International Journal of Multidisciplinary Research and Growth Evaluation.

Typology of an Ecosystem Course to Support the Achievement of the Sustainable Development Goals (SDGs): A Framework Synthesis for Higher Education

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Article Info

ISSN (online): 2582-7138
Volume: 05
Issue: 06
November-December 2024
Received: 11-09-2024
Accepted: 12-10-2024
Published: 13-11-2024
Page No: 1841-1845

Abstract

Ecosystems underpin human well-being by regulating climate, cycling nutrients, supplying food and water, and buffering hazards—functions that directly and indirectly shape progress across the Sustainable Development Goals (SDGs). Yet many "Ecosystem/Ecology" courses in higher education still emphasize disciplinary content without systematically translating ecosystem knowledge into SDG-relevant competencies, decision-making skills, and action-oriented learning. This article develops a typology of an "Ecosystem" course explicitly designed to support SDG achievement through (1) ecosystem typology as an organizing backbone, (2) ecosystem services and nature's contributions to people as a learning bridge, and (3) sustainability competencies as intended outcomes. Using an integrative framework synthesis drawing on global ecosystem typology, ecosystem services assessments, ESD-for-2030 guidance, and competency-based curriculum design, we propose a four-type course typology: Type I—Foundational Ecosystem Literacy, Type II—Ecosystem Services & SDG Linkages, Type III—Socio-ecological Problem-Solving Studio, and Type IV—Transformative/Regenerative Ecosystem Design. Each type is defined by its learning aims, core concepts, pedagogies, assessment patterns, and SDG alignment profile. We provide a practical design toolkit: (a) a matrix to place a course on ecological–social complexity axes, (b) a semester map template using ecosystem functional groups, (c) assessment blueprints for systems thinking, futures thinking, values reasoning, strategy, and collaboration, and (d) example modules connecting local ecosystems to SDG targets. The typology offers a menu for institutions to redesign existing ecosystem courses, scaffold learning progression across years, and document SDG contributions in an evidence-based, assessable way.

DOI: https://doi.org/10.54660/.IJMRGE.2024.5.6.1841-1845

Keywords: Ecosystem course; ecosystem typology; ecosystem services; Education for Sustainable Development; SDGs; sustainability competencies; systems thinking; curriculum design

1. Introduction

Ecosystems are not merely "background nature" for human societies; they are the biophysical infrastructure that makes development possible. Global assessments have repeatedly shown that ecosystem degradation undermines human well-being and development outcomes by reducing the supply and stability of ecosystem services, from food and freshwater provision to climate regulation and hazard mitigation.

The SDGs place ecosystems at the core of development—explicitly in goals such as SDG 14 (Life Below Water) and SDG 15 (Life on Land), and implicitly across SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 6 (Clean Water and Sanitation), SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action).

Higher education faces a persistent gap: ecosystem science is often taught as concept mastery, while SDG achievement requires not only understanding ecosystems but also navigating trade-offs, uncertainty, ethics, governance, and implementation. Many ecosystem courses excel at explaining trophic structure, succession, and biogeochemical cycles, but struggle to help students answer SDG-facing questions about priorities, equity, and feasible action.

This article proposes a typology of ecosystem courses explicitly oriented toward SDG achievement. The goal is to provide a structured set of course types that institutions can select and adapt based on program level, student readiness, field access, and SDG priorities.

2. Literature Review

2.1. Ecosystem typology as an organizing backbone

A typology is more than a list; it is a theory-informed classification system. In ecosystem science, typologies have been developed to describe ecosystem diversity, compare functions across regions, and support conservation planning and reporting. A hierarchical global ecosystem typology differentiates ecosystems by functional drivers at upper levels and by biotic assemblages and local characteristics at lower levels. Such frameworks emphasize convergent ecosystem functioning: ecosystems in different continents may share functional similarities even when species differ.

For teaching, typology supports comparative reasoning, transfer of principles across contexts, clearer system boundaries, and scaffolding from general functional groups to local cases. However, typologies can oversimplify socio-ecological realities if treated as fixed categories rather than heuristic maps; therefore, typology should be paired with attention to gradients, mosaics, and human-modified systems.

2.2. Ecosystem services, nature's contributions, and SDG linkages

The ecosystem services concept provides a bridge between ecosystem science and policy-relevant outcomes. The Millennium Ecosystem Assessment synthesized evidence that many ecosystem services were being degraded, with consequences for development. The IPBES global assessment reinforced that biodiversity loss and ecosystem decline threaten human well-being and development, calling for transformative change. The Economics of Ecosystems and Biodiversity (TEEB) advanced the argument that ecosystem values must be mainstreamed in decisions.

An SDG-oriented ecosystem course needs a translation layer between ecological processes and SDG outcomes. Ecosystem services enable mapping from functions to provisioning, regulating, and cultural benefits, while also enabling critical discussion of trade-offs, distribution, and equity (who benefits and who bears costs), aligned with the SDG principle to leave no one behind.

2.3. Education for Sustainable Development (ESD) and sustainability competencies

ESD for 2030 emphasizes education's role in enabling learners to act for sustainable development, highlighting action competence, transformative learning, and partnerships. In higher education, competency frameworks define intended outcomes beyond content. A widely used framework specifies systems thinking, anticipatory (futures) thinking, normative (values) competence, strategic competence, and interpersonal/collaboration competence.

These competencies align naturally with ecosystem learning because ecosystems are complex adaptive systems with feedbacks, thresholds, and governance entanglements. Literature from Indonesian higher education also emphasizes operational indicators and measurable learning outcomes to support sustainability competence through curriculum and community engagement.

2.4. Course design principles: constructive alignment and experiential learning

Constructive alignment argues that learning outcomes should specify what students can do, learning activities should elicit those performances, and assessments should evaluate them. Experiential learning supports sequences that cycle through experience, reflection, conceptualization, and experimentation—well suited to fieldwork, labs, simulations, and community projects in ecosystem education.

Environmental and sustainability education research supports pedagogies beyond lecture, including field-based learning, place-based education, problem- and project-based learning, case-based reasoning, systems modeling, participatory mapping, and community-engaged learning, when implemented with quality and contextual sensitivity.

3. Method

This article uses a framework synthesis approach to develop a course typology. The "data" are conceptual and documentary sources rather than new field measurements.

We synthesized four knowledge streams: (1) ecosystem typology and classification, (2) global ecosystem services and biodiversity assessments, (3) SDG policy architecture, and (4) ESD and competency-based curriculum design. We extracted design requirements for SDG-relevant ecosystem learning, defined key design dimensions, constructed four coherent course types, and checked each type for constructive alignment and ESD coherence.

4. Results and Discussion

Fig 1: Ecosystem-to-SDG course design chain

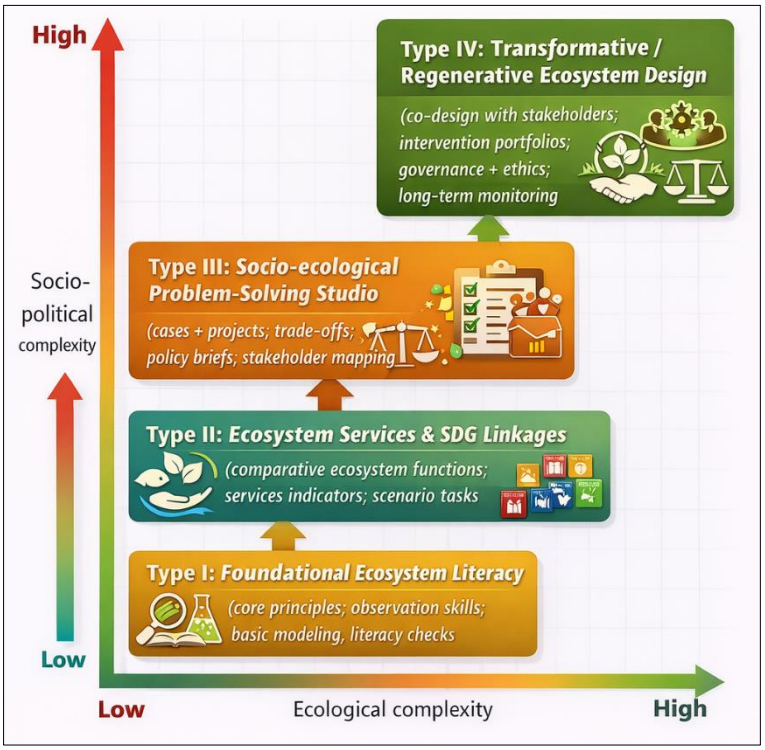

Fig 2: Ecosystem course placement matrix

4.1. Result 1 — The "Ecosystem-to-SDG" course design chain

The design chain uses ecosystem typology to organize content, ecosystem services to translate function into human outcomes, SDG targets to provide societal direction, sustainability competencies as intended outcomes, and constructive alignment to ensure assessability.

4.2. Result 2 — A placement matrix for course ambition

Different institutions have different constraints: field access, class size, partner networks, lab capacity, and student preparedness. The placement matrix helps departments locate their current course and choose a realistic development path (e.g., Type I → II → III across year levels).

4.3. Result 3 — The four course types

The four types represent increasing ecological and socio-political complexity and action orientation. Departments can select or scaffold types across year levels to move from ecosystem literacy to SDG-oriented problem solving and transformative change.

Table 1: Course typology summary: aims, pedagogy, assessment, and SDG alignment.

Course Type	Primary Aim	Organizing Backbone	Signature Pedagogy	Signature Assessment	Typical SDGs Supported
Type I: Foundational Ecosystem Literacy	Ecosystem literacy and basic systems understanding	Ecosystem functional groups/biomes	Observation + mini-labs + concept mapping	Concept inventories; annotated diagrams; short reflections	SDG 4; awareness for 13–15
Type II: Ecosystem Services & SDG Linkages	Translate ecosystem functioning to SDG outcomes	Services bundles + indicators	Comparative cases + scenario tasks	Service dashboards; scenario briefs; posters	SDG 2, 3, 6, 11, 13, 14, 15, 12
Type III: Socio-ecological Problem-Solving Studio	Practice SDG-oriented decision-making under constraints	SES framing + trade-offs	Studio projects + field methods + modeling	Policy brief; stakeholder plan; equity reflection	SDG 6, 11, 13, 14, 15, 16, 17
Type IV: Transformative/Regenerative Ecosystem Design	Co-design and evaluate regenerative interventions	Leverage points + adaptive management	Living lab + co-creation + implementation cycles	Intervention portfolio; monitoring/evaluation report	Broad SDG integration (context-specific)

Table 2: Example 14-week semester map (Type II / Type III hybrid).

Week	Ecosystem Functional Group (Typology anchor)	Core Concept Focus	SDG Linkage Focus	Learning Activity	Assessment Artifact
1	Typology overview (global → local)	Drivers, scales, comparison	SDG architecture & targets	Mapping local ecosystems to typology	Baseline concept map
2	Tropical forests / agroforestry mosaics	Carbon, water, biodiversity	SDG 13, 15, 2	Case: land-use change pathways	Short case memo
3	Freshwater rivers & riparian zones	Connectivity, pollution, flow	SDG 6, 3, 11	Field sampling / virtual dataset	Water service dashboard (v1)
4	Wetlands	Flood regulation, habitat	SDG 11, 13, 15	Trade-off game: drainage vs protection	Reflection: trade-off ethics
5	Coastal/mangrove systems	Coastal protection, fisheries	SDG 14, 1, 2, 13	Scenario: sea-level rise adaptation	Scenario brief
6	Coral reef systems	Resilience, bleaching	SDG 14, 13	Systems model workshop	Causal loop diagram
7	Urban ecosystems	Heat islands, green infrastructure	SDG 11, 3	Urban transect + microclimate	Urban service dashboard (v2)
8	Agricultural ecosystems	Nutrients, soil, pests	SDG 2, 12, 15	Integrated pest + soil health case	Policy options memo
9	Grasslands/savannas	Fire, grazing, livelihoods	SDG 15, 8, 10	Stakeholder mapping	Stakeholder map + risks
10	Montane ecosystems	Water yield, landslides	SDG 6, 11, 13	Disaster risk case	Monitoring indicators draft
11	Human-modified ecosystems	Novel ecosystems, restoration	SDG 15, 13	Restoration design sprint	Intervention sketch
12	Governance & equity	Institutions, rights, inclusion	SDG 16, 10, 17	Negotiation simulation	Negotiation reflection
13	Project integration	Implementation planning	SDG synergies	Studio time + peer review	Draft policy brief
14	Communication & evaluation	Adaptive management	SDG reporting	Public presentation	Final brief + dashboard

Table 3: Assessment blueprint for sustainability competencies in an ecosystem course.

Competency (Wiek *et al.*, 2011) [16]	What it looks like in ecosystem learning	Suitable assessment tasks	Evidence quality markers
Systems thinking	Feedbacks, thresholds, cross-scale dynamics	Causal loop diagram; system boundary justification	Correct links; acknowledged uncertainty; multi-scale reasoning
Futures/anticipatory	Scenarios, early-warning indicators	Scenario pathways; risk register	Plausible assumptions; alternative futures; sensitivity analysis
Normative/values	Equity, justice, ethics, trade-offs	Trade-off reflection; stakeholder equity analysis	Clear values basis; distributive impacts; respectful reasoning
Strategic	Intervention design, feasibility, leverage points	Policy brief; restoration plan; theory of change	Feasible actions; monitoring plan; governance fit
Collaboration	Team science, stakeholder engagement	Peer assessment; engagement plan; meeting minutes	Role clarity; inclusive process; conflict management

5. Conclusion

This article proposes a four-type typology for designing ecosystem courses that explicitly support SDG achievement: Type I (Foundational Ecosystem Literacy), Type II (Ecosystem Services & SDG Linkages), Type III (Socio-ecological Problem-Solving Studio), and Type IV (Transformative/Regenerative Ecosystem Design). The typology integrates ecosystem classification as a pedagogical backbone, ecosystem services as a translation layer to SDG targets, and sustainability competencies as assessable outcomes aligned through constructive alignment and experiential learning. The primary contribution is practical: departments can place existing courses on an ecological–social complexity matrix, select an appropriate course type, and implement aligned assessments that generate credible evidence of SDG-relevant learning.

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