difference of 6.256

percentage points and 95% CI [3.377, 9.135]. The direction of the difference favored the experimental group. Table 11 values imply a rounded difference of 6.26 points.

4. Discussion

4.1 Connections as an explicit design requirement

The results of the Preliminary Research showed that students' mathematical connection ability was relatively low across all analyzed indicators. The ability to connect topics within mathematics reached 42%, the ability to connect mathematics with other disciplines reached 27%, and the ability to connect mathematics with everyday life reached only 21%. These findings indicate a tendency for students' difficulties to become more pronounced as the mathematical relationships to be established move from internal connections among mathematical concepts toward connections involving contexts beyond mathematics and everyday life.

The low ability to connect mathematics with everyday life indicates that mastery of concepts or procedures does not automatically enable students to apply those concepts in different situations. Students still tend to learn concepts as separate components and use formulas to solve familiar types of problems. When problems are presented in contextual forms, students must first identify relevant information, determine appropriate concepts, establish relationships among concepts, and then transform the situation into a mathematical representation. This process constitutes one of the main sources of difficulty in developing mathematical connections.

This pattern is consistent with treating connections as relationships constructed through mathematical activity rather than as isolated recall (de Gamboa et al., 2023). Rafiepour and Faramarzpour (2023) provide related evidence concerning students' connection ability. The present results suggest that interpreting a realistic problem, selecting a representation, and identifying relevant concepts deserve explicit instructional attention. A student who knows an area formula may still need support in

recognizing the appropriate figure, identifying a missing dimension, or explaining the relationship between two solution strategies.

Teacher-centered instruction and limited resources restricted opportunities to explore concepts, discuss strategies, coordinate representations, and apply mathematics to realistic situations. The design therefore addressed both student activity and teachers' need for structured materials.

The six RMI phases respond to these needs as a coordinated trajectory. Meaningful Context activates prior knowledge; Analyze Situation identifies relevant information; Connection relates concepts and representations; Concept Construction organizes and compares strategies; Application extends understanding to new problems; and Highlighting makes the resulting relationships explicit through presentation and reflection. This progression is compatible with guided reinvention in RME (Freudenthal, 1991; Gravemeijer, 1994), but its value depends on the mathematical demands of the tasks and the quality of classroom interaction.

Teacher support remains important during this progression. Vygotsky (1978) offers a theoretical account of socially mediated learning, informing the use of dialogue and assistance as students work on unfamiliar tasks. Freeman et al. (2014) found improved outcomes under active learning in undergraduate STEM courses. That population differs from Grade VII students, so the finding provides broader pedagogical support for participation rather than direct evidence of RMI effectiveness. In the present design, students' explanations and comparisons are opportunities for learning, not simply additions to a conventional lesson.

4.2 Digital resources and multiple representations

The flipbook, video links, diagrams, and worksheets provide representational resources, but their role should be interpreted through the tasks they support. Ainsworth (2006) explains that students need help coordinating multiple representations; Duval (2006) emphasizes the

cognitive demands involved in understanding mathematics through different representational registers. Mayer (2009) further informs coordination of visual and verbal information. These perspectives support deliberate links between context, image, explanation, and symbol, rather than assuming that exposure to several media automatically produces understanding.

4.3 Iterative refinement and interpretation of effectiveness

The validation and trial findings illustrate the distinction between a feasible prototype and an intervention that consistently meets learning goals. Expert judgments were positive, but Trial I achievement remained below the criterion. Trial II showed higher achievement after revision, supporting the practical value of formative development. This pattern is consistent with prototyping and formative evaluation (Nieveen, 1999; Nieveen & Folmer, 2013) and with the empirical refinement of classroom interventions discussed by Brown (1992), Collins (1992), and Cobb et al. (2003).

Design research links the development of practical interventions with examination of how they function in a learning setting (Design-Based Research Collective, 2003; McKenney & Reeves, 2012; Plomp, 2013). Here, the strongest development evidence is the documented sequence from needs analysis through prototype assessment and revision. Because the two trials involved different reported sample sizes, changes between Trial I and Trial II should not be interpreted as a within-student causal effect of revision. They show stage-specific performance of successive prototypes.

The final comparison favored RMI on reported normalized gain. Hake (1998) provides the rationale for interpreting improvement relative to the available gain, although normalized gain does not eliminate selection effects or establish baseline equivalence. The significant t-test and positive confidence interval support a local difference in gain. They do not by themselves show that all six phases are necessary, that digital media caused the improvement, or that the design would produce the same effect in other

schools. The control group also improved substantially, making the relevant interpretation comparative rather than exclusive.

4.4 Contextual applications and wider learning implications

The use of meaningful contexts can be extended through carefully designed problems about measurement, land use, and practical decision-making. Financial literacy education addresses the connection between knowledge and real decisions (Aslam et al., 2024), while investment-fraud education uses discussion of practical situations (Aslam et al., 2025). These publications motivate possible application contexts; they do not investigate junior high school geometry or establish RMI effectiveness.

Community-based agrotourism studies use participatory discussion and practical activities to connect knowledge with local needs (Arief Putra et al., 2023; Hasbiah et al., 2025). A study of entrepreneurship knowledge and technology concerns the deployment of knowledge in business strategy (Idris et al., 2025). These different settings offer contextual examples for designing authentic tasks, such as comparing areas or explaining resource requirements. Any such extension remains a pedagogical proposal and must be adapted to students' age, curriculum, and the mathematical connection objective.

4.5 Limitations and implications for further research

The evidence is limited to one school and one geometry unit. Allocation, intervention duration, instrument reliability, and the comparison instruction require fuller reporting. The two development trials also involved different sample sizes, limiting direct comparison of their outcomes.

Future studies should replicate the design across schools, describe allocation and comparison instruction, and examine retention and transfer. Lesson observations and student explanations could clarify how the Connection and Highlighting phases support mathematical understanding. Studies of digital resources should distinguish media features from task structure

and teacher guidance. The review by Saat et al. (2024), the visualization meta-analysis by Schoenherr et al. (2024), and work on communication by Siswantari et al. (2025) provide directions for this investigation. Evidence from Sembiring et al. (2008), Armiami et al. (2022), and Fredriksen (2021) also supports examining how teachers adapt realistic learning trajectories to different settings.

5. Conclusion

The study produced an RMI learning design for Grade VII triangles and quadrilaterals through preliminary research, prototyping, and assessment. Its guidebook, modules, student books, worksheets, and instruments supported six phases: Meaningful Context, Analyze Situation, Connection, Concept Construction, Application, and Highlighting. Expert assessments rated the design and materials valid

to highly valid, while the instrument validation mean was 3.51. Trial findings informed refinement, with mean learning achievement increasing from 70.33 to 77.94.

At final implementation, the experimental and control groups each included 30 students. The reported table means for normalized gain were 76.16% and 69.90%. The independent-samples comparison favored the experimental group, $t(58) = 4.350$, $p < .001$, mean difference = 6.256, 95% CI [3.377, 9.135]. These findings support local validity, practicality, and comparative effectiveness, subject to fuller methodological reporting and replication. RMI offers a structured way to make mathematical connections explicit; wider use should be accompanied by replication and teacher preparation.

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7. Author Declaration

The authors declare that this manuscript is original, has not been previously published, and is not under consideration for publication elsewhere. All sources used have been appropriately cited and acknowledged. All authors have reviewed and approved the final manuscript, consent to its submission, and agree to be accountable for the integrity of the work. The authors declare no financial or non-financial conflicts of interest related to this study.