Eco–Realistic Mathematics Education (Eco–RME) Module for Students with Special Needs in Inclusive Primary Schools in Aceh Province

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Abstract

This study develops an Eco–Realistic Mathematics Education (Eco–RME) learning module for students with special needs in inclusive primary schools in Aceh Province. The research addresses children with dyslexia, attention deficit hyperactivity disorder, and slow learning difficulties. The module combines principles of Realistic Mathematics Education, eco-literacy, and Universal Design for Learning to ensure contextual, differentiated, and environmentally grounded instruction. A multi-case exploratory design was implemented in two inclusive schools in Aceh, using classroom observations, teacher and parent interviews, and focus group discussions. Findings show that students with dyslexia struggle to recognize number symbols, students with attention difficulties benefit from engaging and game-like tasks, and slow learners require repeated scaffolding. The module incorporates eco-based activities such as shopping simulations, measuring with recycled objects, and classifying waste materials. The initial prototype includes structured lesson scenarios, inclusive worksheets, and alternative assessments. This study contributes to inclusive mathematics pedagogy by integrating environmental awareness with mathematical competence.

Keywords: eco–realistic mathematics education, inclusive primary schools, special needs students, universal design for learning

1. Introduction

Inclusive education emphasizes equal learning opportunities for all students, including those with special needs such as dyslexia, attention deficit hyperactivity disorder (ADHD), and slow learning challenges. In the context of mathematics, these students often face significant barriers due to difficulties in symbol recognition, sustaining concentration, and slower processing speed compared to their peers. Studies have consistently demonstrated that mathematical difficulties among children with special needs are not merely cognitive but also linked to socio-emotional and motivational factors (Geary, 2013; Susanto & Rachbini, 2024). For example, children with dyslexia often struggle with number symbol recognition and arithmetic fact retrieval, which results in persistent difficulties in basic numeracy (Reschly, 2005). Similarly, students with ADHD experience challenges in maintaining attention and working memory, which affect their ability to follow multi-step mathematical procedures (Tosto et al., 2015). Slow learners, meanwhile, require extended time, structured scaffolding, and frequent repetition to achieve basic mathematical competencies(Mardiana, 2023; Wanabuliandari et al., 2025).

Empirical evidence highlights that effective instructional strategies for these groups include contextualized tasks, visual aids, and repetitive practice (Boonk et al., 2018). A study by (Magdadaro, 2020) found that multisensory and contextual approaches significantly improved arithmetic performance among primary school students with dyslexia. Likewise, interventions using short, game-based mathematics activities demonstrated positive effects for students with ADHD by reducing off-task behavior and enhancing motivation (Daley & Birchwood, 2010). For slow learners, scaffolded and step-by-step instruction tailored to their pace of learning was shown to increase numeracy retention and reduce anxiety toward mathematics (Oentoe & Huda, 2020). These findings suggest that mathematics education for special needs students requires pedagogical models that are adaptive, context-driven, and inclusive.

Realistic Mathematics Education (RME), pioneered by Freudenthal, offers a promising framework to address these challenges. RME emphasizes learning mathematics through real-world contexts and promotes progressive formalization from concrete experiences to symbolic representation (Oentoe & Huda, 2020). By situating mathematical concepts in everyday situations such as shopping, measuring, or classifying objects, RME enables students to build meaning and transfer abstract ideas into practical use. Several studies have demonstrated the effectiveness of RME in improving conceptual understanding and problem-solving skills in diverse student populations, including those with learning difficulties (Van den Heuvel-Panhuizen & Drijvers, 2014).

In parallel, eco-literacy and green pedagogy have emerged as critical educational paradigms for fostering sustainability awareness in young learners. Eco-literacy, as defined by (Capra, 2002), involves the ability to understand ecological principles, recognize the interdependence between human and natural systems, and make environmentally responsible choices. In primary education, eco-literacy has been shown to enhance not only environmental awareness but also cognitive engagement, since real-life ecological issues provide rich, meaningful contexts for interdisciplinary learning (Sterling, 2010). Green pedagogy further reinforces this by embedding ecological values into daily classroom practices, encouraging students to relate learning to environmental stewardship (Sibbel, 2009). In mathematics education, eco-based contexts—such as measuring plant growth, analyzing waste categories, or counting recycled objects—can serve as authentic entry points to numeracy while simultaneously cultivating sustainability values (Tilbury, 2004).

Integrating RME with eco-literacy creates opportunities for contextual and socially relevant mathematics instruction. However, for special needs students, such integration must be supported by adaptive instructional design. Universal Design for Learning (UDL) provides a comprehensive framework for this integration. UDL principles advocate for multiple means of representation, engagement, and expression, ensuring that learning experiences are flexible and responsive to diverse learner needs (CAST, 2018). Research has confirmed that UDL-based practices, such as offering multimodal resources, providing alternative ways to demonstrate understanding, and embedding choice in tasks, significantly improve learning outcomes for students with disabilities (Rao et al., 2014) When combined with RME and eco-literacy, UDL ensures that eco-contextual mathematics activities remain accessible and meaningful to students with dyslexia, ADHD, and slow learning challenges.

Despite these theoretical advances, there remains a notable research gap in the Indonesian context, particularly in Aceh Province. Most studies on inclusive mathematics instruction in Indonesia have focused on general adaptations or the use of digital media(Fatwasrie et al., 2025) with limited exploration of eco-based pedagogical designs.

While eco-literacy has gained attention in science education and environmental programs, its integration into mathematics learning for special needs students is still underdeveloped. Similarly, RME has been widely researched in Indonesian mathematics education, but its application in inclusive settings with explicit UDL adaptations remains scarce. This gap underscores the need for a pedagogical innovation that addresses both inclusivity and sustainability in mathematics education.

The present study aims to develop an Eco–Realistic Mathematics Education (Eco–RME) module specifically designed for Phase A (Grades 1–2) students with special needs in inclusive schools in Aceh Province. The novelty of this research lies in its interdisciplinary integration:

a. Pedagogical novelty: combining RME with eco-literacy to situate mathematics in environmentally meaningful contexts.

b. Inclusive novelty: embedding UDL principles to ensure accessibility for diverse learners, particularly those with dyslexia, ADHD, and slow learning profiles.

c. Contextual novelty: addressing the specific educational and ecological context of Aceh Province, where inclusive schools are developing but lack structured eco-mathematics resources.

Accordingly, this study addresses three guiding research questions:

a. What are the mathematical learning needs of special needs students in inclusive primary schools in Aceh?

b. What are the characteristics of eco-based mathematics content and strategies suitable for special needs students?

c. How can the initial design of the Eco–RME module align with RME, eco-literacy, and UDL principles?

2. Methods

This study employed an Educational Design Research (EDR) approach (McKenney & Reeves, 2018) combined with an exploratory multi-case study design. The EDR process was conducted in three iterative stages: exploration, prototype design, and validation. The exploration stage identified the mathematical learning needs of students with special needs while also mapping eco-literacy opportunities available in classroom and school contexts. The prototype design stage focused on developing the initial version of the Eco–RME module by integrating the principles of Realistic Mathematics Education (RME), eco-literacy, and Universal Design for Learning (UDL). The validation stage involved expert review, teacher feedback, and preliminary classroom trials to ensure the practicality, inclusiveness, and contextual relevance of the module. This iterative structure allowed continuous refinement and adjustment of the prototype based on empirical findings.

2.1 Research Sites and Participants

The research was conducted in two inclusive primary schools in Aceh Province, Indonesia. The first site was *Sekolah Alam* iOS Aceh Besar, an eco-based inclusive school where environmental themes are embedded throughout the curriculum. The second site was *Sekolah Perkasa* Alam Banda Aceh, a mainstream school with an inclusion program specifically designed for children with learning difficulties.

Participants were selected purposively to capture diverse perspectives related to inclusive mathematics learning. They included six teachers responsible, ten parents of children with special needs, and twelve students formally identified with dyslexia, ADHD, or slow learning difficulties (four from each category). The purposive sampling ensured that the participants directly represented the target group of the Eco–RME intervention.

Table 1 presents a clear breakdown of participant distribution across both schools. In total, 28 participants took part in this research, consisting of six mathematics teachers, ten parents of children with special needs, and twelve students formally identified as having dyslexia, ADHD, or slow learning difficulties (four from each category). The balanced distribution was intentionally designed to ensure adequate representation of ecoliteracy and inclusion contexts in both schools.

Table 1. Participant Distribution

School	Mathematics Teachers	Parents of Children with Special Needs	Students with Special Needs (Dyslexia, ADHD, Slow Learners)	Total Participants
Sekolah Alam iOS Aceh Besar	3	5	6 (2 students per category)	14
Sekolah Perkasa Alam Banda Aceh	3	5	6 (2 students per category)	14
Total	6	10	12	28

2.2 Instruments

Multiple instruments were employed to collect data:

a. Observation Sheet: Consisting of twelve indicators, the instrument captured student engagement, the use of visual and concrete aids, scaffolding strategies, eco-context integration, and peer collaboration during classroom activities. Reliability was established through inter-rater testing, producing a Cohen's Kappa value of 0.82, which indicates high agreement.

b. Semi-Structured Interview Guide: Comprising ten open-ended questions, the guide was used with teachers and parents to explore their perceptions of mathematical learning challenges, eco-based opportunities, and adaptive strategies. Content validity was confirmed through expert judgment.

c. Focus Group Discussion (FGD) Protocol: Covering eight thematic areas such as media adaptation, eco-context relevance, and assessment adjustments, the FGD protocol allowed collaborative identification of barriers and design preferences. Validity was strengthened through peer review by two senior inclusive education researchers.

2.3 Data Credibility

Several strategies were applied to ensure credibility and trustworthiness of the data. Triangulation was conducted by cross-checking results across classroom observations, interviews, and FGDs. Member checking was employed by sharing preliminary findings with participating teachers and parents for verification and correction. In addition, peer debriefing was conducted with experts in mathematics education and inclusive pedagogy to validate the coding process and thematic interpretations.

2.4 Data Analysis

Data were analyzed thematically following the six phases of (Braun & Clarke, 2006). First, transcripts and observation notes were carefully reviewed for familiarization. Second, initial codes were generated, including “difficulty with number recognition,” “eco-context engagement,” and “scaffolding needs.” Third, the codes were grouped into broader themes, such as numeracy barriers, eco-literacy integration, and inclusive pedagogy. Fourth, the themes were refined and connected to design implications. Fifth, the themes were reviewed to ensure consistency across data sources. Finally, the thematic map was translated into design principles that directly informed the Eco–RME prototype. This analytic process ensured that the resulting module was firmly grounded in empirical evidence.

2.5 Ethical Considerations

The study adhered to ethical standards in educational research by obtaining written informed consent from parents or guardians regarding their children's participation. In addition, to respect the active involvement of children with special needs, the researchers also obtained direct assent from each child. This was essential to ensure that the children were consciously and willingly participating in the research process, in accordance with recommended ethical practices in inclusive research.

2.6 Research Process Visualization

The methodological process is summarized in Figure 1, which illustrates the three iterative stages of the EDR cycle applied in this study.

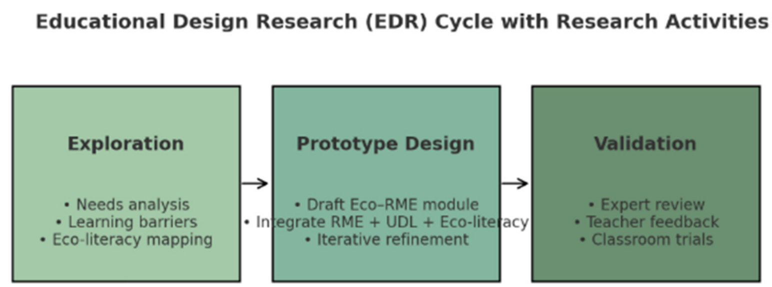

Figure 1. Research Process Visualization

The cycle began with the exploration of learning needs and eco-based opportunities, continued with prototype design that integrated RME, eco-literacy, and UDL, and concluded with validation through expert review and limited classroom trials.

3. Results

The findings of this study are presented thematically based on patterns and dominant themes emerging from the qualitative analysis of classroom observations, interviews, and FGDs. Each theme is supported with illustrative case examples to highlight the variations found among students with different learning needs.

3.1 Theme 1: Numeracy Barriers Among Students with Special Needs

Students with dyslexia exhibited notable challenges in recognizing and processing numerical symbols. One prominent issue was the reversal of numbers, such as confusing 6 and 9, which frequently impeded their progress in basic arithmetic activities. Several students also displayed avoidance toward written tasks, indicating discomfort with symbol-heavy materials.

To address these barriers, Eco–RME strategies incorporating visual and tactile supports were found to be highly effective. For example, a Grade 1 student who struggled with symbol reversals responded positively when taught using color-coded number cards and tactile tokens made from recycled wood. These materials helped reduce cognitive load by providing multisensory cues. The integration of such tools aligns with UDL principles by offering multiple means of representation, especially for learners who require stronger perceptual anchoring.

3.2 Theme 2: Attention and Engagement Challenges in Students with ADHD

Students with ADHD demonstrated significant difficulties in sustaining attention, often maintaining focus for only short durations—typically no more than seven minutes. Instances of impulsive movement, such as leaving their seat or fidgeting excessively, were commonly observed and disrupted participation in teacher-led instruction.

Eco–RME activities embedded with movement and play were particularly effective in enhancing engagement. For instance, a Grade 2 student with ADHD showed marked improvement when participating in short, game-based counting tasks using bottle caps. When these activities involved hopping, sorting, or quick-response challenges, the student sustained attention for longer periods compared to traditional seatwork. Consistent with UDL guidelines, these activities incorporated frequent breaks, structured movement, and flexible response modes, allowing students with ADHD to regulate their attention more naturally.

3.3 Theme 3: Need for Repeated Scaffolding Among Slow Learners

Students identified as slow learners required extended processing time and multiple cycles of guided practice before grasping foundational mathematical concepts. Many of these students exhibited difficulty transitioning from concrete representations to abstract number symbols.

Eco–RME strategies using eco-materials, such as beans, leaves, or sticks, proved helpful in building conceptual understanding. For example, a student who struggled with number sequencing showed noticeable improvement when guided through step-by-step scaffolding that began with counting physical objects, followed by matching activities, and finally symbolic representation. This structured progression reflects the UDL principle of providing multiple means of action and expression, enabling learners to gradually internalize concepts at their own pace.

3.4 Theme 4: General Inclusive Needs in Eco–RME Environments

Beyond students with specific diagnoses, several learners without identified conditions also showed difficulties handling abstract mathematical tasks, particularly when worksheets lacked meaningful context. Eco–RME naturally addressed this challenge by grounding mathematical concepts in authentic, eco-based experiences, such as comparing prices in the school canteen, classifying garden produce, or sorting waste materials.

These real-life contexts increased relevance and motivation for all learners. Differentiated worksheets and collaborative group tasks further supported diverse readiness levels, ensuring that general inclusive needs were not overshadowed by more narrowly defined categories.

3.5 Characteristics of Eco–RME Content and Strategies

Eco–RME content was derived from routine ecological practices in both schools, including activities in the canteen, school garden, recycling stations, and composting areas. These settings provided rich opportunities to teach core mathematical ideas: (1) Number sense through adding and comparing canteen prices; (2) Patterns and early algebra through observing repeated leaf arrangements; (3) Measurement using recycled bottles of varying lengths; (4) Geometry by identifying shapes in natural structures; (5) Data analysis through sorting waste or categorizing harvested vegetables

By situating mathematics within meaningful ecological activities, Eco–RME bridged the gap between abstract concepts and lived experiences, benefiting all learners while especially supporting students with special needs.

Table 2. Mapping of Learning Needs to Strategies and Adaptations

Student Needs	Observed Challenge	Eco–RME Strategies	UDL Adaptations
Dyslexia	Reversal of numbers; difficulty recognizing symbols	Color-coded number cards; tactile tokens from recycled wood	Visual + tactile representation; reduced symbolic load
ADHD	Short attention span; hyperactivity; difficulty staying seated	Short, game-based tasks using bottle caps; movement-integrated activities	Frequent breaks; structured movement; flexible participation modes
Slow learners	Slow processing speed; difficulty shifting from concrete to abstract	Repeated scaffolding using eco-materials (beans, leaves, sticks)	Step-by-step instruction; extended processing time
General inclusive	Difficulty with abstract tasks without real-life context	Learning activities based on canteen, garden, or waste sorting	Differentiated worksheets; collaborative group tasks

3.6 Module Design

The Eco–RME module was structured into five components: (1) Introduction, outlining objectives and theoretical integration; (2) Learning map (CP–TP–ATP), aligning curriculum goals with eco-contexts and inclusive strategies; (3) Lesson scenarios, applying concrete–pictorial–abstract progression; (4) Inclusive Worksheets (LKPD), with simplified visual tasks using recycled objects; and (5) Evaluation and reflection, incorporating observation, portfolios, eco-artwork, and oral reflections.

3.7 Integrated CP–TP–ATP Mapping

To ensure strong curriculum alignment, CP–TP–ATP trajectories were mapped across Numbers, Measurement, and Geometry.

Table 2. CP–TP–ATP Integration for Eco–RME Module

Competence	Curriculum Achievement (CP)	Learning Objectives (TP)	Learning Trajectories (ATP)
Numbers	Recognize, compare, and add ≤20	Perform simple addition in shopping activities	Use recycled tokens as money; add totals ≤20; record in adaptive worksheets
Measurement	Measure using non-standard tools	Compare objects with sticks, bottles, handspan	Measure and compare with eco-tools; record pictorially; discuss in groups
Geometry	Identify basic shapes in environment	Recognize circles, squares, triangles in nature	Group leaves or stones by shape; create collage; present visually

3.8 Sample Lesson (RPP)

An example lesson addressed Addition ≤20 in the context of school canteen shopping. Objectives included number recognition, addition practice, and eco-literacy values. Strategies followed a concrete–pictorial–abstract sequence: tokens and real items (concrete), pictorial worksheets (pictorial), and number sentences (abstract). Media included recycled tokens and colored cards. Assessment combined participation observation, accuracy in shopping tasks, and oral eco-reflection (e.g., “Why should we reuse bottles?”)

4. Discussion

The findings of this study highlight the potential of the Eco–RME module as a pedagogical framework that integrates Realistic Mathematics Education (RME), eco-literacy, and Universal Design for Learning (UDL) in inclusive classrooms. This integration aligns with Freudenthal’s principles of situating mathematics in meaningful contexts (Gravemeijer & Doorman, 1999), while extending its scope by embedding ecological dimensions, a feature comparable to Finland’s eco-pedagogy approaches (Reunamo & Suomela, 2013). Unlike conventional RME studies, which primarily focus on bridging concrete and abstract mathematical understanding, this research adds an environmental perspective that fosters ecological awareness alongside numeracy.

The differentiated adaptations observed in this study resonate with prior international findings. For instance, dyslexic students’ positive responses to visual and color-coded number cues support (Snowling & Hulme, 2012) work on multimodal reinforcement. ADHD learners’ increased engagement in short, game-based activities mirrors findings by (DuPaul & Stoner, 2014) on the effectiveness of interactive and movement-oriented strategies. Similarly, the necessity of scaffolding and repetition for slow learners reflects Swanson and Deshler’s (2003) conclusions on structured support. These alignments validate the relevance of UDL principles (CAST, 2018; Design & Instruction, 2010) while also showing how Eco–RME contributes additional value by embedding eco-literacy within the instructional design.

Compared to previous studies on inclusive mathematics education, Eco–RME demonstrates several distinctive contributions. First, it contextualizes mathematics within environmental practices such as waste management, gardening, and canteen-based transactions, thereby reducing abstraction and increasing relevance. This finding is consistent with (Jordan, 2013), who emphasize eco-social learning as a pathway toward pro-environmental behavior. However, the present research advances the field by linking eco-literacy explicitly to mathematical competencies, an area less explored in existing literature. Second, the study situates its innovation in Aceh, where socio-cultural attitudes toward special needs and limited access to eco-friendly learning resources pose unique challenges(Desfandi et al., 2017; Maulina et al., 2024). This context-sensitive dimension provides fresh insights into how global pedagogical models can be localized.

The implications of these findings are threefold. Theoretically, Eco–RME enriches the RME framework by integrating ecological and inclusive dimensions, offering a novel theoretical bridge between mathematics education, sustainability, and inclusive pedagogy. Practically, the module equips teachers with structured strategies that are both adaptive and eco-oriented, while providing schools with a blueprint for embedding sustainability within mathematics curricula. At the policy level, Eco–RME offers a scalable approach for achieving dual educational goals: inclusive education and environmental stewardship.

Despite these strengths, certain limitations must be addressed. The study remains at the prototype stage, and its effectiveness has not been tested through large-scale implementation or longitudinal assessment. Teacher readiness and resource availability may also limit replication, especially in under-resourced schools. Furthermore, while the qualitative evidence indicates improved engagement, quantitative validation of student learning outcomes and ecological attitudes is necessary to establish broader applicability.

In conclusion, Eco–RME represents both a pedagogical innovation and a socio-ecological intervention. By bridging mathematics, inclusion, and environmental education, this study not only complements existing research but also extends it into new directions. Future studies should focus on experimental trials, long-term impact assessments, and cross-cultural adaptations to evaluate the scalability and sustainability of the Eco–RME approach.

5. Conclusion

This study has produced an initial prototype of the Eco–Realistic Mathematics Education (Eco–RME) module for students with special needs in inclusive primary schools in Aceh Province. The module integrates three key dimensions—Realistic Mathematics Education (RME), eco-literacy, and Universal Design for Learning (UDL)—into a coherent instructional framework that situates mathematical learning in environmentally relevant and contextually meaningful experiences. Through this integration, the module not only bridges abstract numerical concepts with real-life eco-practices but also addresses the varied learning needs of students with dyslexia, ADHD, and slow learners by applying differentiated and adaptive strategies.

The originality of this research lies in demonstrating how mathematics education can function simultaneously as an academic and socio-environmental learning tool. At the pedagogical level, the Eco–RME module provides teachers with structured lesson scenarios, inclusive worksheets, and authentic assessment approaches that are adaptable to diverse learners. At the institutional and policy level, the module offers a replicable and scalable model for inclusive and sustainable curriculum innovation. Theoretically, this study advances the discourse at the intersection of RME and eco-pedagogy, emphasizing the role of mathematics as a medium for cultivating both numeracy skills and ecological responsibility.

Despite its contributions, the study remains at the prototype stage within the framework of educational design research. Broader classroom implementation, quasi-experimental validation, and iterative refinement are required to establish its effectiveness and generalizability. Future directions include the incorporation of digital features to enhance multimodality, accessibility, and scalability across diverse educational contexts.

In conclusion, the Eco–RME module provides a promising pedagogical innovation that addresses gaps in inclusive mathematics education while simultaneously fostering eco-consciousness. Its dual orientation toward cognitive development and ecological awareness strengthens its relevance for local practices in Aceh and contributes to international scholarship on inclusive and sustainable pedagogy.

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Authors contributions

Murni conceptualized the study, coordinated data collection in inclusive primary schools, and drafted background and literature review. Anzora contributed to the methodological design, data analysis, and preparation of research instruments. Fadhillah supervised the overall research process, refined the theoretical framework, and finalized the manuscript. All authors discussed the results, provided critical feedback, and approved the final version of the manuscript.

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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