# From Periphery to Core: A Four-Stage Evolutionary Model of Interdisciplinary Courses in Higher Education

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## Abstract

This paper addresses the gap between the widespread implementation of interdisciplinary courses (IDCs) in higher education and the relative lag in corresponding theoretical development by proposing a dynamic evolutionary framework that elucidates their generative logic and structural dynamics. Drawing on a "core–periphery" curriculum model, the study conceptualizes disciplinary programs as open knowledge networks and advances a four-stage evolutionary pathway for IDCs: peripheral emergence, core penetration, knowledge differentiation, and re-contextualization. Through theoretical analysis and illustrative cases—such as Bioinformatics and Environmental Economics—the paper argues that IDCs are not static content categories, but relational, contextual, and dynamically evolving structural entities. Their evolution reflects both the curricular embodiment of Mode 2 knowledge production and the dialectical rhythm of "differentiation–integration–re-differentiation" in disciplinary development. The study further offers practical recommendations for university administrators and curriculum designers regarding dynamic curriculum governance, the institutionalization of the periphery as an incubation zone, and reforms in faculty evaluation and resource allocation to support sustainable interdisciplinarity. This framework provides a new theoretical lens for understanding curriculum evolution and informs the design of innovative and adaptive higher education systems.

## Full Text

## Preamble

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## Abstract

This paper addresses the theoretical lag behind the widespread practice of interdisciplinary courses (IDCs) in higher education by proposing a dynamic evolutionary framework to reveal their generative logic and structural dynamics. Drawing on a "core-periphery" curriculum model, the study conceptualizes disciplinary programs as open knowledge networks and advances a Four-Stage evolutionary pathway for IDCs: peripheral emergence, core penetration, knowledge differentiation, and re-contextualization. Through theoretical analysis and illustrative cases—such as Bioinformatics and Environmental Economics—the paper argues that IDCs are not static content categories, but relational, contextual, and dynamic structural entities. Their evolution reflects both the curricular embodiment of Mode 2 knowledge production and the dialectical rhythm of "differentiation-integration-re-differentiation" in disciplinary development. The study further offers practical recommendations for university administrators and curriculum designers on dynamic curriculum governance, the institutionalization of the periphery as an incubation zone, and reforms in faculty evaluation and resource allocation to support sustainable interdisciplinarity. This framework offers a new theoretical lens for understanding curriculum evolution and informs the design of innovative, adaptive higher education systems.

**Keywords:** Interdisciplinary courses; Curriculum evolution; Core-periphery structure; Academic disciplines; Knowledge production

## 1. Introduction: Problem Statement and Research Significance

In the 21st century, science and technology have experienced a "dual trend" : on the one hand, knowledge systems have become increasingly specialized, deepening vertical differentiation within disciplines; on the other, the complexity of systemic challenges—such as climate change, global health crises, and artificial intelligence—has made traditional single-discipline research paradigms increasingly inadequate (Nowotny, 2001). In response, interdisciplinary knowledge integration has emerged as a critical pathway for scientific breakthroughs and technological innovation, becoming a central focus in higher education reform.

Top universities around the world have recognized interdisciplinary collaboration as a cornerstone for talent development and research advancement. For example, Stanford University' s Bio-X initiative, launched in 1998, has supported cross-departmental collaboration through its Interdisciplinary Initiatives Program (IIP), with seed funding and doctoral fellowships. This program now engages over 1,300 faculty members across engineering, physics, computation, and life sciences, aiming to integrate research and teaching in transformative ways

(Stanford, 2024). Similarly, the University of Michigan has developed institutional strategies, such as joint faculty appointments and coordinated promotion procedures, to support cross-disciplinary collaboration and career development (University of Michigan, 2023). In China, the Academic Degrees Committee of the State Council and the Ministry of Education established "Interdisciplinary Studies" as the 14th academic category in 2020, elevating it alongside traditional disciplines like Science and Engineering. This policy decision institutionalizes interdisciplinary studies, supporting universities in developing interdisciplinary curricula and research systems. These initiatives aim to reshape knowledge production and curriculum organization in higher education through institutional innovation (Repko and Szostak, 2020).

Despite the macro-level advocacy for interdisciplinarity, conceptual clarity is still lacking at the micro-level of curriculum research in higher education. Interdisciplinary Courses (IDCs) illustrate this gap: while scholars have explored IDC concepts since the late 20th century—focusing on curriculum integration (Jacobs, 1989), cross-disciplinary teaching (Klein, 1990), and transdisciplinary learning (Frodeman, 2014)—a cohesive theoretical framework is still missing (Lattuca and Voigt et al., 2004; Spelt and Biemans et al., 2009). This theoretical fragmentation has led to practical challenges: course designs often become "eclectic patchworks" (Beane, 1997), instructional goals shift unpredictably due to contextual pressures (Spelt and Biemans et al., 2009), and faculty evaluation systems lack interdisciplinary-specific criteria (Boix Mansilla and Dawes Duraisingh, 2007). These issues hinder the development of interdisciplinary talent in higher education.

To address these challenges, this paper argues that IDCs are not static course categories, but dynamic, relational entities that emerge within disciplinary curricula in response to limitations in core knowledge and the integration of new insights. The "interdisciplinary" nature of these courses is relational, defined by their position within their parent disciplines. Building on this concept, this paper proposes a "core-periphery" model for disciplinary curriculum structure, advancing a Four-Stage evolutionary pathway for IDCs: (1) peripheral emergence, (2) core penetration, (3) knowledge differentiation, and (4) re-contextualization. Using case studies like Bioinformatics and Environmental Economics, this paper seeks to clarify the conceptual identity of IDCs, reveal their role in knowledge innovation and disciplinary evolution, and offer actionable guidance for reforms in curriculum design, instructional organization, and administrative mechanisms in higher education institutions.

## 2.1 Classical Theoretical Frameworks of Higher Education Curriculum Systems

The design of a curriculum is crucial to talent development as it not only determines the sequence of knowledge transmission but also shapes the pathways through which educational objectives are achieved. To understand how modern curriculum systems have evolved, we must first consider the seminal contri-

butions of several educational thinkers, whose theories lay the foundation for current curriculum structures in higher education.

John Dewey, in *Experience and Education*, argued that educational experiences must adhere to two principles: continuity and interaction. He proposed that curricula should be rooted in students' lived experiences and allow for continuous reconstruction, thereby enabling students to actively engage with and construct knowledge. Dewey' s experiential philosophy provides the basis for understanding how curriculum content can evolve and be co-constructed in dynamic ways, promoting a learner-centered approach to pedagogy (Dewey, 1938).

Ralph W. Tyler, in *Basic Principles of Curriculum and Instruction*, introduced the influential "objectives model," which asserts that curriculum design should begin with clear, measurable educational goals. From these goals, the selection, organization, and evaluation of content should proceed systematically, thus establishing a structured curriculum framework (Tyler, 1949). While highly influential, Tyler' s model has been critiqued for its rigidity and limited flexibility, particularly regarding learner autonomy (Stenhouse, 1975). Jerome Bruner, on the other hand, proposed the "spiral curriculum," wherein key concepts are revisited at increasing levels of complexity, facilitating deeper understanding and knowledge transfer across contexts (Bruner, 1960).

Together, these theories have shaped the modern university curriculum, which is often organized into hierarchical categories, such as general education, disciplinary foundations, core major courses, and electives (Harden, 2001; Barnett and Coate, 2005). This model aims to balance breadth (through general education) and depth (through specialization), ensuring a comprehensive educational experience. However, this framework primarily focuses on the static distribution of courses within curricular structures and does not adequately address the dynamic processes of knowledge evolution. It is particularly insufficient in explaining the role of IDCs within curriculum systems, as IDCs often blur the boundaries between disciplines and contribute to knowledge innovation (Bernstein, 2000; Maton, 2014).

Building on this critique, this paper introduces a knowledge systems perspective to curriculum theory and proposes the core–periphery model of curriculum structure. The core–periphery model, derived from social network analysis, characterizes how central and peripheral nodes interact within a network (Borgatti and Everett, 2000). Applied to curriculum systems, this model conceptualizes courses as nodes in a knowledge network, allowing for the analysis of how IDCs bridge disciplinary boundaries. This framework enables an understanding of how IDCs evolve within curricula, influencing curriculum positioning, functional transformation, and long-term change.

## 2.2 Clarifying Key Concepts in "Interdisciplinarity"

Before exploring the concept of IDCs, it is important to distinguish between several closely related terms that are often conflated. In higher education research,

interdisciplinary studies, interdisciplinary curriculum, and IDCs all involve the integration of multiple disciplines, but they differ significantly in terms of their scope, institutionalization, and functional roles.

**Interdisciplinary Studies** refers to a research orientation or academic field characterized by collaborative engagement across disciplines. This approach emphasizes the coordinated use of disciplinary resources to co-construct knowledge around complex problems. A paradigmatic example is the institutionalized interdisciplinary program, such as Gender Studies or Environmental Studies, which integrates theories and methodologies from multiple disciplines to address pressing societal challenges (Klein, 2010; Repko and Szostak, 2020).

**Interdisciplinary Curriculum** refers to an educational framework at the curriculum level that integrates multiple disciplines into a cohesive instructional design. This design typically centers around a unifying theme or competency goal, systematically organizing related courses to foster interdisciplinary learning. Frameworks such as the "curriculum integration spectrum" (Jacobs, 1989) and the "ten models of integration"(Fogarty, 1991) emphasize the organization of interdisciplinary themes and alignment of learning objectives (Drake and Burns, 2004).

**IDCs**, in contrast, focuses on the integration of multiple disciplines within a single course. In these courses, instructors blend knowledge, methods, and assessment strategies from various disciplines to tackle complex, multifaceted problems (Ivanitskaya and Clark et al., 2002; Boix Mansilla and Dawes Duraisingh, 2007). An IDC may function as an independent unit or as part of a broader interdisciplinary curriculum. Together, these three constructs—Interdisciplinary Studies, Interdisciplinary Curriculum, and Interdisciplinary Course—represent a hierarchical progression: from the academic domain (studies), to the curriculum level (curriculum), to the instructional level (courses). While they serve different purposes within higher education, they share the common goal of transcending disciplinary boundaries and fostering students' integrative and adaptive competencies.

While the literature on interdisciplinary studies and curriculum design is rich, the theoretical development of IDCs as an independent category remains underexplored. Much of the existing work focuses on pedagogical case studies and collaborative teaching practices (Barnett and Coate, 2005; Newell, 2007). However, current discussions typically view IDCs as transitional entities that bridge interdisciplinary studies and curriculum, facilitating the integration of knowledge across disciplines through intentional course design and teaching practices.

This paper, however, offers a more nuanced understanding. We define IDCs as context-dependent, functionally embedded course forms—institutionalized manifestations of interdisciplinarity within talent development systems. These courses serve as critical experimental spaces where interdisciplinary processes generate tangible interdisciplinary outcomes. Their identity is not defined solely by content but, more importantly, by their position within the broader curricu-

lum and their relational dynamics with core disciplinary knowledge. This relational and contextual nature lies at the heart of IDCs and forms the conceptual foundation for the theoretical framework proposed in the following sections.

## 3. A Theoretical Framework of Dynamic Evolution for Interdisciplinary Courses

### 3.1 Redefining Interdisciplinary Courses: A Dynamic and Relational Perspective

An Interdisciplinary Course is a course that systematically integrates theories, methods, or approaches from two or more disciplines within a specific disciplinary curriculum. These courses arise in response to complex problems that cannot be adequately addressed by the core knowledge of a single discipline, or to incorporate emerging knowledge and technologies essential for the discipline' s advancement. The "interdisciplinary" nature of such a course is defined relationally—its interdisciplinarity is understood in reference to its position within the host curriculum and the knowledge it incorporates.

This definition includes four key features:

1. **Relationality**: The interdisciplinary nature of a course is not defined merely by its content or title, but by its relational position within a curriculum. Specifically, its interdisciplinary nature depends on how it interacts with core disciplinary knowledge. For example, Bioinformatics integrates computer science and molecular biology in a Biology program, positioning it as an IDC that introduces knowledge from outside the core discipline. However, in a dedicated Bioinformatics program, the same course transitions into a core disciplinary component, ceasing to be "interdisciplinary" in that context.

2. **Dynamism**: The position of an IDC within a curriculum evolves over time in response to the progression of disciplinary fields. Initially situated on the periphery, such courses may shift toward the curriculum' s core as the importance of the integrated knowledge increases. This process, referred to as "core shift," can be seen in the evolution of Bioinformatics. Initially offered as an elective in biology programs in the 1990s, Bioinformatics became central to curricula by the early 2000s, following advancements in genomics and high-throughput sequencing. This shift led to its institutionalization as a core course and the development of dedicated degree programs (Luscombe and Greenbaum et al., 2001; Schneider and Orchard, 2010).

3. **Integration**: An IDC does not merely combine content from multiple disciplines; it fosters the organic integration of ideas, methods, and evidence across disciplinary boundaries, creating knowledge structures that offer greater explanatory power and adaptability. This integration is evident through three key characteristics: (a) Learning outcomes that cannot be

fully explained by any one discipline alone; (b) The creation of stable, integrative frameworks at both the curricular and cognitive levels; (c) The ability to function independently, while remaining transferable and applicable across various contexts (National Academy of Sciences et al., 2005).

4. **Catalytic Function**: IDCs act as catalysts, not only adapting curricula to incorporate external knowledge but also incubating emerging disciplines. For example, Bioinformatics, initially introduced as an interdisciplinary elective within biology, evolved into a critical methodological pillar as the Human Genome Project generated vast amounts of data. This shift not only redefined the course' s role within existing programs but also sparked the creation of new academic fields and research trajectories (Collins and Morgan et al., 2003).

Thus, an IDC represents the institutionalized manifestation of interdisciplinarity at the curriculum level. Its key features—relational positioning, temporal dynamism, deep integration, and catalytic role—form the foundation for the dynamic evolutionary framework.

## 3.2 The Core-Periphery Model of Disciplinary Curriculum

To explain the dynamic evolution of IDCs within specialized academic programs, this paper adopts a core-periphery model from knowledge structure and knowledge production theory (Gibbons and Limoges et al., 1994). The model views the disciplinary curriculum as an open, dynamic system that continuously interacts with external knowledge. It consists of two interconnected layers: the core layer, which houses the stable norms, foundational theories, and canonical practices of the discipline, and the peripheral layer, which serves as an interface for experimenting with emerging theories, tools, and interdisciplinary insights. IDCs typically emerge in the periphery, where they are developed and refined before potentially migrating to the core, signaling structural shifts within the curriculum.

1. **The Core Layer**: The core layer comprises the foundational knowledge and established theories of a discipline. These include widely accepted theories, paradigms, and skill-based courses that define the discipline' s identity and professional boundaries. The core functions to maintain continuity, reinforce disciplinary belonging, and ensure high standards in talent development (Becher and Trowler, 2001). For instance, in a Biology program, foundational courses such as Introduction to Biology, Biochemistry, Cell Biology, and Genetics form the core, providing students with a deep understanding of the discipline's principles and professional practices (Clark, 1983).

2. **The Peripheral Layer**: The peripheral layer represents the dynamic interface between the curriculum and external knowledge sources. This layer is characterized by flexibility and innovation, incorporating exploratory or IDCs such as electives, cross-disciplinary seminars, or experimental mod-

ules. The periphery plays a crucial role in knowledge innovation by introducing new theories and problem-solving approaches, expanding the breadth of learning. For example, in Biology programs, peripheral courses like Bioinformatics, Genetic Engineering, and Neurobiology offer students exposure to emerging fields and cutting-edge research, often reflecting institutional strengths and evolving research agendas (Neumann, 2001).

3. **Dynamic Function and Course Migration**: The core-periphery model provides a useful framework for understanding the lifecycle of IDCs. Initially, these courses are located in the periphery of the curriculum, supplementing or challenging established core knowledge. As their theoretical significance and practical relevance become more widely recognized, IDCs may migrate toward the core, resulting in changes to the curriculum' s structure. This "core shift" is exemplified by the evolution of Bioinformatics. Initially introduced as an elective in Biology programs in the late 1990s to support DNA sequence analysis, Bioinformatics grew in importance as genomics and high-throughput sequencing advanced. Over time, it became a core course, reshaping the curriculum and eventually leading to the development of specialized degree programs.

## 3.3 A Four-Stage Evolutionary Pathway Model for Interdisciplinary Courses

Building on the core-periphery curriculum model, this paper proposes a Four-Stage evolutionary pathway for the development of IDCs. The evolution of Environmental Economics within academic curricula is used as a case study to illustrate this dynamic process.

**Stage 1: Emergence and Supplementation -A Peripheral Course**: An IDC typically emerges in the curriculum as a peripheral offering when the host discipline encounters complex issues it cannot address with its core knowledge, or when new tools are needed. At this stage, the course is often introduced as an elective or restricted elective, aiming to supplement existing knowledge and expand students' intellectual horizons. In the 1960s and 1970s, as environmental issues like pollution and resource depletion became critical global challenges, traditional environmental science methods proved insufficient for addressing these socio-ecological problems. A new framework was needed, and Environmental Economics began to develop at the margins of the curriculum. Initially offered as an elective in Environmental Science or Economics programs, the course introduced market-based policy tools such as taxes, subsidies, and tradable permits to address environmental externalities (Pigou, 1920; Coase, 1960).

**Stage 2: Permeation and Core-orientation -Migration Toward the Core**: As the theories and methods of an IDC prove essential to the host discipline, its status within the curriculum shifts—often becoming a required or core course—and its content becomes increasingly integrated with the discipline' s foundational theories. In 1974, the *Journal of Environmental Economics*

*and Management* (JEEM) was launched, providing a platform for scholarly exchange. This was followed by the creation of the Association of Environmental and Resource Economists (AERE) in 1979, which institutionalized the field. Environmental Economics rapidly became a core component in programs related to public policy, environmental management, and sustainable development, embedding key topics like cost-benefit analysis, pollution trading, and the internalization of externalities. Over time, it also became a key module in Master' s programs in Economics, embedded within research methods and policy analysis curricula.

**Stage 3: Differentiation and Independence -The Birth of a New Discipline**: As the knowledge structure of an IDC becomes more cohesive, it may transcend the boundaries of its original discipline, giving rise to a new academic field. With the development of specialized methodologies—such as non-market valuation, auction design, and carbon trading—Environmental Economics has established a distinct and self-sustaining knowledge framework. This shift is marked by the widespread adoption of authoritative textbooks, such as Hanley et al. (2007), signaling the professionalization of the field. Today, dedicated programs in Environmental Economics are offered at numerous universities, featuring specialized curricula in microeconomic theory, non-market valuation, energy econometrics, and environmental policy evaluation. This marks the transition from an IDC to an independent academic discipline with its own curricular structure and research agenda.

**Stage 4: Transformation and Re-contextualization -The Re-definition of Curricular Identity**: As a discipline matures, the courses that once existed as IDCs are integrated as core components, and their "interdisciplinary" nature naturally dissipates. However, within the original disciplines, simplified or applied versions of these courses continue as IDCs, broadening students' perspectives while retaining their interdisciplinary characteristics. This illustrates the relational nature of curricular identity—whether a course is seen as interdisciplinary depends on its structural position within the curriculum, not solely on its content. For instance, in Environmental Economics programs, courses such as Environmental Valuation and Natural Resource Economics have become core offerings. In contrast, in traditional programs such as Economics or Environmental Science, introductory courses like Introduction to Environmental Economics remain interdisciplinary, tailored to specific programmatic goals.

The dynamic evolutionary process of Environmental Economics, as outlined above, is visually summarized in Figure 1 [Figure 1: see original paper]. This diagram illustrates the Four-Stage pathway—from peripheral emergence to recontextualization—within the core-periphery structure of the curriculum.

**Figure 1** The Four-Stage evolution of environmental economics: a core-periphery model of interdisciplinary curriculum development

### 3.4 The Internal Drivers of Evolution: Knowledge Expansion and Disciplinary Differentiation

The evolution of IDCs is driven by two primary forces: the Mode 2 knowledge production paradigm (Gibbons and Limoges et al., 1994) and the dialectical process of differentiation and integration in scientific and academic development. These forces shape how IDCs emerge, evolve, and influence the broader curriculum.

1. **Mode 2 Knowledge Production Paradigm**: The evolution of IDCs is fundamentally linked to the Mode 2 knowledge production paradigm, as described by Gibbons et al. (1994). Unlike Mode 1, which emphasizes discipline-specific research, Mode 2 focuses on problem-solving and transdisciplinary collaboration. It responds to complex, real-world problems by encouraging research that transcends traditional disciplinary boundaries. This shift demands that educational curricula evolve to integrate knowledge across fields, providing students with the tools to address multifaceted challenges. Mode 2 knowledge production highlights the need for context-driven inquiry and heterogeneous participation, which is reflected in the growing prominence of IDCs within higher education. IDCs thus serve as vehicles for incorporating multiple disciplinary perspectives, fostering the flexibility and collaboration necessary to solve contemporary societal problems.

2. **Differentiation and Integration in Scientific Development**: The evolution of IDCs also mirrors the dialectical process of differentiation and integration in the development of knowledge systems. While disciplines continuously differentiate into specialized fields, this specialization can lead to fragmentation, limiting the ability to address complex, cross-disciplinary problems (Miller, 1982). To overcome this, scientific fields must engage in integration, combining insights from disparate areas to create more comprehensive frameworks. IDCs play a key role in this integrative process, serving as the interface where fragmented knowledge is reassembled. These courses facilitate the reorganization of existing knowledge systems into more holistic frameworks, contributing to the development of new interdisciplinary domains.

3. **IDCs as Incubators for New Knowledge Systems**: Furthermore, IDCs are not just a means to bridge existing disciplines; they also act as incubators for new knowledge systems. For example, fields such as Bioinformatics, Digital Humanities, and Computational Social Science began as IDCs before evolving into fully established academic disciplines. These new fields often grow out of the integration of knowledge from multiple disciplines, eventually forming their own research agendas, methodologies, and academic identities (Burdick and Drucker et al., 2012; Trowler and Saunders et al., 2012). This transformation—where IDCs evolve into distinct disciplines—demonstrates the dynamic nature of higher education

curricula. IDCs function as testbeds for emerging academic fields, providing the foundation for new areas of study that address complex, contemporary issues.

### 3.5 The Dialectics Understanding of Integration and Differentiation: Toward a Unified Framework

The evolution of IDCs embodies the dialectical relationship between integration and differentiation in scientific knowledge and curriculum development. These forces are not mutually exclusive but interact in a way that allows knowledge systems to adapt to the growing complexity of modern challenges. Understanding this relationship is essential to grasp how IDCs function within higher education.

1. **Integration: The Catalyst for Innovation**: Integration in the context of IDCs involves synthesizing knowledge, methods, and perspectives from multiple disciplines to address complex, real-world problems. This process is essential for fostering innovative thinking, as it allows students to engage with issues that cannot be adequately addressed by any single discipline. The integration of diverse knowledge forms the foundation for interdisciplinary learning, where students gain insights from various fields and apply them in novel ways. The primary goal of IDCs is to integrate knowledge, allowing students to see the interconnectedness of disciplines and think beyond traditional boundaries. This integrative approach nurtures the development of new theories, methods, and solutions, enabling higher education to respond effectively to societal challenges.
2. **Differentiation: Specialization within Integration**: However, integration alone is insufficient to fully understand the complexity of modern issues. As knowledge expands, there is a need for differentiation—the specialization of knowledge to tackle specific problems within broader interdisciplinary frameworks. Differentiation allows for the deepening of knowledge in particular areas, which is necessary for advancing research and understanding complex issues. While IDCs serve as spaces for integration, they also encourage differentiation by cultivating specialized expertise within interdisciplinary frameworks. As IDCs evolve, they may give rise to new subfields or specialized tracks within broader disciplines. This differentiation is not a departure from interdisciplinarity but an essential component of it, enabling fields to develop the depth required for meaningful advancement.
3. **A Unified Understanding of IDC Evolution**: The evolution of IDCs can be understood as a process that moves between integration and differentiation. Initially, IDCs integrate knowledge from various disciplines, but as the interdisciplinary knowledge matures, it may give rise to specialized subfields that demand deeper focus. This dynamic interplay allows IDCs to drive both innovative integration and focused specialization, providing a comprehensive response to contemporary challenges. This dialectical

process of integration and differentiation is central to the ongoing development of academic curricula. As new interdisciplinary fields emerge, they simultaneously integrate diverse knowledge and evolve into specialized areas of study. The result is a recursive process in which IDCs contribute to both the broadening and the deepening of knowledge, ensuring that higher education systems remain adaptive and responsive to the changing needs of society.

## 4. Practical Implications and Applications of the Theoretical Framework

The "core–periphery" curriculum structure and the "Four-Stage evolutionary pathway" introduced in this study offer more than just an analytical lens for understanding the emergence and evolution of IDCs; they provide practical guidance for the design, management, pedagogy, and faculty development of interdisciplinary curricula in higher education. This theoretical framework reconceptualizes courses, not as static knowledge repositories, but as dynamic structural nodes within the broader processes of knowledge production and disciplinary evolution. The evolution of these courses serves as a vital mechanism through which higher education systems adapt to external changes. Building on this perspective, this section delves into the practical implications of the framework for curriculum governance, pedagogical innovation, and talent development.

### 4.1 Implementing Dynamic Curriculum Management

1. **Dynamic Curriculum Governance**: University administrators should adopt a dynamic approach to curriculum management, moving beyond the traditional view of curricula as fixed and predetermined. Instead, they should implement flexible management and evaluation systems that respond to emerging academic trends and societal needs (Barnett and Coate, 2005). The curriculum, particularly in interdisciplinary areas, should be seen as a dynamic entity, continuously evolving in response to new knowledge and societal challenges. Institutions should regularly assess the structural dynamics within disciplinary programs, paying particular attention to innovative trends in peripheral courses. These courses, often seen as experimental or supplementary, may eventually prove valuable enough to migrate into the core curriculum. To facilitate this process, universities need institutionalized mechanisms, such as a curriculum lifecycle review system and early-warning protocols for identifying promising IDCs. Additionally, open channels should be created for the development and experimentation of new courses, encouraging cross-disciplinary collaboration and fostering innovation in course design.

2. **Strengthening the Incubation Function of the Periphery**: The peripheral layer of the curriculum should be strategically positioned as an incubator for emerging academic fields and innovative learning approaches

(Frodeman and Klein et al., 2017). Higher education institutions must intentionally create space for IDCs that are in their developmental stages but demonstrate strong potential for contributing to new academic directions. This can be achieved by offering targeted support, such as an IDC Innovation Fund, cross-school enrollment options, and collaborative learning opportunities that provide real-world, problem-based industry-university platforms. Moreover, when an IDC matures and gains academic recognition, it should not be treated as a static entity. Instead, the institution should establish formal pathways to integrate these courses into full-fledged academic tracks and eventually develop them into independent disciplines. This process helps prevent the imbalance of having vibrant IDCs without a corresponding academic discipline or research community, ensuring that new fields have the resources and institutional support to thrive.

### 4.2 Implications for Pedagogy and Talent Development

1. **Core Pedagogical Challenges**: Teaching IDCs presents three primary challenges: First, students often come from highly diverse disciplinary backgrounds and cognitive frameworks. Second, instructors must be able to integrate knowledge across multiple disciplines and move beyond single-discipline paradigms in course design. Third, there is a risk that the course content may fall into "physical juxtaposition" —a mere aggregation of disciplinary knowledge—rather than achieving "chemical integration," where concepts, methods, and perspectives are genuinely synthesized. These challenges call for pedagogical models that move beyond traditional lecture-based teaching toward more integrative, collaborative, and dynamic approaches.

2. **Innovative Pedagogical Models**: To address these challenges, IDCs should adopt problem-driven learning models (such as Problem-Based Learning, PBL), project-based learning, and case-integrated approaches, complemented by team teaching (Thomas, 2000; Hmelo-Silver, 2004; Michaelsen and Knight et al., 2008). By engaging students with real-world, complex problems, these models encourage interdisciplinary connections and foster transdisciplinary problem-solving skills. Team teaching, in particular, bridges epistemic divides by enabling collaborative course design, mutual learning, and reflective practice among faculty members from different disciplines.

3. **Core Goals of Talent Development**: The ultimate goal of IDCs extends beyond simple knowledge transfer to the cultivation of integrative thinking and metacognitive skills (Golding, 2009). Integrative thinking enables students to critically assess the strengths and limitations of different disciplinary perspectives and to synthesize these insights when addressing complex problems. Metacognitive skills refer to students' awareness and regulation of their own thinking processes, which empowers them to

flexibly apply knowledge in uncertain or novel contexts. This transformation—from knowledge accumulation to cognitive restructuring—is essential for IDCs to fulfill their mission of developing a new generation of talent equipped to tackle complex, systemic challenges.

### 4.3 Rethinking Faculty Management and Resource Allocation

1. **Optimizing Workload Calculation**: IDCs place greater demands on faculty, requiring more extensive preparation, disciplinary integration, and collaboration across departments. Instructors not only need to master their own field but also dedicate significant time to learning and integrating concepts, theories, and methods from related disciplines. Designing these courses involves more than simply compiling content; it requires the creative synthesis of diverse knowledge systems. In the classroom, faculty must navigate a wide range of student backgrounds and questions while often co-teaching with colleagues from other departments. These additional responsibilities, which are cognitively demanding, are often not fully accounted for in traditional workload models. To address this, institutions should introduce complexity-adjusted weighting factors in workload calculations that reflect the interdisciplinary nature of IDCs. For example, a 3-credit IDC could be weighted at 1.2 to 1.5 times its nominal credit value. This adjustment would formally recognize the additional intellectual effort required and help incentivize high-quality interdisciplinary teaching.
2. **Cross-Departmental Resource Allocation**: IDCs often rely on resources that span multiple departments, but traditional departmental structures can fragment access to infrastructure, funding, and expertise. To address this, leading universities have adopted platform-based management models that provide shared resources across disciplines. These resources may include jointly developed laboratories, databases, and case repositories, along with flexible funding mechanisms to support interdisciplinary initiatives. For example, the Massachusetts Institute of Technology (MIT) has implemented an open-access resource platform for interdisciplinary initiatives, available to both faculty and students across various departments. Managed and funded at the institutional level, this platform ensures that IDCs receive resource support comparable to, or even exceeding, that of single-discipline courses (Mitchell and McConnell, 2020). Such centralized coordination helps prevent resource silos and ensures equitable access to interdisciplinary infrastructure.
3. **Reforming Evaluation Mechanisms**: Faculty promotion and performance evaluations are crucial factors influencing academic behavior and motivation. However, traditional evaluation systems remain largely based on single-discipline criteria, which can marginalize interdisciplinary educators by failing to recognize their contributions both within their home discipline and across interdisciplinary spaces. To address this imbalance, institutions must formally recognize interdisciplinary contributions in their

evaluation systems (OECD, 2019). This could be achieved by establishing interdisciplinary review panels within tenure and promotion committees and incorporating interdisciplinary outputs into evaluation metrics. These metrics might include publications in transdisciplinary journals, patents from integrative research, and the development of innovative IDCs. By adopting such a composite evaluation framework, universities can more accurately reflect the diverse contributions of interdisciplinary faculty (UNESCO, 2021). Only through these systemic reforms can institutions create a supportive ecosystem for the sustainable development of interdisciplinary education.

## 5. Conclusion and Future Directions

This paper addresses the dual challenges of knowledge complexity and context-sensitive problem-solving in 21st-century higher education, focusing on the IDC as a key curricular vehicle. It presents a dynamic theoretical framework that integrates a core–periphery structure model with a Four-Stage evolutionary pathway, offering a systematic account of how IDCs evolve within institutional settings. Moving beyond traditional curriculum studies, which rely on static, content-based taxonomies, this framework reconceptualizes IDCs as relational, contextual, and evolutionary structural entities. It traces their full life cycle—from peripheral emergence and core penetration to disciplinary differentiation and eventual re-contextualization.

The findings show that IDCs are not merely pedagogical supplements, but essential outcomes of the transformation in knowledge production. They represent the institutionalization of Mode 2 knowledge practices and reflect the dialectical rhythm of "differentiation–integration–re-differentiation" in scientific development. The evolution of IDCs highlights not only a curriculum' s capacity to absorb emerging knowledge but also a co-evolutionary mechanism through which higher education systems adapt to shifts in disciplinary boundaries, talent development paradigms, and organizational structures.

This study makes three key theoretical contributions. First, it introduces the core–periphery network model—originally from social network analysis—into curriculum theory, offering a novel lens for understanding the generative logic and structural dynamics of IDCs. Second, the Four-Stage evolutionary pathway —emergence, permeation, differentiation, and re-contextualization—provides a clear theoretical trajectory for how courses evolve from pedagogical experiments into institutionalized disciplines. Third, by emphasizing relationality and contextuality as core attributes, this framework shifts the focus from content to the way knowledge is positioned and reassembled within curricula.

In practical terms, this study calls for a paradigm shift. Universities should move beyond treating IDCs as isolated "flagship projects" and instead integrate them into systemic institutional design. This requires establishing dynamic curriculum governance mechanisms, empowering the peripheral layer as an in-

cubation zone for emerging fields, and transforming pedagogy from traditional knowledge transmission to problem-driven, project-based integration. Crucially, institutions must reform faculty workload models, cross-departmental resource allocation, and tenure evaluation systems to dismantle the structural barriers that hinder interdisciplinary collaboration. Only through these comprehensive reforms can higher education evolve from offering isolated IDCs to cultivating interdisciplinary disciplines and ultimately fostering an interdisciplinary academic culture.

Looking ahead, as technologies like artificial intelligence, big data, and global existential challenges continue to reshape knowledge landscapes, IDCs will face new tensions and opportunities. How can humanistic values be preserved in algorithmically driven knowledge recombination? How can equitable integration be achieved across diverse cultural and epistemic traditions? And how can the long-term impact of IDCs on students' complex thinking and adaptive reasoning be rigorously assessed? These questions not only call for future research but also pose immediate challenges for higher education leaders who must navigate the tensions between technological advancement, humanistic values, and equitable knowledge integration.

Ultimately, this study aims to inspire deeper reflection on the curriculum as a node in a knowledge ecosystem—not as a fixed structure, but as a living, evolving system. By advancing curriculum theory from static architectures to dynamic processes, we move closer to realizing a higher education system that is more adaptive, inclusive, and creatively responsive to the complexities of our time.

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*Note: Figure translations are in progress. See original paper for figures.*