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FROM MOLECULAR COORDINATION TO SUSTAINABLE PRODUCTION: INTEGRATING GREEN CATALYSIS, SDG 12, AND CHEMISTRY EDUCATION

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Abstract

This study examines the conceptual relationships among coordination bonding, environmentally responsible catalyst design, Sustainable Development Goal 12, and sustainability-oriented chemistry education. The study used a qualitative research approach through document analysis, narrative literature review, and thematic synthesis of peer-reviewed publications published mainly between 2020 and 2025. The researcher selected documents purposively according to their relevance to coordination chemistry, green catalysis, green chemistry, sustainable production, systems thinking, and chemistry education. The analysis produced five interconnected themes: coordination bonding as the molecular basis of catalytic interaction, molecular and electronic structures as determinants of catalytic performance, green catalysis as a pathway toward energy and resource efficiency, SDG 12 as a framework for evaluating responsible production, and chemistry education as a space for developing sustainability reasoning. The findings show that catalytic sustainability depends not only on reaction activity but also on selectivity, energy demand, material availability, catalyst stability, recovery, toxicity, and waste generation. This study proposes an integrated conceptual framework that connects molecular interactions, catalyst performance, green chemistry, sustainable production, and chemistry learning through systems thinking and Project Based Learning. The framework expands the educational role of coordination chemistry from structural knowledge toward a basis for understanding and evaluating the sustainability consequences of chemical decisions.

Keywords: coordination chemistry; green catalysis; green chemistry; SDG 12; sustainability-oriented chemistry education

Introduction

The transition toward sustainable production systems has placed chemistry at the center of contemporary environmental and technological challenges. Modern societies depend on chemical knowledge to produce medicines, materials, fertilizers, fuels, electronics, and other products that support daily life. However, conventional chemical production frequently depends on non-renewable raw materials, hazardous reagents, energy-intensive operations, and multistep pathways that generate considerable waste. Zimmerman et al. [1] argue that chemistry should move beyond controlling pollution after its formation and instead redesign chemicals and processes from the beginning. This approach requires scientists to consider toxicity, resource renewability, degradation, energy requirements, and life-cycle