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The Development of Competency-based Online Course for Course for Improving Literacy of Ecological Civilization

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ABSTRACT

This study investigates the ecological civilization literacy of Visual Communication Design majors in Zhejiang Province. It develops a competency-based online curriculum to strengthen students' knowledge, skills, and values related to sustainable design. Using an explanatory sequential mixed-methods design, the research was conducted in five stages: diagnostic analysis, needs assessment, competency modeling, curriculum development, and expert-guided iterative optimization. Quantitative data were collected from 336 students and 307 graduates, revealing a structurally imbalanced profile characterized by strong ecological attitudes, moderate conceptual understanding, and weak behavioral competence. Qualitative data from faculty (n = 24), employers (n = 25), and experts (n = 24) further indicated fragmentation in current ecological instruction, misalignment between educational supply and industry requirements, and a strong demand for project-based and context-relevant learning experiences. Based on Delphi consultation and content analysis, the study constructed the "Three Dimensions–Nine Competencies" ecological civilization literacy model, which integrates ecological knowledge, sustainable design skills, and value-oriented professional ethics. Guided by Competency-Based Education (CBE) and backward design principles, an online course titled Ecology and Vision: Integrating Sustainable Design Competencies was developed. The curriculum comprises 64 hours across four modules, incorporating localized Zhejiang case studies, interdisciplinary resources, PBL-driven rural revitalization projects, learning analytics, and diversified assessment aligned with the K–S–V competency framework. Expert review demonstrated the curriculum's high validity and feasibility (IOC averages 0.89–0.95; satisfaction scores 4.3–4.6/5). Through iterative refinement, the final model presents a scalable pathway for integrating ecological civilization education into design disciplines. The study contributes a theoretical framework, a methodological model, and a practical solution to advancing sustainability-oriented design education in Chinese higher education institutions. It also provides a transferable curriculum development paradigm for other regions and disciplines seeking to integrate ecological civilization into professional training.

Keywords: Ecological Civilization Literacy; Competency-Based Education; Sustainable Design; Online Curriculum Development

INTRODUCTION

The intensifying global environmental crisis—characterized by climate change, energy depletion, and biodiversity loss—has reshaped the trajectory of human development. The Intergovernmental Panel on Climate Change (IPCC, 2021) reports that global temperatures have risen by 1.1°C above pre-industrial levels, accelerating extreme weather events and ecological degradation. These challenges compel nations to reconsider conventional models of economic growth and advance transformative pathways toward sustainability (Rockström et al., 2009).

Within this global shift, the concept of Ecological Civilization has emerged as an expanded framework of sustainable development, emphasizing the restructuring of social values, production systems, and educational foundations (Zhang & Liu, 2020). International initiatives, notably the United Nations' 2030 Agenda and Sustainable Development Goals (SDGs), reinforce the central role of education—particularly sustainability literacy—as a driver of societal transformation (UN, 2015; UNESCO, 2017).

China has demonstrated a strong institutional and strategic commitment to building an Ecological Civilization. Since the articulation of the "Beautiful China" vision in 2012, ecological values have been integrated into national governance, culminating in the 2018 constitutional amendment that formally embedded Ecological Civilization into the country's legal framework (National People's Congress, 2018; Xi, 2017). The report to the 20th National Congress highlights education as a foundational pillar of national modernization, calling for the cultivation of environmentally responsible, innovative, and socially engaged youth (CCCPC, 2022). In alignment with this mandate, scholars emphasize that enhancing ecological literacy—encompassing knowledge, ethics, awareness, affection, and responsible behavior—is pivotal to advancing Ecological Civilization (Li & Zhang, 2021; Liu et al., 2023). The Ministry of Education's Core Competencies and Values for Chinese Student Development further affirms ecological literacy as a key dimension of social participation (Ministry of Education, 2016; Chen, 2018).

Zhejiang Province plays a pioneering role in China's Ecological Civilization construction. Rooted in the principle that "lucid waters and lush mountains are invaluable assets," Zhejiang has positioned ecological development as a strategic priority. The province's education plan during the 14th Five-Year period mandates systematic integration of Ecological Civilization education into universities through curriculum, campus culture, and experiential learning (Zhejiang Provincial Department of Education, 2021). However, research shows that ecological literacy cultivation remains insufficient in discipline-based curricula—particularly in art and design majors (Wu, 2023).

Meanwhile, Competency-Based Education (CBE) provides a promising avenue for curriculum reform. CBE emphasizes measurable competencies, flexible learning pathways, and the integration of knowledge, skills, and attitudes (Blank, 1994; Young, 2003). Its global expansion—especially through online and hybrid learning—demonstrates its potential for personalized and practice-oriented education (Johnstone & Soares, 2014; Fain, 2015). In China, CBE's compatibility with online education has led to its growing influence in undergraduate and postgraduate training (Chen, 2014; Wang, 2020). The rapid rise of online education, accelerated by MOOCs and post-pandemic digital transformation, further expands possibilities for flexible, scalable curriculum delivery (Pappano, 2012; Dhawan, 2020). Yet in art and design education, online courses often lack strong connections to practice (Zhao, 2021). Integrating Ecological Civilization literacy into a CBE-based online curriculum thus represents an innovative and necessary pathway—particularly for Visual Communication Design majors in Zhejiang—aligning national strategies, provincial initiatives, and educational modernization.

Research Gap

Despite Zhejiang Province's leading position in China's ecological civilization construction, significant gaps remain in the integration of ecological civilization literacy within higher education—particularly in art and design majors. Existing studies have mostly focused on policy interpretation, theoretical discussion, or general curriculum integration, yet there is a lack of empirical research specifically targeting visual communication design majors, whose professional training is closely linked to sustainability, creative practice, and the cultural transformation required for ecological civilization.

First, the current curriculum structure in many universities remains insufficiently aligned with ecological civilization education. Courses often focus on technical skills or aesthetic principles, while ecological values, environmental responsibility, and sustainable design concepts are minimally represented or treated as optional content. Research also indicates that students' understanding of ecological civilization literacy is fragmented, lacking systematic guidance and practical application pathways.

Second, although Competency-Based Education (CBE) and online learning have been recognized as promising directions for higher education reform, there remains a scarcity of models that integrate CBE, ecological civilization literacy, and design education into a cohesive online curriculum. Few studies have explored how competencies such as ecological awareness, creativity, and innovation can be jointly cultivated through digital platforms tailored for art and design learners.

Third, there is limited research involving expert validation and iterative refinement of ecological civilization–oriented courses in the design discipline. Consequently, a scientifically grounded, pedagogically practical, and professionally relevant online curriculum model remains absent.

To address these gaps, this study proposes the development and expert evaluation of a competency-based online course tailored to visual communication design majors in Zhejiang Province.

Research Objectives

(1) To investigate the current situation and challenges of ecological civilization literacy cultivation among visual communication design majors in Zhejiang Province.
1. This includes examining curriculum structure, teaching content, pedagogical methods, faculty expertise, and students' levels of ecological understanding and engagement.
(2) To develop a competency-based online course that systematically integrates ecological civilization literacy with professional training in visual communication design.
2. The course aims to strengthen ecological awareness, encourage innovative thinking, and enhance students' application of ecological principles in creative practice through case studies, practical tasks, and project-based learning.
(3) To engage experts in evaluating and refining the newly developed course to ensure scientific rigor, pedagogical effectiveness, and practical applicability.

CONCEPTUAL FRAMEWORK

This study establishes a systematic conceptual framework to guide the development and formative evaluation of a competency-based online course designed to enhance ecological civilization literacy among visual communication design students in Zhejiang Province. The framework integrates theoretical foundations with empirical research procedures, forming a closed-loop structure of theoretical grounding → empirical input → iterative development → output validation, while limiting the research scope to curriculum design and formative evaluation.

Theoretical Foundations

Four theoretical pillars support the framework.

- Competency-Based Education (CBE) provides the overarching structure, emphasizing measurable learning outcomes and alignment between objectives, content, and assessment (Bloom, 1970; Patrick & Sturgis, 2013).
- Ecological Civilization Education Theory contributes the value orientation, focusing on developing ecological knowledge, awareness, ethics, and behavior (Lucas, 1972; Chen, 2018).
- Constructivist Learning Theory offers methodological guidance through learner-centered, inquiry-based, and collaborative learning (Piaget, 1923; Jonassen, 1999).
- Educational Evaluation Theory ensures systematic feedback and continuous improvement of the curriculum (Tyler, 1949; Biggs & Tang, 2011).

Core Components and Logical Flow

The framework consists of five interconnected phases.

(1) ***Drivers and Evidence:*** Curriculum development is grounded in strategic policy directives (Xi, 2017), a situational diagnosis of ecological literacy cultivation in Zhejiang universities, and empirical needs analysis using interviews and questionnaires (Creswell & Plano Clark, 2017).
(2) ***Competency Model Construction:*** Theoretical integration results in a three-dimensional model comprising Knowledge, Skills, and Values/Attitudes, which converts ecological literacy into measurable competency indicators.
(3) ***Course Development and Formative Evaluation:*** Using backward design (Wiggins & McTighe, 2005), the course is developed and evaluated through expert review, peer assessment, and curriculum mapping, followed by iterative refinement (Patton, 2015).
(4) ***Outputs:*** The process produces a validated curriculum framework, a clear literacy-enhancement pathway, and a scalable development model for similar courses.
(5) ***Feedback and Iteration:*** Continuous feedback ensures ongoing curriculum evolution, maintaining relevance within dynamic ecological and educational contexts.

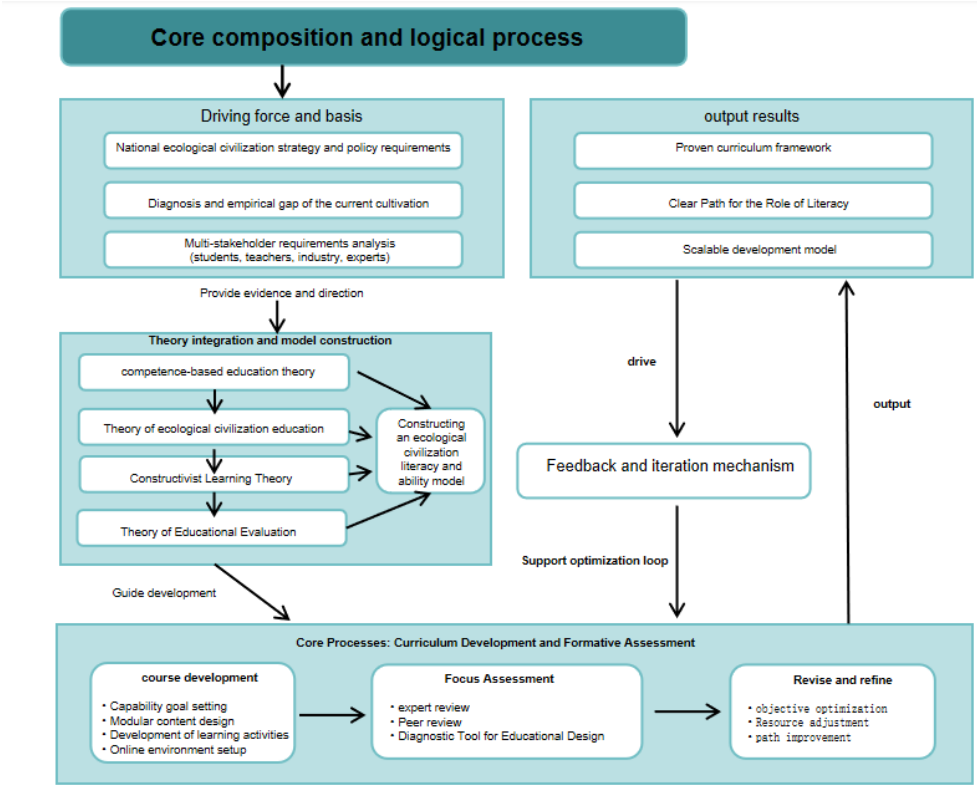

Figure 1: Conceptual Framework

Ecological Civilization Literacy in Higher Education

Over the past two decades, ecological civilization literacy (ECL) has emerged as a vital concept in environmental education, sustainable development, and China's ecological civilization discourse. The literature reflects a clear evolution from traditional notions of "environmental awareness" toward a comprehensive competency-based framework integrating knowledge, attitudes, values, skills, and sustainable behaviors (Sterling, 2010; Hollweg et al., 2011). In Western scholarship, related concepts such as "environmental literacy" and "ecological literacy" emphasize individuals' capacities to understand ecological systems, assume environmental responsibility, and take informed action (Orr, 1992; Wals, 2015). In contrast, Chinese scholars embed ECL within the national agenda of ecological civilization, emphasizing ethical reconstruction and a transformed relationship between humans and nature (Yang Guorong, 2020).

The literature highlights higher education as a central arena for cultivating ECL. Universities increasingly incorporate ecological content into general education and disciplinary curricula, adopting interdisciplinary, inquiry-based, and problem-oriented approaches to enhance students' systems thinking and sustainable development competencies (Tilbury, 2011). Practical learning modes—including project-based activities, community service, and green campus initiatives—are widely recognized for deepening ecological understanding and fostering pro-environmental actions (O'Brien, 2012; Chen & Sun, 2020). Campus culture also plays a significant role, with studies showing that sustainable campus practices and social participation activities reinforce ecological values and responsible behavior (Liu, 2018; UNESCO, 2017). Despite progress, the literature identifies persistent challenges. Many university curricula remain fragmented and lack coherence; teaching approaches continue to favor lectures over experiential learning; and assessment tools fail to capture multi-dimensional literacy outcomes (Wang, 2019; Yang, 2022). Furthermore, limitations in faculty expertise and variability in student engagement hinder the implementation of effective ecological civilization education.

Overall, existing studies suggest that while higher education has made meaningful strides in advancing ECL, further improvements are needed in curriculum integration, innovative pedagogy, multi-dimensional evaluation, and cross-sector collaboration. Strengthening these areas will help transition ECL from a peripheral educational component to a core competency essential for fostering sustainable societal development.

Competency-Based Education (CBE) and Its Application in Higher Education and Art & Design Disciplines

Competency-Based Education (CBE) has developed from its vocational training origins in the 1970s into a major paradigm for contemporary educational reform. Literature shows that the core philosophy of CBE—emphasizing measurable competencies, demonstrable performance, and outcome-oriented learning—has gradually expanded from vocational education into higher education, continuing education, and online learning (Spady, 1977; Patrick & Sturgis, 2013). International research highlights that CBE institutions such as Western Governors University, Brandman University, and the University of Wisconsin have successfully implemented modular curricula, flexible learning pathways, and competency-based assessments, providing empirical evidence for the scalability and quality of CBE models in university settings (Johnstone & Soares, 2014). Academic discussions converge on three structural pillars of CBE: competency frameworks, modularized curriculum design, and authentic assessment. Competency frameworks articulate observable knowledge, skills, and values required for professional performance (McClarty & Gaertner, 2015). Modular curricula break learning into self-paced units, enabling individualized and flexible progression (Cornford, 1997). Authentic assessments—including portfolios, performance tasks, and e-portfolios—serve as evidence of learner mastery and ensure alignment with industry standards (Horohov, 2017).

Recent literature emphasizes the suitability of CBE for art and design education due to its project-based, practice-oriented nature. Portfolio assessment, real-world design tasks, and interdisciplinary collaboration naturally align with CBE's emphasis on demonstrable competencies and context-based evaluation (Boks & Diehl, 2006). However, challenges persist—especially regarding assessment subjectivity, faculty readiness, and the integration of creativity into measurable competency indicators. Studies in China indicate that while CBE has influenced vocational education reforms, its adoption in higher education remains limited due to institutional constraints, insufficient teacher training, and low employer recognition (Wang, 2019). Overall, the literature affirms CBE's potential to enhance learning relevance, employability, and educational quality, while also underscoring the need for systematic curriculum reform, robust evaluation mechanisms, and industry collaboration for effective implementation.

Online Course Development in Higher Education

The literature on online course development shows that online and blended education has evolved from early distance learning to MOOCs and immersive digital environments, with COVID-19 acting as a major accelerator rather than an origin point. Research indicates that well-designed online and especially blended courses can match or outperform traditional face-to-face teaching, particularly when supported by sound instructional design, active learning, and robust learner support systems. Core curriculum development theories—Tyler's objective model, Backward Design, constructivism, and systematic models such as ADDIE—provide the methodological backbone for online course design, helping align intended learning outcomes, assessment, and learning activities in a competency-oriented way.

In the online context, constructivism and social constructivism underpin task-based, collaborative, and reflective learning through forums, group projects, and virtual studios. Flipped classroom and blended learning models redistribute content delivery and interaction, using pre-class micro-learning and in-class (or synchronous) application to foster higher-order skills. Project-based learning, VR/AR, virtual labs, and interactive platforms (LMS, e-portfolios, digital whiteboards) are widely recognized as key strategies for supporting practice-oriented and interdisciplinary learning, particularly in design and creative disciplines. Quality assurance frameworks such as Quality Matters, together with learning analytics and authentic assessment (projects, portfolios, industry critique), are emphasized as crucial for monitoring course quality and learning outcomes. However, the literature also highlights persistent gaps: fragmented design, limited integration of complex literacies (such as ecological civilization), uneven faculty capacity, and under-developed evaluation systems. These gaps justify the need for competency-based, outcome-oriented online course models tailored to specific disciplines such as visual communication design.

Ecological Civilization Construction and Education in Zhejiang Province

The literature on ecological civilization construction and education in Zhejiang Province shows that the region has moved through three major stages: early exploration focused on environmental governance, institutional deepening linked to high-quality development, and the current phase of institutional demonstration and standardization. Policy frameworks such as the "Two Mountains Theory," the "Eight-Eight Strategy," the "Beautiful Zhejiang" initiative, and the 14th Five-Year Ecological and Environmental Protection Plan have driven substantial improvements in water and air quality, ecosystem restoration, and the establishment of comprehensive ecological institutions.

Ecological civilization education has been promoted across multiple levels—primary and secondary schools, higher education, vocational institutions, and cadre training—through curriculum integration, campus culture, and the construction of ecological education bases. Universities such as Zhejiang University and Zhejiang A&F University, alongside the Zhejiang Academy of Ecological Civilization, play a leading role in disciplinary development, research, and talent cultivation, supported by strong fiscal capacity and digital ecological governance platforms. Public participation, green lifestyle norms, and a solid socio-cultural foundation further reinforce these educational efforts.

However, the literature also highlights persistent challenges. Ecological civilization education remains fragmented and often activity-based rather than embedded within coherent, longitudinal curriculum systems—particularly in specialized and art-related majors. Evaluation standards, measurement tools, and literacy frameworks are still underdeveloped, and resource and faculty disparities between key universities and local or vocational institutions are significant. Moreover, the integration of ecological civilization education with competency-based education, online learning, and internal systems of credits, degrees, and professional catalogues is still at an exploratory stage. These gaps provide clear justification and space for developing a competency-based online course targeting ecological civilization literacy in Zhejiang's visual communication design programs.

Visual Communication Design Education in Zhejiang Province

Existing literature shows that Visual Communication Design (VCD) has evolved globally from craft-oriented "graphic design" to a cross-media, research-driven field emphasizing information strategy, user experience, and social impact. Internationally, leading institutions such as RCA, RISD, and QUT adopt studio- and project-based models that integrate theory, cross-media practice, and industry collaboration, with assessment centered on portfolios, real projects, and external review. These curricula increasingly embed sustainability, design for social good, and interdisciplinary collaboration as core learning outcomes. In China, and particularly in Zhejiang, VCD has expanded rapidly within a favorable policy environment shaped by the digital economy and cultural-creative industries. Provincial education policies under the "Eight-Eight Strategy" and the education "14th Five-Year Plan" call for integrating green development concepts and supporting green industry talent. Zhejiang's universities, application-oriented colleges, and higher vocational institutions have thus strengthened "art + technology" integration through courses in digital media, interaction design, UX, and motion graphics, while promoting industry–education collaboration, studio teaching, and "promoting learning through competitions." However, the ecological dimension remains weakly embedded. Ecological themes tend to appear in scattered lectures, short-term projects, or competition topics rather than as a coherent curricular thread. Evaluation still privileges aesthetics, technical execution, and commercial value over ecological responsibility or life-cycle awareness. Interdisciplinary collaboration with environmental science, materials, or social sciences is limited, and existing online resources focus mainly on software skills rather than competency-based ecological literacy. These gaps underline the need for a competency-based online course that systematically integrates ecological civilization literacy into the VCD curriculum in Zhejiang Province.

Global and Domestic Development of Competency-Based Online Curriculum for Enhancing Ecological Civilization Literacy

The literature reveals significant international progress in Competency-Based Education (CBE), online learning, and ecological literacy education, yet integrated models remain limited. Globally, CBE has developed robustly since the 1970s, with countries such as the United States, the United Kingdom, and Australia establishing national qualification frameworks that link competencies directly to industry standards. Online CBE programs offered by institutions such as Western Governors University demonstrate the potential of modular, self-paced, and performance-based learning, supported by digital badges and e-portfolios. However, challenges remain concerning assessment reliability, institutional restructuring, and recognition of higher-order competencies. The development of online learning has been shaped by the transition from MOOCs to blended, project-based, and simulation-enhanced instruction. International studies highlight both opportunities—such as expanded access and flexibility—and persistent challenges including low completion rates, limited interaction, and uneven recognition. Recent innovations integrate VR/AR, virtual laboratories, and global collaborative platforms to enhance active learning and authenticity.

Ecological civilization literacy, closely aligned with global Education for Sustainable Development (ESD), emphasizes interdisciplinary, action-oriented, and problem-based approaches. While universities abroad—such as Arizona State University and institutions in Finland—apply these principles through community-linked sustainability projects, online ecological curricula remain fragmented. In China, CBE and online education have advanced rapidly through national policy initiatives, yet ecological curricula remain largely theoretical, fragmented, and weak in interdisciplinary integration. The literature identifies gaps in systematic competency frameworks, online assessment tools, and technology-supported ecological learning. These gaps highlight the need for an

integrated curriculum model that combines CBE, online course design, and ecological literacy to support higher education reforms—particularly in applied disciplines such as visual communication design.

RESEARCH METHODOLOGY

This study adopts a pragmatist research paradigm and employs an explanatory sequential mixed-methods design, aiming to develop a competency-based online course that enhances ecological civilization literacy among Visual Communication Design students in Zhejiang Province. Pragmatism emphasizes problem-solving and methodological flexibility, making it particularly suitable for curriculum development and design-oriented education. The mixed-methods design enables the systematic integration of quantitative breadth and qualitative depth through sequential data collection and interpretation.

The research is implemented across four structured phases:

Phase 1: Diagnosis of Current Status and Needs. A large-scale questionnaire survey is conducted among students and recent graduates to assess their ecological literacy, online learning needs, and perceived gaps in existing curricula. Stratified sampling ensures representativeness across institution types. Quantitative data are analyzed through descriptive statistics, correlation tests, regression analysis, and structural equation modeling. In-depth interviews with teachers, employers, and experts further contextualize and explain quantitative findings.

Phase 2: Competency Framework Construction. Based on literature analysis and empirical findings, a preliminary competency model is developed. The Delphi method with 15 experts is used to refine and validate competencies related to ecological knowledge, ethics, behavior, design practice, and interdisciplinary communication.

Phase 3: Course Prototype Development. Guided by Competency-Based Education and Backward Design, the course structure, modules, micro-lectures, activities, and assessments are constructed on an online learning platform. A focus group involving educators, employers, and experts provides formative evaluation to improve usability, accuracy, and instructional effectiveness.

Phase 4: Summative Evaluation. Experts review the completed course using standardized evaluation criteria covering objectives, content accuracy, instructional strategies, assessment alignment, and technical quality. Revisions lead to a finalized online course package.

Reliability and validity are ensured through expert review, pilot testing, triangulation, and standardized instruments. Ethical approval, informed consent, anonymity, and secure data handling underpin all research procedures. This systematic methodology supports the development of a scientifically rigorous and practically applicable competency-based online course.

RESULTS

Table 1 Comparison of Findings Across Students, Graduates, Faculty, Employers, and Experts

Dimension / Themes	Students (n = 336)	Graduates (n = 307)	Faculty (n = 24)	Employers (n = 25)	Experts (n = 24)
Overall Ecological Civilization Literacy	M = 3.41, SD ≈ 0.62 (Moderate)	M = 3.69, SD ≈ 0.58 (Moderately High)	Recognize weak implementation quality	Graduates insufficient for eco-design needs	High recognition of ecological literacy importance
Values / Attitudes (Affective Dimension)	M = 4.12, SD ≈ 0.55 (Strong attitude)	M = 3.88, SD ≈ 0.60 (Strong ethics)	Values emphasized but weakly internalized	Value-driven responsibility required	Strong support for values-based curriculum
Knowledge Literacy (Cognitive Dimension)	M = 3.24, SD ≈ 0.68 (Moderate; weak SDGs & LCA knowledge)	M = 3.75, SD ≈ 0.63 (Good awareness; weak systemic thinking)	Fragmented curriculum; lack of integration	Weak understanding of standards & sustainability metrics	Endorse structured K–S–V knowledge system
Behavior / Practice Skills (Behavioral Dimension)	M = 2.43, SD ≈ 0.71 (Weakest; poor design application)	M = 3.42, SD ≈ 0.66 (Weak practical competence)	Limited platforms; outdated cases	Weak eco-material use & circular design skills	Recommend PBL & project-based design training

Curriculum Issues Identified	Not directly measured	—	Fragmented courses; plug-in ecological content	Need systematic eco-design curriculum	Support alignment with national & regional policy
Resource Limitations	—	—	Insufficient localized Zhejiang cases	Demand for up-to-date real-world cases	Recommend regional ecological case integration
Assessment & Evaluation	—	—	Difficult to evaluate values & behaviors	Require measurable eco-design indicators	Support competency-based & formative evaluation
Differences / Influences	Higher literacy in seniors; public universities	Higher literacy in advanced degrees & design-focused workplaces	Faculty shortage in interdisciplinary teaching	Eco-literacy affects hiring, promotion, salary	Favor blended, digital-supported curriculum
Summary Insight	High attitudes → moderate knowledge → low behavior	Strong values & awareness → skills gap remains	Systemic barriers hinder implementation	Mismatch between graduate skills & industry needs	Validates competency model & course framework

The comparison of ecological civilization literacy across five respondent groups—students, graduates, faculty, employers, and experts—reveals both shared patterns and critical disparities in ecological knowledge, skills, and values within the field of visual communication design. The quantitative results for students (n = 336) indicate an overall moderate level of ecological literacy (M = 3.41), with a distinctive structure characterized by strong ecological attitudes (M = 4.12, SD ≈ 0.55), moderate knowledge (M = 3.24, SD ≈ 0.68), and notably weak behavioral competence (M = 2.43, SD ≈ 0.71). This configuration reflects a pronounced "knowing–doing gap," where ecological values do not translate into actionable design practices. Graduates (n = 307) displayed a generally higher level of ecological literacy (M = 3.69, SD ≈ 0.58), though still unbalanced. Their strongest dimension was professional ethics (M = 3.88, SD ≈ 0.60), followed by sustainable design awareness (M = 3.75, SD ≈ 0.63), while practical competencies—such as eco-material application, circular design, and adherence to ecological standards—remained comparatively weak (M = 3.42, SD ≈ 0.66).

Qualitative insights from faculty (n = 24) helped explain these patterns. Faculty acknowledged the necessity of ecological civilization education but described several barriers, including fragmented curriculum structure, insufficient practical platforms, outdated case resources, and difficulties in assessing values and behaviors. These structural limitations hinder students' deeper knowledge internalization and the development of ecological design skills. Employers (n = 25) reinforced this interpretation by emphasizing a widespread lack of systematic eco-design knowledge and insufficient practical competencies among graduates entering the workforce. From an industry perspective, ecological literacy is increasingly recognized as a professional asset that influences employability, project allocation, and career advancement, underscoring the urgency of curriculum reform.

Experts (n = 24) provided a broader strategic viewpoint, affirming the national significance of ecological civilization education and supporting the competency-based, digitally supported model adopted in this study. Their consensus strongly endorsed the three-dimensional, nine-competency structure and advocated project-based, problem-driven approaches aligned with Zhejiang's local ecological and industrial context.

Overall, the narrative comparison demonstrates a consistent cross-group recognition of the importance of ecological literacy, accompanied by a shared concern regarding insufficient practical competence. The alignment of findings across students, graduates, faculty, employers, and experts provides robust justification for developing a competency-based online course to bridge the gap between ecological awareness and ecological design capability.

Curriculum Development Outcomes (Development Phase)

Based on: (a) quantitative diagnostics of students' and graduates' ecological civilization literacy; (b) qualitative needs and expectation analyses from faculty and employers; and (c) the K–S–V competency framework established through Delphi expert consultation, the development phase produced a competency-based online curriculum entitled "Ecology and Vision: Integrating Sustainable Design Competencies." The curriculum is explicitly designed to address the structural weaknesses identified in the empirical phases—fragmented knowledge, insufficient practical ability, weak behavioral transformation, and lack of systematic pedagogical support—and is grounded in CBE and backward design principles. It proposes a three-year, 60-hour modular structure for undergraduate and vocational students in Zhejiang Province.

Overall Curriculum Framework and Design Logic: Anchored in the core philosophy of "Understanding Ecology, Excelling in Design, and Acting Responsibly," the curriculum adopts the K–S–V model as its organizing principle. The content is structured into three progressive modules:

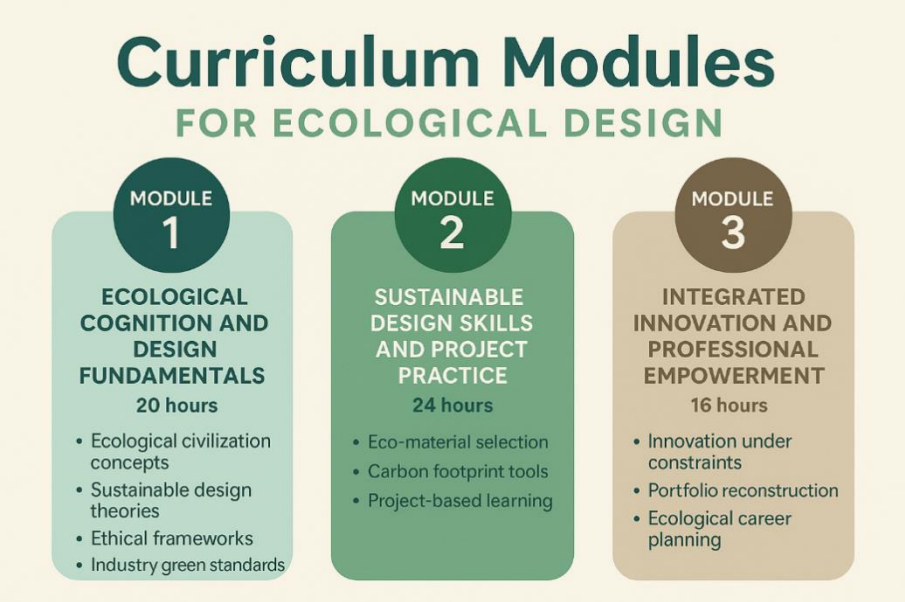

Figure 1: Conceptual Framework

Module 1: Ecological Cognition and Design Fundamentals (20 hours): Responding directly to the quantitative finding of fragmented and shallow knowledge, this module systematically delivers foundational ecological civilization concepts, sustainable design theories, ethical frameworks, and industry green standards.
Module 2: Sustainable Design Skills and Project Practice (24 hours): Addressing the empirically observed practical skill gaps (62.3% of students self-reporting insufficient eco-design ability) and strong demand for hands-on learning, this module introduces: eco-material selection and evaluation, carbon footprint tools, and project-based learning (PBL) with real-world rural contexts and interdisciplinary collaboration.
Module 3: Integrated Innovation and Professional Empowerment (16 hours): Bridging the "knowledge–behavior gap," this module focuses on: innovation under ecological constraints, sustainable design portfolio reconstruction, and long-term ecological career planning. Together, the three modules build a scaffolded progression from conceptual understanding to applied practice and value internalization, precisely mirroring the structural issues identified in the QUAN–QUAL phases.

Module-Level Curriculum Design

Figure 2: Module-Level Curriculum Design

Module 1: Ecological Awareness and Design Fundamentals: Through micro-lectures, VR-based policy visualization, concept map exercises, and reflective journals, students engage with: ecological civilization theories, sustainable design concepts, designer ethics, and policy frameworks. This module primarily enhances K1–K3 (knowledge of ecology, sustainable design, and standards) and V1 (foundational ecological responsibility).

Module 2: Sustainable Design Skills and Project Practice: This module operationalizes eco-design knowledge via: eco-material selection and assessment (S1), carbon footprint tools and lifecycle thinking (S2), rural revitalization PBL projects (S3), and interdisciplinary teamwork simulating industry environments. Formative assessments (material reports, carbon footprint calculations, project portfolios, peer evaluations) provide measurable and observable evidence of skill development.

Module 3: Integrated Innovation and Professional Empowerment: Students: develop innovative design solutions under ecological constraints, refine sustainable design portfolios, and formulate long-term ecological career plans. This module consolidates V2–V3 (higher-level value orientation and professional ethics) and strengthens advanced project competence (S3), preparing students for high-impact sustainable design roles.

Textbook and Case Library Development

To support implementation, a three-volume digital textbook and an extensive case library were developed: Localized Zhejiang Cases (approx. 60%), Examples include the green transformation of Longquan celadon, the Anji White Tea eco-brand, and other regional practices in ecological culture and industry. International Benchmark Cases (approx. 40%), Cases such as Japan's D&Department and Netherlands' circular design models provide comparative perspectives. Digital Resource System: A digital material library, carbon footprint simulators, interdisciplinary design tools, and real-time case updates address the previously identified shortage of localized and dynamic educational resources and support self-directed learning.

Curriculum Implementation and Support System

To overcome institutional and resource barriers identified in the qualitative phase, a multi-layered support system was constructed: Dual-/Multi-Qualified Teaching Team, Integrating academic staff, ecological/environmental scholars, industry mentors, and outstanding alumni. Digital Learning Platform, Hosting videos, toolkits, discussion forums, and learning analytics to support continuous monitoring and feedback. Technology-Enhanced Learning, VR/AR simulations, remote collaboration tools, and interactive media to bridge the gap between abstract theory and real-world application. Enterprise–University Partnerships, Providing authentic project briefs, competitions, internships, and career pathways, thereby forming a "learning–practice–employment" closed loop.

Evaluation System

A diversified, CBE-aligned evaluation system was designed: Formative Assessment (60%): Quizzes, reflective journals, peer evaluations, and process documentation. Summative Assessment (40%): Team sustainable design projects, individual innovation proposals, and sustainable career plans. All assessment tasks are mapped to the K–S–V competency model via detailed rubrics, ensuring clear performance criteria, transparency, and measurability.

Expected Outcomes and Innovation Highlights

The curriculum exhibits four main innovations: Problem-Driven, Evidence-Based Design: Directly derived from the empirical diagnostics of student and graduate literacy. Multi-Stakeholder Educational Ecosystem ("Government–University–Industry–Community"): Integrating policies, academic knowledge, industry practice, and rural needs. Deep Online–Offline Integration: Moving beyond theoretical online learning to practice-oriented and context-responsive design experiences. Learning–Career Articulation: Linking competency development and value internalization to portfolio development and career planning, supporting sustainable professional trajectories.

Expert Review, Curriculum Optimization, and Final Version Generation (Validation & Optimization Phases)

Expert Review Results

The validation phase employed a two-round Delphi process, IOC analysis, and thematic content analysis. The main results are: IOC Evaluation, Experts reported high levels of alignment between curriculum objectives and competency outcomes: Course objectives vs. competencies: 0.92. Overall curriculum goals vs. competency model: 0.95. Module content vs. competency indicators: 0.91. Teaching and evaluation rationality: 0.89. These scores demonstrate strong expert consensus on the curriculum's goal orientation and structural coherence. Overall Satisfaction (5-point scale), Rationality of curriculum structure: 4.6, Relevance of content to student needs: 4.5, Innovativeness of teaching methods: 4.4. Implementability: 4.3. Experts affirmed the curriculum's practicality and

innovative integration of CBE with online pedagogies, while recommending refinement in operational feasibility and resource support. Core Feedback Categories, Thematic analysis yielded five key areas: Course content (call for more localized Zhejiang cases and interdisciplinary resources); Course structure and instructional design (addition of a preparatory module, stronger process guidance); Online teaching and technical support (enhanced analytics, multimedia resources); Assessment system (clearer weightings, integration of learning behavior data); Implementability and scalability (differentiated guidelines and stronger industry–community collaboration).

Curriculum Optimization and Final Architecture

Following the expert review, a systematic optimization process was undertaken in line with the "responsiveness–implementability–practice & feedback" principles defined in the methodology. Key optimizations included: Content System: Addition of "Module Zero: Eco-Design Embarkation" as an optional preparatory module; Systematic embedding of Zhejiang elements and integration of interdisciplinary digital resources. Implementation System: Establishment of a blended online–offline learning loop; Institutionalized process guidance through mandatory mentor–team meetings; Introduction of learning analytics–driven interventions. Evaluation System: Development of transparent, competency-aligned rubrics with explicit weightings; Inclusion of a "learning engagement" dimension based on platform behavior data; Expanded multi-stakeholder assessment involving teachers, industry mentors, peers, and students. Support System: Enhanced technical infrastructure (platform integration, VR/AR, toolkits); Strengthened partnerships with local governments, enterprises, and communities; Drafting of a "Guideline for Differentiated Curriculum Implementation" to support scalability across institutional types. The final curriculum framework spans 64 hours (including Module Zero). It forms a progressive, competency-oriented pathway from "Knowing" (Module I) to "Doing" (Module II) to "Creating" (Module III), supported by a robust ecosystem of resources, evaluation, and collaboration.

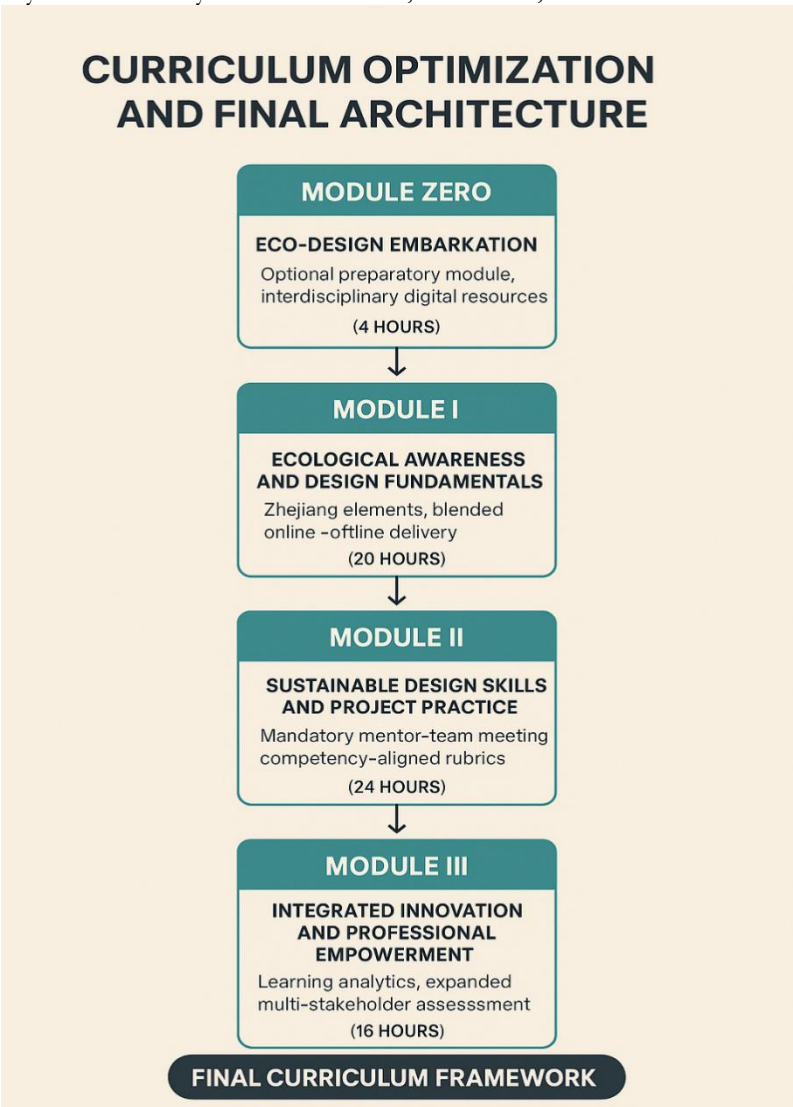

Figure 3: Curriculum Optimization and Final Architecture

Overall Summary of Results, Taken together, the QUAN–QUAL findings, curriculum development, expert validation, and optimization phases demonstrate that: Ecological civilization literacy among Visual Communication Design students and graduates in Zhejiang Province is moderate but structurally imbalanced, with strong attitudes but weaker knowledge and behaviors. Stakeholders (faculty, employers, experts) strongly support a systematic curriculum reform grounded in competencies, projects, and digital environments. The resulting curriculum, "Ecology and Vision: Integrating Sustainable Design Competencies," represents a practice-centered, evidence-based, and context-responsive solution that aligns closely with local needs while offering a replicable model for ecological civilization education in design disciplines at the national level.

CONCLUSION

This study developed and validated a competency-based online curriculum designed to enhance the ecological civilization literacy of Visual Communication Design majors in Zhejiang Province. Using an explanatory sequential mixed-methods design, the research systematically diagnosed the current literacy status of students and graduates, identified gaps in existing educational provision, constructed a scientifically validated "Three Dimensions–Nine Competencies" model, and iteratively developed the online curriculum Ecology and Vision: Integrating Sustainable Design Competencies. Empirical results demonstrated that students' ecological knowledge is moderate, practical competencies remain weak, and value internalization is insufficient. Significant misalignments exist between educational supply and student needs, particularly regarding localized resources, practical opportunities, and diversified assessment.

The competency model constructed through Delphi consultation provides a clear and operational framework for guiding curriculum development. The final curriculum—optimized through expert review—shows strong alignment with CBE principles, local development priorities, and the professional characteristics of design education. It also represents an evidence-based, context-responsive, and scalable educational solution. Overall, the study contributes a theoretically grounded and practically feasible model for ecological civilization education within design disciplines, offering insights with broader national applicability.

DISCUSSION

The findings reinforce the structural imbalance characterizing students' ecological civilization literacy: higher ecological attitudes but limited practical abilities and weak behavioral transformation. This mirrors global research showing that sustainability awareness alone does not guarantee the transfer of knowledge into action. The study's identification of gaps between current educational provision and learner needs echoes earlier arguments that design education must transition from content-centered to competency-centered and practice-oriented models.

The "Three Dimensions–Nine Competencies" model represents a major theoretical advancement. It operationalizes ecological literacy—traditionally abstract and value-dominated—into measurable knowledge, skills, and values tailored to the design discipline. This supports UNESCO's call for competency-based sustainable development education and fills a theoretical gap within ecological design pedagogy.

In practice, the curriculum Ecology and Vision demonstrates the feasibility of integrating CBE, digital learning, and localized ecological content. The blend of online learning analytics and authentic project-based practice provides a strong response to the shortcomings of traditional lecture-driven approaches. However, challenges remain: the shortage of interdisciplinary teachers, uneven resource distribution across institutions, and the need for continued updating of localized case libraries. These challenges highlight the long-term nature of ecological civilization education and reinforce the importance of institutional support and multi-stakeholder collaboration.

RECOMMENDATIONS

Recommendations for Education Policy

1. Institutionalize ecological civilization education by integrating it into national and provincial quality assurance and professional accreditation systems for art and design disciplines.
2. Strengthen interdepartmental collaboration (education, ecology, culture, industry) to build a shared ecosystem of teaching resources, practice bases, and joint training programs.
3. Increase policy and funding support through sustainability education grants, faculty training initiatives, and national demonstration course schemes.

Recommendations for Curriculum Implementation

1. Deepen CBE-oriented reform by continually aligning objectives, competencies, teaching activities, and rubrics.
2. Expand project-based learning through a dynamic bank of authentic, industry-linked design tasks, particularly those reflecting Zhejiang's ecological and cultural features.
3. Enrich digital and immersive resources, including VR/AR case simulations, eco-material databases, and updated sustainability design repositories.

Recommendations for Faculty Development

1. Implement systematic interdisciplinary training combining ecology, materials science, design methodology, and digital pedagogy.
2. Establish interdisciplinary teaching teams and "master teacher studios" to support ongoing innovation in ecological design education.
3. Encourage faculty action research to refine teaching models and develop evidence-based best practices.

Recommendations for Student Development

1. Cultivate sustainable career identities by integrating ecological literacy into career planning, portfolio development, and ethics courses.
2. Strengthen interdisciplinary learning pathways via elective courses, learning communities, and cross-major project platforms.
3. Enhance digital and practical competencies through studio-based learning, industry mentorship, and participation in real-world eco-design projects.

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