Research Article

Transformational Learning Design: Developing an Environment-Based Mathematics Model for Quality and Outcome Improvement

Abstract

This study develops and evaluates the Environment-Based Mathematics Learning (EBML) model as a transformational instructional approach to improve learning quality and outcomes in secondary mathematics. The model integrates environmental exploration, contextual problem-solving, and collaborative inquiry to strengthen students' conceptual understanding. Using a developmental research design, EBML was validated through expert assessments, classroom observations, student responses, and pre–post learning performance. The validation results show a high level of conceptual and structural validity (average score 3.72), while practicality tests indicate strong acceptance among teachers (90.63%) and students (92.16%). Effectiveness analysis demonstrates significant improvement in learning outcomes, with achievement increasing from 62.06% to 87.79% and a gain index of 0.68. Student activity also remained consistently high across all learning stages. The findings confirm that EBML is a feasible, effective, and contextually rich model that transforms mathematics learning by connecting abstract concepts to meaningful environmental experiences.

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1. Introduction

The rapid changes in the 21st century, driven by digitalization, environmental challenges, and evolving educational demands, have highlighted the need for transformative approaches in teaching and learning. Traditional instructional models, especially in mathematics education, often rely on abstract computation and teacher-centered delivery, resulting in limited student engagement and weak conceptual understanding. Learners frequently perceive mathematics as disconnected from real-life contexts, leading to low motivation, performance anxiety, and declining achievement. These challenges are amplified in secondary schools where students are expected to master increasingly complex mathematical concepts that require critical reasoning, problem-solving, and the ability to apply knowledge meaningfully. As global education systems shift toward competency-based learning and contextual problem-solving, there is a growing demand for learning models that transform classroom practices and support improved learning quality and outcomes [1].

Environmental-based learning provides a promising foundation for such transformation. By grounding mathematics instruction in the natural and social environment surrounding the learners, this approach connects abstract concepts to meaningful experiences. Environmental phenomena such as shapes, patterns, measurements, and spatial structures offer rich opportunities to contextualize mathematical ideas. When students explore their local environment measuring objects, identifying geometric patterns in buildings, analyzing rainfall data, or modeling real-world problems, they develop stronger cognitive links between content and context. Research shows that contextualized learning increases engagement, strengthens retention, and promotes higher order thinking skills. Moreover, environmental-based learning aligns with broader educational goals such as sustainability awareness, character development, and the cultivation of responsible citizenship [2].

Despite its potential, the implementation of environment-based learning in mathematics remains limited and fragmented. Many teachers still rely heavily on textbook-driven instruction, with minimal integration of real-world environmental experiences. Environmental contexts are often introduced superficially, without structured stages that guide inquiry, exploration, and reflection. This results in inconsistent learning outcomes and a lack of systematic instructional design. To address these gaps, a transformational learning design is needed one that not only integrates environmental elements but also reshapes the pedagogical process toward active, student-centered, and inquiry-driven learning [3].

Transformational learning design refers to the deliberate restructuring of instructional processes to shift learners from passive knowledge reception to meaningful engagement with problems rooted in authentic contexts. It emphasizes the development of deep understanding, personal relevance, and reflective thinking. In the context of mathematics education, transformational design signifies an approach that uses real environmental experiences as catalysts for conceptual mastery. Such a design encourages collaboration, exploration, creativity, and evidence-based reasoning, all of which contribute to improved learning quality and outcomes [4].

The environment-based mathematics model (EBML) proposed in this study is rooted in the principles of transformational learning. The model positions environmental contexts not as supplementary examples but as core instructional drivers. Students interact with their surroundings, collect data, observe patterns, engage in hands-on problem-solving, and construct mathematical meaning through guided exploration. The EBML model also integrates structured stages that support inquiry, conceptualization, application, and reflection, making learning not only more meaningful but also measurable and aligned with curriculum standards [5].

At the systemic level, the call for innovative and relevant mathematics instruction is aligned with national and global educational frameworks. International assessments such as PISA and TIMSS emphasize reasoning, real-world application, and problem-solving competencies that are often underdeveloped in traditional mathematics classrooms. Countries with strong mathematics performance invest heavily in student-centered and contextual learning approaches. Likewise, environmental education initiatives, including the Adiwiyata program in Indonesia, encourage schools to embed environmental responsibility into daily learning activities. Mathematics, as a universal language, offers rich opportunities to connect cognitive development with environmental stewardship [6].

However, existing models of environmental-based mathematics learning lack comprehensive instructional structures, validated pedagogical components, and clear indicators of quality and outcomes. Many previous studies focus on thematic integration or environmental awareness without deeply analyzing the mathematical learning process or its impact on conceptual mastery. There is also limited research that positions environment-based learning as a transformational tool rather than as an enrichment activity. This gap highlights the need for a robust, validated, and practical model that bridges environmental contexts with structured mathematical learning.

This study aims to develop a transformational learning design for mathematics instruction through the Environment-Based Mathematics Learning (EBML) model. The goal is to produce an instructional framework that enhances learning quality, deepens conceptual understanding, and improves student outcomes. The model addresses contextual relevance, inquiry dynamics, teacher

facilitation roles, environmental literacy, and structured learning stages. By integrating these components, the EBML model offers a structured and scalable approach to redesigning mathematics learning in secondary education.

The introduction sets the foundation for the study by highlighting the need for transformational models in mathematics education, the potential of environmental-based learning, and the research gap in existing instructional designs. The following sections will elaborate on the methodological approach, model development, validation process, and implications for educational practice and policy.

2. Literature review

The development of the Environment-Based Mathematics Learning (EBML) model is grounded in several theoretical and empirical foundations that highlight the importance of contextualization, transformational learning, and active engagement in mathematics instruction. This section reviews key concepts, including environmental-based learning, contextual and constructivist theories, transformational learning, mathematical literacy frameworks, and the role of learning environments in shaping student outcomes. Together, these perspectives provide the conceptual basis for designing a pedagogically robust and contextually meaningful mathematics learning model [7].

Environmental-based learning has gained recognition as an approach that situates instruction within the real-world surroundings of learners. Scholars argue that the environment offers authentic stimuli that allows students to explore mathematical ideas through direct observation and hands-on interaction. When students measure objects, identify geometric forms in nature, analyze patterns in local structures, or interpret environmental data such as rainfall or temperature, they are not merely performing abstract calculations but engaging in experiential learning. Research shows that environmental-based instruction increases relevance, boosts motivation, and strengthens students' ability to transfer mathematical concepts to new situations. This contextual grounding is essential for cultivating mathematical literacy, which encompasses the capacity to apply mathematics meaningfully in everyday life [8].

The theoretical roots of EBML can also be traced to constructivist learning theory, which posits that students actively construct knowledge through interactions with their environment, prior experiences, and social collaboration. Constructivist theorists such as Piaget and Vygotsky emphasize the importance of exploration, discovery, and problem-solving as mechanisms for internalizing concepts. In this perspective, learning is not the passive absorption of information but the dynamic process of meaning-making. EBML aligns closely with constructivism by positioning students as active participants who investigate real-world phenomena, interpret results, and develop mathematical generalizations. Through these processes, learners form deeper conceptual connections and develop a more coherent understanding of mathematical relationships [8].

Transformational learning theory provides another important lens for understanding the value of EBML. Transformational learning, as articulated by Mezirow and later scholars, refers to the process of shifting learners' perspectives through critical reflection, meaningful experience, and the re-evaluation of prior assumptions. In mathematics education, transformational learning occurs when students move from procedural, rote-driven thinking toward conceptual, reflective, and contextually grounded understanding. By engaging students with environmental problems that require exploration, analysis, and reasoning, EBML encourages transformative shifts in how learners perceive mathematics. Instead of viewing mathematics as abstract and disconnected, students come to see it as a tool for understanding the world around them. This reorientation not only deepens comprehension but also supports long-term retention and adaptive problem-solving [8].

Contextual learning theory further reinforces the significance of linking instruction to real-life situations. According to contextual learning principles, knowledge becomes meaningful when learners see clear relevance between academic content and their lived experiences. In mathematics education, contextual approaches have been shown to improve student engagement, reduce anxiety, and foster positive attitudes toward learning. EBML operationalizes contextual learning by embedding mathematical tasks within environmental contexts, such as studying plant growth

patterns, measuring distances in school facilities, or analyzing natural shapes and symmetry. These contextual tasks allow students to situate mathematical ideas within familiar settings, making learning more intuitive and accessible [9].

The role of the learning environment itself has been extensively documented in educational research. Studies highlight that physical, social, and cultural environments influence students' learning behaviors, motivation, and sense of agency. When students work in environments that encourage exploration and collaboration such as school gardens, local surroundings, or community spaces, they exhibit higher levels of curiosity and engagement. EBML leverages the environment as a "third teacher," allowing physical surroundings to serve as a catalyst for inquiry and discovery. This approach also supports the development of environmental awareness and sustainability values, which are increasingly emphasized in modern curricula [10], [11], [12], [13].

Mathematical literacy frameworks, including those used in international assessments such as PISA, also underscore the importance of applying mathematics to real-world problems. PISA defines mathematical literacy as the ability to formulate, employ, and interpret mathematics in a variety of contexts. EBML directly supports this definition by engaging students in formulating environmental problems, employing mathematical tools to analyze phenomena, and interpreting results in meaningful ways. This alignment suggests that environment-based learning not only improves classroom performance but also cultivates skills relevant to global competencies [13], [14].

Finally, research on inquiry-based and collaborative learning supports the structure of EBML. Inquiry-based learning encourages students to investigate questions, gather evidence, test assumptions, and draw conclusions processes that are fundamental in EBML's stages of exploration, data collection, and generalization. Collaborative learning enhances communication, teamwork, and shared meaning-making, all of which are essential in group-based environmental activities. Together, these approaches strengthen students' cognitive and social skills while promoting deeper understanding.

3. Methods

This study employed a developmental research methodology with a qualitative foundation to design, validate, and refine the Environment-Based Mathematics Learning (EBML) model. Developmental research was chosen because it allows the systematic creation and evaluation of instructional models through iterative analysis, expert input, and empirical observations. Qualitative orientation supports an in-depth exploration of contextual needs, pedagogical challenges, and environmental integration within real instructional settings [15].

The research process consisted of three main stages: (1) preliminary investigation, (2) model design, and (3) expert validation and refinement. Each stage involved multiple data sources and analytical procedures to ensure the credibility and robustness of the resulting model [16].

During the preliminary investigation, the researcher conducted a comprehensive analysis of curriculum documents, learning outcomes, mathematics textbooks, school environmental profiles, and existing instructional practices. Additional insights were obtained through classroom observations and semi-structured interviews with mathematics teachers, school administrators, and environmental education coordinators. These activities aimed to identify learning difficulties, contextual opportunities, and pedagogical gaps that could be addressed through environmental-based learning. The data revealed common challenges such as passive student participation, limited contextual examples, repetitive procedural teaching, and minimal use of the school environment as a learning resource [16].

The second stage involved designing the initial model based on the needs identified. The EBML model was constructed using principles derived from transformational learning theory, contextual instruction, and inquiry-based learning. The design included structured stages: orientation to environmental problems, contextual exploration, mathematical conceptualization, collaborative application, reflection, and evaluation. Each stage was mapped with instructional strategies, teacher facilitation roles, learning activities, and expected student behaviors. To ensure alignment with curriculum standards, the model incorporated core mathematical competencies such as problem-

solving, reasoning, representation, and communication [16].

The third stage focused on expert validation using a review panel of mathematics educators, curriculum specialists, and environmental education experts. They evaluated the clarity, coherence, practicality, and theoretical alignment of the model. Their feedback contributed to refining conceptual definitions, improving flow between learning stages, adjusting teacher guidelines, and strengthening the assessment components. The iterative revision ensured that the model was both pedagogically sound and feasible for classroom implementation [17], [18].
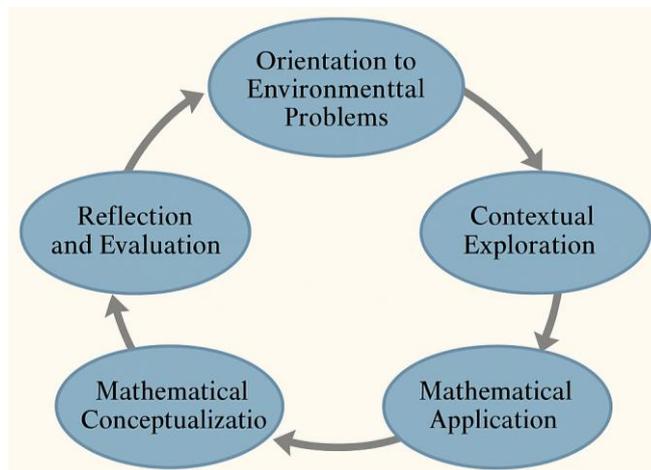
Figure 1. Research model of conseptual

Data from interviews, documents, and observations were analyzed using content analysis. Coding categories were developed to identify patterns related to instructional needs, environmental integration, conceptual difficulties, and pedagogical expectations. Themes emerging from this analysis directly informed the design elements of the EBML model. Triangulation across data sources strengthened validity, while reflective analysis helped minimize researcher bias [19].

In summary, the methodological approach combined developmental research with qualitative inquiry to produce a well-grounded and systematically validated instructional model. The integration of field data, expert insights, and theoretical foundations ensured that the EBML model is not only conceptually strong but also practically applicable in secondary mathematics classrooms.

4. Results

Based on the data and findings from the dissertation document, the implementation of the Environment-Based Mathematics Learning (EBML) model generated a set of results related to model validity, practicality, effectiveness, and improvements in student learning behaviors. These results were triangulated through expert validation, classroom observations, student response questionnaires, and pre-test/post-test performance assessments.

4.1 Model Validity

The validity of the EBML model and its supporting learning tools including lesson plans (RPP), worksheets (LKS), performance assessments, and teacher guides were evaluated by expert validators. Table 1 presents the validation results.

Table 1. Validation Results of the Environment-Based Learning Model.

No	Assessment Aspect	Validator I	Validator II	Average	Category
1	Conceptual Foundation	4.0	4.0	4.0	Very Valid
2	Language Feasibility	3.8	3.7	3.7	Very Valid
3	Content Alignment	3.8	3.8	3.8	Very Valid
4	Learning Design	4.0	3.3	3.7	Very Valid

No	Assessment Aspect	Validator I	Validator II	Average	Category
5	Implementation Structure	3.6	3.4	3.5	Valid
6	Assessment Component	3.7	3.7	3.7	Very Valid
—	Overall Average	—	—	3.72	Very Valid

Table 1 indicates that all aspects of the model obtained average scores ≥ 3.5, placing the EBML model in the valid to very valid category. The highest scores were found in the conceptual foundation and content alignment components. These results confirm that the EBML model is theoretically grounded, logically structured, and pedagogically appropriate for secondary mathematics learning.

4.2 Practicality of the Model

The practicality of the EBML model was examined through classroom implementation and evaluative questionnaires completed by teachers and students. Table 2 summarizes the practicality results for the instructional materials.

Table 2. Practicality of Learning Materials

No	Learning Material	Validator 1	Validator 2	Average	Category
1	Lesson Plans (RPP)	3.00	3.60	3.20	Valid
2	Worksheets (LKS)	3.00	3.40	3.23	Valid
3a	Learning Achievement Test	3.00	3.50	3.33	Valid
3b	Attitude Assessment	3.00	3.40	3.33	Valid
3c	Performance Assessment	3.00	4.00	3.50	Valid

All learning materials fall into the valid category, indicating that teachers found them easy to use and functionally suitable for EBML implementation. The performance assessment rubric scored the highest (3.50), showing strong clarity in evaluating students' hands-on activities and environmental problem-solving tasks. Furthermore, practical responses from users reflect very high acceptance is Teacher practicality = 90.63%, Student practicality = 92.16%. These findings demonstrate that EBML tools are not only usable but also highly compatible with real classroom conditions.

4.3 Effectiveness of the Model

Model effectiveness was determined through student learning outcomes. Table 3 and Table 4 present the readability and comprehension responses to the worksheets and tests.

Table 3. Student Responses to Symbol Readability

Statement	Yes (%)	No (%)
Symbols on LKS are clear	84	16
Symbols on Test are clear	84	16

Table 4. Student Responses to Language Readability

Statement	Yes (%)	No (%)
LKS language is easy to understand	90	10
Test language is easy to understand	84	16

Table 5. Student Understanding of LKS and Test Problems

Statement	Understand (%)	Do Not Understand (%)
Understand problems in LKS	95	5
Understand problems in Test	82	18

The high readability and comprehension percentages indicate that the EBML materials are

accessible and aligned with students' cognitive development. This supports the model's effectiveness in promoting clarity, reducing cognitive overload, and enabling deeper engagement during environmental-based activities. Learning outcome data confirms this effectiveness.

- Pre-test average: 62.06% (adequate)
- Post-test average: 87.79% (very good)
- Gain index: 0.68 (moderate–high improvement)

These results show substantial growth in students' mathematical understanding, attributable to contextual and experiential learning processes.

4.4 Student Activity During Learning

Classroom observations across three sessions show consistently high engagement in EBML activities. Table 6 summarizes the reconstructed observation data.

Table 6. Summary of Student Learning Activities

Activity	Meeting 1	Meeting 2	Meeting 3
Paying attention to teacher explanations	√	√	√
Understanding worksheet problems	√	√	√
Group discussion	√	√	√
Asking/answering questions	√	√	√
Collecting environmental data	√	√	√
Analyzing data	√	√	√
Making mathematical generalizations	√	√	√

The consistent "√" marks across all activities reflect active participation, inquiry-based exploration, teamwork, and problem-solving all essential components of the EBML approach. Students not only were engaged with environmental stimuli but also demonstrated progressive independence in interpreting, analyzing, and contextualizing real-world mathematical tasks.

5. Discussion and Implications

The findings of this study demonstrate that the Environment-Based Mathematics Learning (EBML) model is an effective transformational instructional approach that enhances learning quality, strengthens conceptual understanding, and improves student outcomes in secondary mathematics. Several central themes emerge from the results, each contributing to a deeper understanding of how environmental-based pedagogical design reshapes mathematics learning [20].

5.1 Strengthening Conceptual Understanding Through Environmental Contexts

One of the most compelling outcomes of the EBML implementation is the substantial improvement in students' conceptual understanding. As shown in the pre-test and post-test comparisons, students' achievement increased from 62.06% to 87.79%, accompanied by a gain index of 0.68. These results indicate that contextualizing mathematics within real environmental settings promotes deeper cognitive processing.

Transformational learning theory posits that knowledge becomes more meaningful when learners engage in reflective interpretation of authentic experiences. In EBML, students explore patterns, structures, shapes, measurements, and relationships embedded in their immediate environment, such as plants, buildings, school facilities, and natural objects. This process encourages them to construct mathematical meaning rather than merely memorizing procedures. Such experiential engagement supports the development of higher-order thinking skills including analysis, synthesis, and application competencies essential to 21st-century learning.

Moreover, environmental contexts help bridge the abstract nature of mathematics by grounding concepts in observable, tangible situations. This addresses common learning barriers where students perceive mathematics as disconnected from real life. EBML transforms the learning

environment into a "mathematics laboratory" where students investigate natural phenomena, gather real data, and convert it into mathematical representations. This alignment between concrete experience and abstract reasoning strengthens retention and accelerates conceptual mastery [21], [22].

5.2 Increasing Motivation, Engagement, and Active Learning

The observational data provides consistent evidence that EBML fosters high levels of student engagement across all meetings. Students actively participated in discussions, asked questions, collaborated in groups, collected data, and developed generalizations. Engagement of this kind is rarely achieved in conventional, teacher-centered classrooms, indicating that EBML promotes intrinsic motivation by making learning meaningful and relevant.

Student responses to readability and comprehensibility of the learning worksheets further reinforce this point. With more than 90% of students reporting clear language and understandable problem statements, EBML materials appear to be accessible and user-friendly. This clarity reduces cognitive load, enabling students to focus their mental energy on problem-solving and conceptual reasoning rather than decoding instructions.

From a pedagogical perspective, engagement is a key indicator of effective learning. Active learners tend to retain information more effectively, demonstrate stronger problem-solving skills, and show greater persistence in tackling challenging tasks. EBML stimulates active learning by guiding students through cycles of inquiry, exploration, interpretation, and reflection principles consistent with constructivist and contextual learning theories [23].

5.3 Practicality and Feasibility of the Model for Secondary Schools

Practicality results indicate that both teachers and students find EBML highly usable, with practicality scores of 90.63% and 92.16%, respectively. These findings hold significant implications for educational implementation. Teachers reported that the model's design is intuitive, the procedures are logical, and the supporting tools such as lesson plans, worksheets, and assessment instruments are easy to apply in classroom settings. This is particularly important because many innovative instructional models fail to be adopted widely due to complexity or impractical implementation routines.

The EBML model, however, leverages the environment as a learning resource, reducing dependence on expensive laboratory equipment or digital technologies. Schools with limited facilities can adopt EBML without additional financial burden, as it uses real-life environmental objects readily available around the school. This makes EBML a low-cost, high-impact instructional innovation suitable for a variety of school contexts.

The high student practicality score further emphasizes that EBML is accessible to learners from diverse backgrounds. Its emphasis on real-world exploration allows students to approach mathematics not as a set of isolated procedures but as a meaningful tool for understanding and interacting with their environment [24].

5.4 Validity and Reliability of Learning Tools Enhance Instructional Quality

The validity scores of 3.72 across key instructional components affirm that the EBML model is pedagogically sound and theoretically coherent. High validity in foundational aspects such as learning design, content alignment, and assessment strategies suggests that the model was constructed carefully in alignment with curriculum demands and educational standards. Furthermore, the strong validity of the achievement test items indicates that the improvements observed in student outcomes reflect actual learning gains rather than measurement bias. This reliability strengthens the legitimacy of EBML as an effective instructional approach [25].

5.5 EBML as a Transformational Learning Framework

Transformational learning emphasizes shifts in perspectives, behavioral change, and

meaningful, long-lasting learning. EBML embodies transformational principles by providing learners with opportunities to [25]:

• Observe and question real-world phenomena.
• Engage in collaborative inquiry.
• Apply mathematical concepts to interpret environmental data.
• Reflect on findings and convert them into generalizable mathematical principles.

This shift from passive to active learning changes not only what students learn but how they perceive the value of mathematics. Students begin to understand mathematics as a relevant, practical, and empowering tool for solving real problems in their surroundings.

5.6 Implications for Teachers and Educational Management

The success of EBML has practical implications for mathematics teachers, curriculum developers, and school leaders. For teachers, EBML provides a clear, structured, and validated instructional model that can enhance teaching effectiveness. Environmental focus encourages teachers to incorporate local wisdom, ecological awareness, and sustainability concepts into mathematics. For educational leaders and policymakers, EBML aligns with broader goals of improving learning quality, fostering innovation, and promoting contextualized, competency-based education. Its low-cost implementation makes it suitable for scaling across schools, particularly those in developing regions where resource limitations pose major challenges [26].

6. Conclusion

This study concludes that the Environment-Based Mathematics Learning (EBML) model is a valid, practical, and effective instructional design capable of transforming mathematics education in secondary schools. The strong improvement in student learning outcomes, high engagement levels, and positive teacher and student responses collectively demonstrate the model's ability to enhance both the quality and the process of learning. The model's validity is affirmed through expert evaluations, which highlight the strength of its theoretical foundation, pedagogical structure, and content alignment. These validity scores indicate that EBML is conceptually rigorous and suitable for supporting meaningful mathematics learning.

Its practicality is demonstrated by very high percentages of acceptance among teachers and students. Teachers find the model clear, implementable, and compatible with standard instructional routines, while students experience enjoyment, clarity, and motivation during environmental-based activities. This practicality ensures that the model can be implemented widely across various educational contexts. The effectiveness of EBML is shown through significant gains in student achievement, supported by a moderate-to-high gain index and consistent improvements across multiple indicators. Students become active participants in their own learning, engaging in exploration, observation, data collection, analysis, and mathematical generalization. These competencies reflect the development of higher-order thinking and problem-solving skills required for the 21st century.

In addition, EBML promotes meaningful learning by bridging the gap between abstract mathematical concepts and real-life environmental contexts. This contextual grounding enhances student interest, supports deeper understanding, and encourages the development of reflective thinking, a hallmark of transformational learning. Overall, EBML offers:

• A sustainable and low-cost innovation suitable for diverse school environments.
• A powerful strategy for integrating environmental awareness with mathematics learning.
• A scalable model that aligns with national curriculum goals and international standards for quality education.

Given its strong empirical support, the EBML model is recommended for wider adoption in secondary mathematics classrooms. Future research may extend its application to different mathematical topics, evaluate its long-term impact on student attitudes, or integrate digital tools to further enhance environmental exploration. The findings of this study provide a solid foundation for rethinking mathematics instruction through a transformational, context-based, and

environmentally grounded approach.

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