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Teachers' Roles in Sustainable Education-Based Mathematics Learning: Toward an Ideal Curriculum

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ABSTRACT

Purpose This study aims to examine teachers' roles in sustainable education-based mathematics learning as a conceptual foundation for developing an ideal curriculum. The study responds to the need to shift mathematics learning from procedural, formula-oriented, and routine instruction toward contextual, meaningful, and sustainability-oriented learning.

Methods This study employed a qualitative literature study with thematic content analysis. The reviewed sources consisted of journal articles, academic books, curriculum documents, scientific reports, and relevant literature discussing mathematics learning, sustainable education, numeracy, mathematical modelling, curriculum development, teachers' roles, and authentic assessment. The analysis was conducted by identifying key ideas, grouping themes, comparing concepts, and developing a conceptual synthesis.

Findings The findings show that an ideal curriculum for sustainable education-based mathematics learning should emphasize conceptual understanding, numeracy, mathematical reasoning, contextual problem-solving, sustainability issues, authentic assessment, and responsible decision-making. Teachers play a central role as curriculum interpreters, context designers, facilitators of reasoning, developers of mathematical tasks, and learning evaluators. Sustainability issues such as waste, water and energy use, green spaces, circular economy, and environmental change can serve as meaningful contexts for mathematics learning.

Research Implications This study implies that curriculum development in mathematics should provide space for contextual learning, mathematical modelling, numeracy projects, authentic assessment, teacher professional development, and learning resources connected to students' real-life experiences.

Originality This study contributes a conceptual framework that positions teachers as key actors in connecting mathematics learning, sustainable education, authentic assessment, and the development of an ideal curriculum.

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INTRODUCTION

Mathematics learning plays an important role in developing students' reasoning, data interpretation, problem-solving, and decision-making skills. However, students' mathematics achievement still indicates serious challenges (Anggoro et al., 2021; Putra et al., 2024). The 2025 National TKA data show that the average achievement score in Mathematics is only 36.10, with 44.7% of students categorized as Low. In Advanced Mathematics, the average achievement score reaches 39.32, with 25.6% of students categorized as Low. Although Advanced Mathematics shows relatively better achievement, both sets of data indicate that students' mastery of mathematics remains suboptimal. A comparison of the achievement in these two subjects is presented in Figure 1.

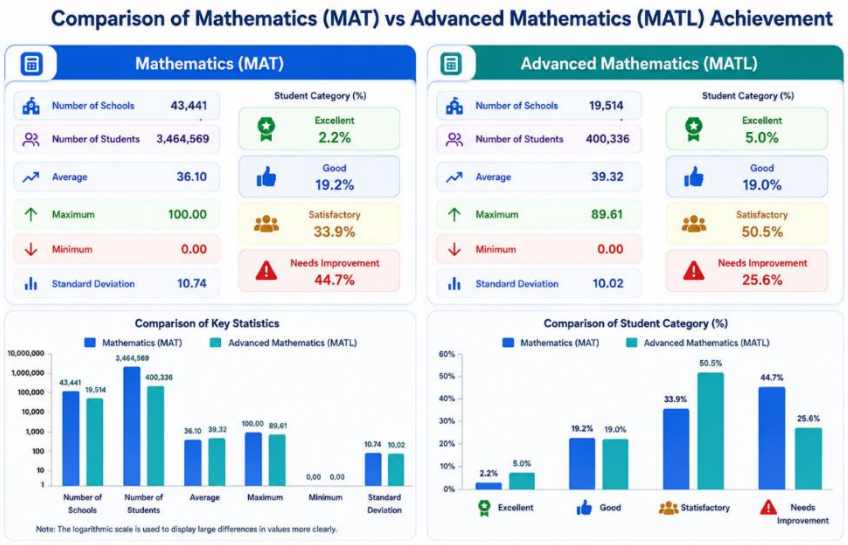

Figure 1. Achievement in Mathematics and Advanced Mathematics Subjects

The low achievement indicates that mathematics learning should not be directed solely toward practice exercises and procedural mastery. One of the main issues in mathematics learning is the dominance of procedural approaches that emphasize formulas, solution steps, routine exercises, and correct answers. Borji et al., (2021), emphasize that mathematics learning needs to balance procedural and conceptual understanding so that students' mathematical performance can develop more meaningfully. In line with this, Mathematics (2000), highlights the importance of problem solving, reasoning, communication, connections, and representation in mathematics learning. Therefore, mathematics learning needs to move toward a more conceptual, contextual, and meaningful approach. One relevant direction for renewal is sustainable education-based mathematics learning. Renert (2011), through the idea of Mathematics for Life: Sustainable Mathematics Education, emphasizes that mathematics should be connected to life and a sustainable future. Mathematics can be used to understand real-world issues such as waste, water, energy, green spaces, consumption, circular economy, and environmental change through data, measurement, comparison, statistics, and modelling (Anggoro et al., 2021; In'am et al., 2010). Lafuente-Lechuga et al., (2024), also affirm that integrating sustainability into mathematics learning requires support from curriculum, assessment, competence, and teacher training.

This direction requires an ideal curriculum for mathematics learning. An ideal curriculum should not merely be understood as a document containing learning materials and learning outcomes, but as a design of learning experiences that connects objectives, content, context, learning strategies, assessment, life values, and students' future needs. Ferrini-Mundy (1991), emphasizes the importance of mathematics education reform so that learning is not only oriented toward procedural skills, but also toward understanding, reasoning, and the meaningful use of mathematics. In the Indonesian context, the spirit of the Merdeka Curriculum can serve as a foundation because it provides space for flexible, student-centered learning that focuses on essential content and emphasizes literacy and numeracy**.** Teachers hold a central position in realizing this ideal curriculum. Remillard (1999), explains that teachers do not use curriculum mechanically; rather, they interpret, adapt, and transform curriculum materials into classroom learning practices. In sustainable education-based mathematics learning, teachers serve as curriculum interpreters, context designers, facilitators of reasoning, developers of mathematical tasks, and learning evaluators. In addition, assessment needs to be directed authentically so that it does not merely evaluate correct answers, but also students' thinking processes, reasoning, problem-solving, reflection, and data-based decision-making (Cokely et al., 2012; Gulikers et al., 2004; Wiggins, 1990).

Although many studies have discussed sustainable education, mathematics learning, curriculum, assessment, and teachers' roles, these topics are still often examined separately (D. D. Pratiwi & Kuswanto, 2021; Yulianti et al., 2021). Studies on sustainable education tend to emphasize environmental values, while studies on mathematics learning mostly focus on instructional strategies or learning outcomes. Therefore, this article aims to examine teachers' roles in sustainable education-based mathematics learning as an effort to move toward an ideal curriculum. This study is guided by two questions: how do teachers integrate sustainable education values into mathematics learning, and what principles are needed to develop an ideal curriculum for sustainable education-based mathematics learning?

METHOD

This study employed a qualitative literature study with a thematic content analysis technique. The data sources consisted of journal articles, academic books, curriculum documents, scientific reports, and other relevant literature discussing mathematics learning, sustainable education, numeracy, mathematical modelling, curriculum development, teachers' roles, and authentic assessment. The literature was selected based on its relevance to the focus of the study, namely teachers' roles in sustainable education-based mathematics learning toward an ideal curriculum. The analysis was conducted through several stages: reading the literature, identifying key ideas, grouping themes, comparing concepts, and developing a conceptual synthesis. The findings are presented in the form of a literature synthesis matrix, a comparison table, examples of integrating mathematical content with sustainability issues, and a conceptual framework of the ideal curriculum.

RESULTS

This section presents the main findings from the literature study. The findings are not presented as empirical field data, but as a conceptual synthesis of various relevant studies on mathematics learning, sustainable education, teachers' roles, authentic assessment, and the ideal curriculum. This synthesis is used to show the relationships among key ideas and to formulate the direction for developing sustainable education-based mathematics learning.

1. Literature Synthesis

The literature review indicates that sustainable education-based mathematics learning requires a shift in orientation from predominantly procedural learning toward learning that is more conceptual, contextual, reflective, and grounded in real-world problems. The reviewed literature shows that low mathematics achievement is not only related to students' abilities, but is also influenced by how mathematics is taught, how the curriculum is interpreted by teachers, and how assessment is designed to measure mathematical thinking in a meaningful way.

Table 1. Literature Synthesis Matrix

Synthesis Theme	Main Source	Main Idea	Contribution to the Article
Low mathematics achievement	Mathematics and Advanced Mathematics achievement data	Mathematics achievement remains low and indicates the need to improve the orientation of mathematics learning.	Provides the basis for the urgency of developing an ideal curriculum for mathematics learning.
Procedural learning	Borji, Radmehr, & Font (2019)	Mathematics learning needs to balance procedural and conceptual understanding.	Strengthens the critique of mathematics learning that only emphasizes formulas, fixed steps, and correct answers.
Numeracy and reasoning	NCTM (2000); Mulhern & Wylie (2006)	Mathematics learning should develop reasoning, problem-solving, representation, and the ability to understand quantitative information.	Provides the basis that mathematics learning should develop numeracy and decision-making skills.
Sustainable mathematics education	Renert (2011); Lafuente-Lechuga et al. (2024)	Mathematics can be connected to life, the environment, resources, and a sustainable future.	Strengthens the direction of sustainable education-based mathematics learning.
Teachers' roles and curriculum	Remillard (1999)	Teachers interpret, adapt, and transform curriculum materials into classroom learning practices.	Emphasizes teachers as key actors in realizing an ideal curriculum.
Mathematics curriculum reform	Ferrini-Mundy (1991)	Mathematics learning needs to move from procedural skills toward understanding and the meaningful use of mathematics.	Provides the foundation for the concept of an ideal curriculum for mathematics learning.
Authentic assessment	Wiggins (1990); Gulikers et al. (2004)	Assessment should evaluate the application of knowledge in meaningful contexts.	Strengthens the argument that an ideal curriculum should include assessment that evaluates reasoning, reflection, and problem-solving.

Based on the matrix, six main themes serve as the foundation for developing this article: low mathematics achievement, the dominance of procedural learning, the need for numeracy and reasoning, sustainable mathematics education, teachers' roles in interpreting the curriculum, and the need for authentic assessment. These six themes are interconnected and form the conceptual basis for developing an ideal curriculum for mathematics learning.

2. Comparison between Procedural and Contextual-Sustainable Mathematics Learning

The synthesis shows that procedural mathematics learning and contextual-sustainable mathematics learning have different orientations. Procedural learning focuses on mastering formulas, solution steps, and correct answers. In contrast, contextual-sustainable mathematics learning emphasizes conceptual understanding, numeracy, reasoning, problem-solving, and the use of mathematics to understand real-life issues.

Table 2. Comparison between Procedural and Contextual-Sustainable Mathematics Learning

Aspect	Procedural Mathematics Learning	Contextual-Sustainable Mathematics Learning
Orientation	Formulas, fixed steps, routine exercises, and correct answers.	Conceptual understanding, numeracy, reasoning, real-life contexts, and sustainability.
Students' role	Imitating the teacher's examples and solving closed-ended problems.	Analyzing problems, reading data, modelling, discussing, and making decisions.
Teacher's role	Explaining procedures, giving examples, and correcting answers.	Designing contexts, facilitating discussions, guiding reasoning, and evaluating thinking processes.
Nature of problems	Routine, closed-ended, and often disconnected from real life.	Contextual, open-ended, data-based, and related to real-life issues.
Learning activities	Solving exercises similar to the examples.	Investigation, numeracy projects, modelling, data analysis, and reflection.
Assessment	Assessing correct answers and procedural accuracy.	Assessing understanding, strategies, arguments, reflection, and data-based decisions.
Learning impact	Understanding tends to be mechanistic and short-term.	Understanding becomes more meaningful, reflective, and sustainability-oriented.

The comparison shows that contextual-sustainable mathematics learning does not reject procedures, but positions procedures as part of a broader understanding. Students still need to master basic mathematical skills; however, these skills should be directed toward understanding concepts, interpreting situations, and solving real-world problems.

3. Integration of Sustainability Issues into Mathematics Learning

The review also shows that sustainability issues can be integrated into various mathematics topics. This integration can be carried out through data, measurement, comparison, statistics, geometry, functions, modelling, and social arithmetic. In this way, mathematics is not merely learned as an abstract concept, but as a tool for understanding

Table 3. Examples of Integrating Mathematical Content with Sustainability Issues

Mathematical Content	Sustainability Issue	Example of Learning Activity	Competencies Developed
Statistics	School waste	Students collect, present, and analyze data on types of waste in the classroom or school.	Data literacy, graph interpretation, and decision-making.
Ratio and proportion	Water and energy use	Students compare water or electricity consumption before and after a saving program.	Proportional reasoning and practical numeracy.
Geometry	Green spaces and water absorption areas	Students calculate the area of gardens, water absorption areas, or green open spaces.	Measurement, spatial visualization, and problem-solving.
Functions and modelling	Environmental change	Students model plant growth, waste increase, or changes in resource consumption.	Mathematical modelling and prediction.
Social arithmetic	Consumption and circular economy	Students calculate recycling costs, savings, or the economic value of used goods.	Financial literacy and responsible decision-making.

The table shows that sustainability integration in mathematics learning can be carried out without eliminating the substance of mathematics. Sustainability issues can instead serve as contexts that strengthen students' conceptual understanding and numeracy.

4. Teachers' Roles in Sustainable Education-Based Mathematics Learning

The synthesis shows that teachers play an important role in transforming the curriculum into learning experiences. Teachers do not merely function as transmitters of content, but also as curriculum interpreters, context designers, facilitators of reasoning, developers of mathematical tasks, and learning evaluators.

Table 4. Teachers' Roles in Sustainable Education-Based Mathematics Learning

Teachers' Role	Description	Example of Implementation
Curriculum interpreter	The teacher translates learning objectives and outcomes into activities that meet students' needs.	Connecting statistics topics with data on waste or energy use in the school environment.
Context designer	The teacher selects real-life issues that are relevant to mathematical content and students' lives.	Using issues such as water use, green spaces, or electricity consumption as contexts for mathematical problems.
Facilitator of reasoning	The teacher encourages students to ask questions, explain strategies, compare solutions, and construct arguments.	Asking students to explain their reasons for choosing a particular model or calculation strategy.
Developer of mathematical tasks	The teacher designs tasks that require not only final answers but also thinking processes.	Conducting a school environmental data analysis project and developing data-based recommendations.
Developer of authentic assessment	The teacher assesses understanding, processes, reflection, and the ability to use mathematics in real-life contexts.	Using numeracy project rubrics, portfolios, data analysis reports, and result presentations.
Connector of sustainability values	The teacher helps students reflect on the mathematical, social, and ecological impacts of a decision.	Discussing energy-saving actions based on calculations of electricity consumption.

Based on the table, teachers become the key actors who determine whether the curriculum remains merely an administrative document or is transformed into meaningful mathematics learning. Teachers' roles serve as a bridge between mathematical content, students' needs, real-life contexts, and sustainability values.

5. Principles of an Ideal Curriculum for Sustainable Education-Based Mathematics Learning

The literature synthesis produces seven principles of an ideal curriculum for sustainable education-based mathematics learning. These principles include an orientation toward conceptual understanding, the strengthening of numeracy, real-life contexts, sustainability, modelling and problem-solving, teachers' roles, and authentic assessment.

Table 5. Principles of an Ideal Curriculum for Sustainable Education-Based Mathematics Learning

Principles of an Ideal Curriculum	Description	Implications for Learning
Oriented toward conceptual understanding	The curriculum does not only emphasize procedures, but also the relationships among concepts.	Teachers need to provide opportunities for exploration, discussion, and explanation of mathematical reasoning.
Strengthening numeracy	The curriculum helps students use mathematics to read data and make decisions.	Learning activities need to include data interpretation, measurement, estimation, and analysis of quantitative information.
Contextual and close to real life	Mathematical content is connected to real-life problems that are relevant to students.	Teachers use data and problems from the school, home, or community environment.
Sustainability-based	Learning integrates environmental, social, economic, and future-oriented issues.	Mathematics is used to understand waste, energy, water, consumption, green spaces, and environmental change.
Encouraging modelling and problem-solving	The curriculum provides space for students to construct models and solve open-ended problems.	Tasks should not have only one answer, but should require strategies, arguments, and reflection.

Positioning teachers as curriculum developers	Teachers are given space to interpret and develop learning experiences.	Teachers do not merely follow textbooks, but adapt materials according to students' contexts.
Using authentic assessment	Assessment does not only measure correct answers, but also thinking processes and the application of concepts.	Assessment may take the form of projects, portfolios, data reports, presentations, and reflections.

These principles show that an ideal curriculum is not merely a curriculum that contains complete mathematical content. An ideal curriculum is one that connects mathematical concepts with students' lives, develops thinking skills, and builds awareness of sustainability issues.

6. Conceptual Framework Toward an Ideal Curriculum

Based on the literature synthesis, an ideal curriculum for sustainable education-based mathematics learning is developed through a process of transformation, beginning with low mathematics achievement, the dominance of procedural learning, the need for numeracy and reasoning, sustainable education-based mathematics learning, teachers' roles as curriculum interpreters and developers, authentic assessment, and finally the formation of an ideal curriculum. This conceptual flow is presented in the following figure.

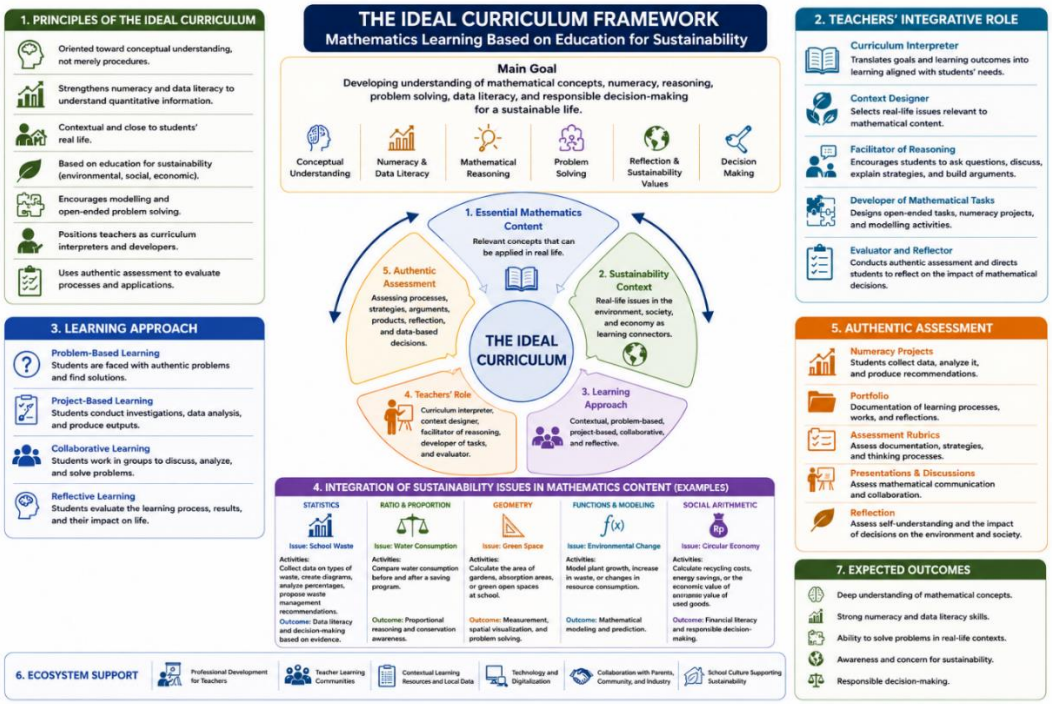

Figure 2. Copceptual Framework Toward an Ideal Curriculum

The figure shows that an ideal curriculum for sustainable education-based mathematics learning is built through the integration of essential mathematical content, sustainability contexts, learning approaches, teachers' roles, and authentic assessment. The curriculum is not only directed toward the mastery of formulas, but also toward strengthening conceptual understanding, numeracy, reasoning, problem-solving, reflection, and responsible decision-making. Within this framework, teachers serve as curriculum interpreters, context designers, facilitators of reasoning, developers of mathematical tasks, and learning evaluators. With the support of the school ecosystem, the ideal curriculum is expected to position mathematics as a tool for understanding real-life problems and sustainability issues.

DISCUSSION

The findings indicate that mathematics learning needs to move from a procedural orientation toward learning that is more conceptual, contextual, and sustainability-oriented. Low mathematics achievement should not be understood solely as a matter of students' ability, but also as an issue related to how mathematics is taught. When learning overly emphasizes formulas, fixed steps, and routine exercises, students tend to understand mathematics mechanically. Therefore, mathematics learning should be directed toward developing conceptual understanding,

numeracy, reasoning, and the ability to use mathematics in real-life situations (Pickering et al., 2025; Sofnidar et al., 2024). Sustainable education provides space for mathematics to be learned more meaningfully. Issues such as waste, water, energy, green spaces, consumption, circular economy, and environmental change can serve as contexts for mathematics learning (Mulhern & Wylie, 2006; Pratami et al., 2018; D. D. Pratiwi et al., 2024). Through these contexts, students do not merely solve problems; they also read data, conduct measurements, make comparisons, construct models, interpret results, and make evidence-based decisions (D. D. Pratiwi, 2016; S. A. Pratiwi et al., 2024). Thus, mathematics can function as a thinking tool for understanding social, economic, and environmental issues.

The findings also affirm that an ideal curriculum should not be understood merely as a document containing learning materials and outcomes. An ideal curriculum should be understood as a design of learning experiences that connects objectives, essential content, life contexts, learning strategies, assessment, and sustainability values (Kementerian Pendidikan Riset, dan Teknologi, 2024). Such a curriculum provides space for problem-based learning, numeracy projects, mathematical modelling, collaboration, and reflection. In this way, mathematics learning does not only prepare students for examinations, but also equips them to deal with real-life problems (Pelemeniano & Siega, 2023; Pratami et al., 2018). In realizing an ideal curriculum, teachers play a central role. Teachers are not merely curriculum implementers, but also interpreters, developers, context designers, facilitators of reasoning, and learning evaluators. Teachers determine how mathematical content is connected to sustainability issues, how students are engaged in thinking processes, and how learning is assessed authentically (Baki & Noss, 1996; Faisyal et al., 2023; Lafuente-Lechuga et al., 2024). Therefore, strengthening teachers' competence is essential so that sustainable education-based mathematics learning does not remain a normative idea, but is truly implemented in classroom practice.

Authentic assessment is also an important component of an ideal curriculum. If assessment only evaluates correct answers, learning will continue to be procedural. In contrast, assessment that evaluates thinking processes, strategies, arguments, problem-solving, projects, reflection, and data-based decisions will encourage more meaningful mathematics learning. Therefore, an ideal curriculum needs to integrate learning and assessment as a unified process that supports the development of numeracy, mathematical reasoning, sustainability literacy, and students' social responsibility. Conceptually, this article shows that sustainable education-based mathematics learning requires synergy among curriculum, teachers, context, learning strategies, assessment, and support from the school ecosystem. Support in the form of teacher training, professional learning communities, contextual learning resources, technology, and collaboration with the surrounding environment is an important factor in ensuring that the ideal curriculum can be implemented in practice. Thus, developing an ideal curriculum is not merely a matter of revising documents, but also of transforming mindsets and mathematics learning practices

CONCLUSION

This article concludes that sustainable education-based mathematics learning requires an ideal curriculum that goes beyond the mastery of formulas, procedures, and routine exercises. The ideal curriculum should be designed as a learning experience that connects mathematical concepts with real-life contexts, sustainability issues, numeracy, reasoning, problem-solving, reflection, and responsible decision-making. In this framework, mathematics is not merely positioned as an abstract subject, but as a tool for understanding social, environmental, and economic issues in students' daily lives. The findings also emphasize that teachers play a central role in realizing this ideal curriculum. Teachers act as curriculum interpreters, context designers, facilitators of reasoning, developers of mathematical tasks, and learning evaluators. Through these roles, teachers transform curriculum documents into meaningful classroom practices. Therefore, sustainable education-based mathematics learning requires teachers who are able to connect mathematical content with issues such as waste, water and energy use, green spaces, circular economy, and environmental change through contextual learning, mathematical modelling, numeracy projects, and authentic assessment. An ideal curriculum for sustainable mathematics learning should be built on several principles: conceptual understanding, numeracy strengthening, contextual and real-life learning, sustainability orientation, modelling and problem-solving, teacher agency, and authentic assessment. Assessment should not only measure correct answers, but also evaluate students' reasoning, strategies, arguments, reflection, and ability to make data-based decisions. Future studies are recommended to examine this conceptual framework empirically through classroom observations, teacher interviews, teaching module analysis, or the development of sustainable education-based mathematics learning materials.

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