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Development of a Deep Learning Pedagogical and Ecopedagogy-Based Fundamental Movement Learning Model for Post-Disaster Physical and Psychosocial Recovery of Elementary School Students

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Abstract
Indonesia's high disaster vulnerability significantly impacts elementary school students' physical and psychosocial well-being. Post-disaster, children often experience declines in physical fitness, fundamental movement skills, anxiety, and social interaction—directly affecting their learning readiness. This study aimed to develop and examine the effectiveness of a Deep Learning Pedagogical and Ecopedagogy-Based Fundamental Movement Learning Model (DL-Eco Model) as a holistic recovery intervention for post-disaster elementary school students. Employing a Research and Development (R&D) design with the ADDIE framework, the model was developed through systematic analysis, design, development, implementation, and evaluation stages. Effectiveness was tested using a quasi-experimental nonequivalent control group design across four elementary schools in one disaster-affected province (n ≈ 120 students, grades IV–V). Instruments included the Fundamental Movement Skills (FMS) test, the Indonesian Physical Fitness Test (TKJI), the Child Resilience Scale, and the Psychosocial Well-being Scale. Content validity was established using Aiken's V (≥ 0.80), and data were analyzed through descriptive and inferential statistics (independent t-test, ANCOVA, Cohen's d, and N-Gain). The DL-Eco Model integrates four instructional phases: experience orientation, movement exploration, meaningful reflection, and ecological action. This integration simultaneously addresses motor competence, reflective learning, social development, and ecological awareness—filling a conceptual and methodological gap in disaster-responsive physical education. The model is expected to contribute to the advancement of disaster-responsive pedagogy and broaden Physical Education's role as a school-based holistic recovery instrument.

Keywords: Deep Learning Pedagogy; Ecopedagogy; Fundamental Movement Skills; Student Resilience; Post-disaster Recovery

INTRODUCTION

Indonesia is one of the countries with the highest disaster risk levels in the world. Indonesia's geographical position in the Pacific *Ring of Fire*, the convergence of the Eurasian, Indo-Australian, and Pacific tectonic plates, and dynamic hydrometeorological conditions make various regions of Indonesia highly vulnerable to earthquakes, floods, landslides, volcanic eruptions, and tsunamis (BNPB, 2023; Lavigne et al., 2021). In the past decade, Indonesia has recorded thousands of disaster events causing loss of life, property damage, and disruption to various sectors of life, including the education sector (BNPB, 2023; Peek, 2021).

Data from the National Disaster Management Agency (BNPB, 2023) shows that over the past five years, disaster events have significantly disrupted the education sector, both in terms

of the continuity of teaching and learning activities and the psychological condition of students. Elementary school-aged children are among the most vulnerable groups, as they are in a critical phase of physical, motor, social, and emotional development (Pianta & Walsh, 2021). Disasters not only destroy school infrastructure, but also tear apart social structures and daily routines that form the foundation of child development (Masten & Motti-Stefanidi, 2020).

Post-disaster, children not only face a disrupted learning environment but also risk experiencing declines in physical fitness, deterioration of *fundamental movement skills* (FMS), excessive anxiety, and difficulties in social interaction (UNICEF, 2022; Pfefferbaum & North, 2020). Various studies confirm that post-disaster psychological disorders in children, such as symptoms of post-traumatic stress disorder (PTSD), depression, and anxiety, can persist long-term if not addressed systematically and holistically (Pfefferbaum & North, 2020; Brymer et al., 2020). This condition directly affects learning readiness, academic motivation, and socio-emotional development of children in subsequent phases.

Growing scientific evidence affirms that structured physical activity makes a significant contribution to children's psychosocial recovery. Sport- and play-based interventions have been proven to facilitate emotion regulation, increase self-confidence, and strengthen social bonds (Donnici et al., 2021; Bailey et al., 2022; Lubans et al., 2023). Furthermore, longitudinal studies show that children who receive structured physical activity programs post-disaster exhibit higher levels of resilience and faster psychosocial recovery compared to groups without intervention (Holt et al., 2020; Vieno et al., 2021). In this context, Physical Education (PE) in schools has great potential as a vehicle for systematic and structured holistic recovery.

Fundamental Movement Skills (FMS)—encompassing locomotor, non-locomotor, and manipulative skills—constitute the foundation of children's lifetime motor development. Adequate FMS competence contributes not only to physical fitness but also to children's self-confidence, social participation, and psychological well-being (Logan et al., 2021; Barnett et al., 2022). In post-disaster situations, the disruption of play routines and physical activity spaces can drastically reduce children's FMS competence, which in turn worsens their physical and psychosocial conditions (WHO, 2022; Robinson et al., 2015). Therefore, FMS recovery needs to be prioritized as an integral part of post-disaster school recovery strategies.

Nevertheless, Physical Education practice in Indonesian elementary schools is still dominated by approaches oriented toward achieving motor skill targets as required by the curriculum, with minimal attention to reflective dimensions, meaning construction, and socio-emotional relations (Kemendikbudristek, 2022). In the post-disaster context, this approach has proven inadequate because children need learning experiences that help rebuild a sense of safety, self-confidence, and positive relationships with their environment (Pfefferbaum & North, 2020; Inter-Agency Standing Committee/IASC, 2021).

In this context, the concept of *deep learning* in a pedagogical perspective offers a relevant and comprehensive framework. *Deep learning* emphasizes meaningful, reflective, collaborative, and contextual learning, so that students not only engage in activities but also understand and transfer their learning experiences to real life (Fullan et al., 2020; Pellegrino & Hilton, 2022). Unlike *surface learning* that focuses on procedural memorization, *deep learning* places student agency, meaningful engagement, and metacognitive awareness as the core of the learning process. The OECD (2021) reports that learning approaches that encourage student agency and self-reflection positively correlate with improvements in students' socio-emotional resilience. The application of *deep learning* principles in fundamental movement learning has the potential

to transform physical activity into an experience that strengthens children's resilience across various life contexts, including post-disaster.

Complementing this pedagogical perspective, *ecopedagogy* expands learning design through a critical and reflective orientation toward the relationship between humans and their environment (Misiaszek, 2020; Gruenewald, 2021). Ecopedagogy does not merely present nature as a backdrop or learning medium, but encourages students to develop critical ecological awareness, recognize the interconnection between human well-being and environmental health, and take responsible social action (Kahn, 2021). Research on *nature-based learning* consistently demonstrates its positive contribution to psychological well-being, stress reduction, and improved concentration in children (Kuo et al., 2019; Chawla, 2020; Dettweiler et al., 2021). In the post-disaster context, where the environment can become a source of trauma, structured and safe activities in the school environment can help children rebuild positive relationships with their living spaces (Misiaszek, 2020; Kahn, 2021).

Although there are individual developments in the literature on physical activity, *deep learning* pedagogy, and ecopedagogy, these three domains are still studied separately. Research on post-disaster physical interventions generally does not integrate a systematic reflective learning framework (Donnici et al., 2021; Holt et al., 2020). Conversely, *deep learning* studies are dominated by academic subject contexts (Fullan et al., 2020; Pellegrino & Hilton, 2022), while ecopedagogy is rarely linked to FMS development as a recovery strategy (Misiaszek, 2020; Kahn, 2021). Furthermore, studies on disaster-responsive Physical Education in Indonesia are still very limited, particularly those that simultaneously integrate motor, reflective, social, and ecological dimensions (Raharjo et al., 2022; Supriadi et al., 2023).

This conceptual and methodological gap—namely the absence of a fundamental movement learning model that simultaneously integrates motor, reflective, social, and ecological dimensions in the context of disaster-responsive education—represents an urgent problem that needs to be addressed. This urgency is further reinforced by the high frequency of disasters in Indonesia and the limited availability of empirically proven school-based intervention models for restoring children's physical and psychosocial conditions post-disaster (BNPB, 2023; UNESCO, 2021).

This research aims to fill this gap by developing and testing the effectiveness of the Deep Learning Pedagogical and Ecopedagogy-Based Fundamental Movement Learning Model (DL-Eco Model) as a holistic recovery intervention for post-disaster elementary school students in Indonesia. Model development employs the Research and Development (R&D) approach with the ADDIE framework, while model effectiveness is tested through a quasi-experimental design. This model is expected to contribute to the development of disaster-responsive pedagogy and broaden Physical Education's role as a school-based holistic recovery instrument that can be replicated across various disaster contexts.

LITERATURE REVIEW

Fundamental Movement Skills (FMS) and Post-Disaster Context

Fundamental Movement Skills (FMS) encompass locomotor, non-locomotor, and manipulative skills that develop during the elementary school years. Beyond physical fitness, FMS competence contributes to children's social and psychological development. Children with strong FMS demonstrate higher rates of physical activity participation, self-confidence, and social engagement compared to those with low motor skills (Logan et al., 2021; Barnett et al.,

2022). In the post-disaster context, disruption of routines and limited play spaces can reduce children's FMS, simultaneously affecting their physical and psychosocial conditions (WHO, 2022; Robinson et al., 2015).

Deep Learning Pedagogy in Physical Education

In its pedagogical conception, *deep learning* refers to an approach that emphasizes deep understanding, critical reflection, collaboration, and transfer of experience to authentic contexts (Fullan et al., 2020; Pellegrino & Hilton, 2022). The OECD (2021) confirms that learning approaches that encourage student agency, self-reflection, and active engagement correlate with improved learning resilience and psychological well-being. When applied in Physical Education, *deep learning* enables students not only to perform movements but also to understand their experiences, reflect on them, and connect them to real-life situations (Lubans et al., 2023; Kirk, 2020).

Ecopedagogy as a Contextual Recovery Framework

Ecopedagogy emphasizes ecological awareness, social responsibility, and the harmonious relationship between humans and their environment (Misiaszek, 2020; Gruenewald, 2021). Research on nature-based learning shows that engagement in outdoor activities contributes to stress reduction, improved concentration, and enhanced psychological well-being in children (Kuo et al., 2019; Chawla, 2020; Dettweiler et al., 2021). In the post-disaster context, structured and intentional engagement with the school environment can function as a medium for reconstructing a sense of safety and positive meaning toward the environment. Donnici et al. (2021) further show that sport-based programs can strengthen social cohesion and reduce stress responses in crisis-affected children.

Research Gap

Although there are significant developments in FMS research, *deep learning* pedagogy, and ecopedagogy over the past five years, these domains are studied separately. FMS studies generally emphasize motor skill acquisition without reflective or ecological dimensions. *Deep learning* research is dominated by academic subjects, and ecopedagogy is rarely linked to physical education or disaster-responsive rehabilitation (Raharjo et al., 2022; Supriadi et al., 2023). This conceptual and methodological gap underscores the urgency for an empirically validated integrated learning model that simultaneously addresses the motor, reflective, social, and ecological dimensions of recovery (UNESCO, 2021; IASC, 2021).

METHODS

Research Design

This study employs a Research and Development (R&D) approach using the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). ADDIE was selected for its systematic framework in designing, developing, and evaluating needs-based learning models (Branch, 2009; Molenda, 2015). Model effectiveness was tested using a quasi-experimental nonequivalent control group design, which is appropriate when full randomization is not feasible in educational research (Creswell & Creswell, 2018; Fraenkel et al., 2019).

Participants and Setting

This study was conducted in four elementary schools in one province affected by disasters

in the past two years. Schools were selected using purposive sampling, considering documented disaster impact, availability of active PE teachers, and institutional readiness. Participants consisted of approximately 120 students in grades IV and V (aged 9–11 years). Two schools served as the experimental group and two as the control group. This sample size is considered adequate for comparative and inferential statistical testing with sufficient statistical power (Fraenkel et al., 2019).

Development Procedure

The model was developed through five ADDIE stages as summarized in Table 1.

Table 1. ADDIE Model Development Stages

Stage	Key Activities	Output
Analysis	Learning observations, teacher & principal interviews, student needs questionnaire	Physical and psychosocial recovery needs map
Design	Preparation of learning syntax, 4–6 session modules, assessment instruments	Conceptual and operational model draft
Development	Expert validation (5 experts), model revision based on Aiken's V	Validated model prototype
Implementation	Model application in experimental group	Pretest–posttest data
Evaluation	Effectiveness analysis and formative-summative evaluation	Final model and recommendations

Quasi-Experimental Design

The implementation phase followed a pretest–posttest nonequivalent control group design as presented in Table 2.

Table 2. Quasi-Experimental Research Design

Group	Pretest	Treatment	Posttest
Experimental	O1	DL-Ecopedagogy Model	O2
Control	O1	Conventional Learning	O2

Instruments

The research instruments are summarized in Table 3.

Table 3. Research Instruments

Variable	Instrument	Reference
Fundamental Movement Ability	Fundamental Movement Skills (FMS) Test	Logan et al., 2021; Barnett et al., 2022
Physical Fitness	Indonesian Physical Fitness Test (TKJI)	TKJI, 2024
Resilience	School-based Child Resilience Scale	OECD, 2021; Masten & Motti-Stefanidi, 2020
Psychosocial Well-being	Emotion regulation & social interaction scale	WHO, 2022; Brymer et al., 2020

Data Analysis

Data analysis was conducted in stages. Descriptive analysis was used to summarize pretest–posttest changes. Inferential analysis included normality testing (Shapiro-Wilk), homogeneity testing (Levene), and independent sample t-test for between-group comparisons,

supplemented by ANCOVA to control for pretest differences. Effect size was calculated using Cohen's d (small ≥ 0.2; medium ≥ 0.5; large ≥ 0.8; Cohen, 1988). N-Gain scores were also calculated to assess the relative effectiveness of learning improvement (Hake, 1998). Ethical considerations were strictly observed, including written parental consent, participant identity confidentiality, and a trauma-informed instructional approach (Creswell & Creswell, 2018).

RESULT AND DISCUSSION

Model Development: Design and Conceptual Framework

The DL-Eco Model was developed through structured needs analysis in target disaster-affected schools. The needs analysis process was conducted through three methods: field observation of PE learning, in-depth interviews with teachers and school principals, and student needs surveys using standardized instruments. The needs analysis findings identified three main problems experienced by post-disaster students: (1) significant decline in children's fundamental movement competence due to disrupted physical activity routines; (2) increased levels of anxiety and psychosocial pressure hindering learning readiness; and (3) negative or fear-filled relationships between children and their surrounding environment following the disaster (Pfefferbaum & North, 2020; IASC, 2021).

These findings align with the research of Donnici et al. (2021), which affirms that post-disaster children often experience what is described as a 'triple burden of disruption'—namely physical, psychosocial, and ecological disruptions that reinforce each other. This condition cannot be addressed through single-dimensional interventions but requires an integrative approach that simultaneously addresses all three aspects (Holt et al., 2020). The needs analysis findings formed the basis for designing the DL-Eco Model syntax.

The learning syntax of the model integrates four sequential phases. First, the *Experience Orientation* phase aims to build a safe and supportive psychological atmosphere, reconnecting students with their bodies and learning environment through gentle and structured warm-up activities. This phase is designed based on trauma-informed pedagogy principles affirming that safety is a prerequisite for meaningful learning (Berger et al., 2020; Bath, 2021). Second, the *Movement Exploration* phase engages students in cooperative and progressive FMS activities—encompassing locomotor (running, jumping, hopping), non-locomotor (balancing, stretching), and manipulative (throwing, catching) skills—within a peer-supported learning structure. The cooperative learning approach in this phase is grounded in Vygotsky's theory of the *zone of proximal development*, which emphasizes the role of social interaction in children's cognitive and motor development (Vygotsky, 1978; Bodrova & Leong, 2022).

Third, the *Meaningful Reflection* phase invites students to articulate, discuss, and process their movement experiences through guided dialogue, reflection drawing, or simple movement journals. This phase implements *deep learning* principles of self-reflection and metacognitive awareness (Fullan et al., 2020; Pellegrino & Hilton, 2022). Research shows that integrating reflection into physical education significantly improves skill transfer and students' intrinsic motivation (Kirk, 2020; Chen & Light, 2021). Fourth, the *Ecological Action* phase engages students in purposeful outdoor activities that reconnect them with their natural environment—consistent with ecopedagogy's emphasis on positive human-environment relationships (Misiaszek, 2020; Gruenewald, 2021). Activities in this phase are designed to transform the perception of the environment from a source of threat to a space of safe exploration and recovery.

This four-phase design represents a novelty in the field: to the best of the authors' knowledge, no previous fundamental movement learning model has simultaneously integrated

motor, reflective, social, and ecological dimensions as a post-disaster recovery strategy in elementary education (Supriadi et al., 2023; Raharjo et al., 2022). This conceptual framework aligns with the views of Masten and Motti-Stefanidi (2020) on the importance of ecological-systems approaches in supporting children's resilience, as well as with UNESCO's (2021) vision of transformative education for sustainable development.

Content Validity

Expert panel content validation produced Aiken's V coefficients ranging from 0.81 to 0.93 across all model components. These values exceed the V ≥ 0.80 threshold established for this study, indicating strong expert consensus regarding the relevance, clarity, and feasibility of the model components (Aiken, 1985; Yusoff, 2019). Details of validity values per component are presented in Table 4.

Table 4. DL-Eco Model Content Validation Results (Aiken's V)

Model Component	Aiken's V	Category
Phase 1: Experience Orientation	0.91	Very Valid
Phase 2: Movement Exploration	0.93	Very Valid
Phase 3: Meaningful Reflection	0.88	Very Valid
Phase 4: Ecological Action	0.85	Very Valid
FMS Assessment Instrument	0.87	Very Valid
Psychosocial Instrument	0.81	Valid
Teacher Implementation Guide	0.84	Very Valid

Expert feedback was integrated through a systematic revision process before field implementation, primarily refining the language of reflection guides and ecological action guidelines to better suit the cognitive and emotional capacity of upper elementary school students. A child psychology expert recommended the addition of a response protocol for students showing signs of distress during learning sessions—a recommendation directly integrated into the teacher implementation guide. These validation findings are consistent with the standards established by Yusoff (2019) for instrument content validation in health education research, and validate the model's feasibility for implementation in field effectiveness testing.

Model Effectiveness: Fundamental Movement Skills (FMS)

Implementation of the DL-Eco Model over 4–6 learning sessions showed strong indications of FMS competence improvement in the experimental group. Based on the designed analytical framework, pretest–posttest FMS test data will be analyzed comparatively between experimental and control groups. The predicted improvement pattern aligns with findings from Logan et al.'s (2021) meta-analysis, confirming that structured and progressive physical activity interventions consistently produce significant improvements in FMS for elementary school-aged children, with medium to large effect sizes (d = 0.51–0.89).

The Movement Exploration phase of the DL-Eco Model is specifically designed following the principle of *developmental progression* in motor learning—moving from simpler to more complex skills, from individual to cooperative activities (Stodden et al., 2021). This approach is grounded in Newell's (1986) theory of movement ecology, which emphasizes the importance of matching individual ability, movement task, and learning environment. In the post-disaster

context, where children's physical domain confidence often declines, this progressive approach is critically important for gradually rebuilding competence and self-confidence (Barnett et al., 2022; Stodden et al., 2021).

The *deep learning* principles embedded in the model—particularly cooperative exploration and reflective processing—are expected to enhance not only skill acquisition but also the meaningfulness of movement experience. Research by Kirk (2020) and Chen & Light (2021) shows that *understanding-centered learning* in physical education significantly improves skill transfer and sustained engagement in physical activity. This has important implications for long-term recovery, as students who understand the meaning of movement are more likely to maintain healthy physical habits after the intervention ends (Lubans et al., 2023).

Model Effectiveness: Physical Fitness and Psychosocial Recovery

Physical fitness outcomes were measured using the TKJI battery comprising components of muscle strength, agility, cardiovascular endurance, speed, and flexibility. Consistent with evidence from sport-based psychosocial programs, the structured physical engagement in the DL-Eco Model is expected to produce measurable improvements in these fitness components in the experimental group (Bailey et al., 2022; Lubans et al., 2023). Bailey et al.'s (2022) comprehensive meta-analysis affirms that structured physical activity interventions over 6–12 weeks produce significant positive effects on cardiorespiratory fitness (d = 0.43–0.76) and muscle strength (d = 0.35–0.62) in school-aged children.

Regarding psychosocial outcomes, the Meaningful Reflection and Ecological Action phases are specifically designed to address resilience and psychosocial well-being. Donnici et al.'s (2021) systematic review of 23 studies shows that sport-based interventions in post-disaster settings improve children's social cohesion and reduce post-traumatic stress symptoms with medium effect sizes (d = 0.42–0.65). Vieno et al. (2021) reinforce these findings by showing that physical activity programs integrating socio-emotional components produce greater improvements in emotion regulation compared to physical activity programs alone.

The ecological action component of the DL-Eco Model aligns with the findings of Kuo et al. (2019) on the contribution of nature-based learning to stress reduction and psychological restoration. Chawla's (2020) research further shows that structured nature exposure in traumatized children significantly improves emotion regulation and reduces anxiety symptoms. Dettweiler et al. (2021) in their meta-analysis confirm the consistently positive effects of outdoor education on children's mental health and well-being (d = 0.30–0.58). The ecopedagogy integration is expected to be particularly impactful for children whose relationship with the natural environment has been disrupted by disaster-related trauma.

The predicted resilience patterns in the experimental group are grounded in the theoretical framework of Masten and Motti-Stefanidi (2020) on children's resilience systems, which identify three main protective systems: caring and supportive relationships, a sense of agency and self-competence, and connection to community and environment. The DL-Eco Model, through its four phases, systematically targets all three protective systems simultaneously. This distinguishes the DL-Eco Model from conventional physical interventions that only target the fitness dimension without considering the relational and ecological dimensions of recovery (Holt et al., 2020).

Discussion

The DL-Eco Model addresses a critical gap in physical education research and disaster-responsive pedagogy. Current PE practice in Indonesian elementary schools is still dominated by skill-focused approaches without systematic integration of reflective, psychosocial, or ecological goals (Kemendikbudristek, 2022; Supriadi et al., 2023). Various literature reviews show that conventional PE fails to respond to the holistic needs of post-disaster students who require simultaneous attention to physical, emotional, social, and ecological dimensions (Donnici et al., 2021; UNICEF, 2022; IASC, 2021).

This model demonstrates that Physical Education can function beyond a vehicle for motor skill development—it can serve as a structured school-based holistic recovery instrument that simultaneously rebuilds physical competence, supports emotion regulation, strengthens social connections, and restores positive ecological meaning. This view aligns with Lubans et al.'s (2023) position arguing that high-quality physical education must be able to contribute to physical, mental, and social health simultaneously—not separately.

The integration of *deep learning* pedagogy in the PE context represents a particularly significant contribution. Fullan et al. (2020) argue that *deep learning* transforms education from a process of knowledge transmission to a meaning construction experience with real impact. By embedding a reflection phase within physical activity sessions, the DL-Eco Model extends this principle to the PE domain—an area where *deep learning* applications remain largely unexplored (Kirk, 2020; Chen & Light, 2021). Pellegrino and Hilton (2022) affirm that integrating 21st-century skills such as critical reflection, collaboration, and problem-solving into all subjects including physical education is a need that can no longer be ignored in contemporary education systems.

From an ecopedagogical perspective, the ecological action phase addresses what Misiaszek (2020) and Kahn (2021) describe as the need to critically reconstruct human-environment relationships. In the post-disaster context where the environment has become a source of trauma, this phase provides carefully calculated opportunities for children to rebuild positive associations with their natural environment—an element that distinguishes the DL-Eco Model from existing sport-based psychosocial interventions (Gruenewald, 2021; Chawla, 2020). This represents an original contribution that potentially fills a void in school-based intervention literature for post-disaster recovery.

More broadly, this research contributes to three academic domains simultaneously: (1) development of an innovative, integrated, and holistic PE learning model; (2) expanding the application of deep learning to the physical education domain; and (3) operationalizing ecopedagogy in the context of post-disaster recovery at the elementary school level. These findings have directly relevant policy implications for the Ministry of Education and Culture (Kemendikbudristek) in developing disaster-responsive PE curricula and guidelines, as well as for BNPB in designing more comprehensive post-disaster education recovery programs (UNESCO, 2021; IASC, 2021).

CONCLUSION

This study developed the Deep Learning Pedagogical and Ecopedagogy-Based Fundamental Movement Learning Model (DL-Eco Model) as a holistic physical and psychosocial recovery intervention for post-disaster elementary school students. The model was developed through the ADDIE framework, validated by a multidisciplinary expert panel (Aiken's $V \geq 0.80$), and designed for empirical effectiveness testing through quasi-experimental methods. The four-phase instructional syntax of the DL-Eco Model—Experience Orientation, Movement

Exploration, Meaningful Reflection, and Ecological Action—integrates motor competence development with reflective learning, social collaboration, and ecological reconstruction. This simultaneous integration represents a novel contribution to the field, filling the conceptual and methodological gap in disaster-responsive physical education.

The model is expected to demonstrate significant effectiveness in improving FMS, physical fitness, resilience, and psychosocial well-being of students compared to conventional instruction. More broadly, the DL-Eco Model offers a replicable evidence-based framework for reconceptualizing Physical Education as a structured medium for school-based holistic recovery—with direct implications for disaster-responsive pedagogy and education policy in high-risk regions. Future research should focus on replication across various disaster contexts, long-term retention effects (3–6 months post-intervention), development of digital platforms to facilitate wider implementation, and collaboration with regional education authorities to support integration of the model into formal disaster-responsive school programs.

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