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Integrating Earthquake Technologies into Physics Learning for Education for Sustainable Development: A Systematic Literature Review

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ABSTRACT

Objective: *This study aims to synthesize current research on integrating earthquake-related technologies into physics education within the framework of Education for Sustainable Development (ESD). The objective is to examine how these technologies contribute to students' scientific literacy, critical thinking, and disaster preparedness, while also aligning with sustainability goals such as SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities).* ***Method:*** *A Systematic Literature Review (SLR) was conducted using the PRISMA 2020 framework. A total of 546 records were identified from databases, including Scopus, Web of Science, ERIC, and ScienceDirect, with 38 studies meeting the inclusion criteria after screening. Data were analyzed thematically and categorized into technological approaches, pedagogical strategies, and reported learning outcomes.* ***Results:*** *The findings demonstrate that earthquake technologies, including VR/AR simulations, shake tables, and real-time sensors, have a positive impact on student engagement, conceptual understanding, and disaster risk awareness. Pedagogical integration through inquiry-based, project-based, gamification, and problem-solving approaches enhances collaboration, critical thinking, and contextual application of physics concepts. However, challenges remain in terms of limited access to technology, insufficient teacher training, and the lack of longitudinal evidence.* ***Novelty:*** *Unlike previous studies that treated disaster education and physics pedagogy separately, this review bridges both domains under the ESD agenda. It highlights the transformative role of physics classrooms as laboratories for resilience and sustainability, providing a comprehensive framework for integrating disaster-related technologies into science education.*

INTRODUCTION

Physics education has long been envisioned as a platform not only for developing students' conceptual mastery of natural laws but also for cultivating their capacity to apply scientific knowledge in addressing real-world problems. Within the global framework of Education for Sustainable Development (ESD), physics learning is expected to go beyond abstract derivations and formulas by nurturing scientific literacy, critical thinking, and disaster preparedness. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) emphasizes that education must equip learners with the competencies to build a sustainable and resilient society, particularly in regions vulnerable to natural hazards such as earthquakes (UNESCO, 2020; Fekete, 2021; O'Keeffe et al., 2023). Ideally, physics classrooms can function as laboratories for resilience, where concepts like waves, resonance, and energy transfer are directly linked to earthquake risk reduction and mitigation strategies (Malavoloneque & Costa, 2021; O'Reilly et al., 2020). This expectation aligns with the Sustainable Development Goals (SDG 4: Quality Education) and SDG 11 (Sustainable Cities and Communities), which