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Research on the Dynamic Adjustment Mechanism of Undergraduate Programs from the Perspective of Complex Adaptive Systems

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Abstract: The theory of complex adaptive systems emphasizes the interactions between adaptive agents and their external environment, offering new approaches for establishing dynamic adjustment mechanisms in undergraduate programs. The behavioral choices and interactions among adaptive entities—including governments, universities, markets, teachers, and students—create characteristics of aggregation, diversity, nonlinearity, and "flow" in these adjustment mechanisms, influenced by modular mechanisms, labeling mechanisms, and internal modeling mechanisms. Through nonlinear interactions, these entities spontaneously evolve into organizational systems with information processing and proactive response capabilities. Therefore, building a dynamic adjustment mechanism for undergraduate programs requires respecting diverse needs of multiple stakeholders, shifting from administrative dominance to agent collaboration, creating digital communication platforms, transitioning from "precise prediction" to "agile adaptation," and establishing feedback and continuous improvement systems.

Keywords: Complex Adaptive System; Undergraduate Major; Multi-Agent; Dynamic Adjustment

The dynamic adjustment of academic disciplines is an essential requirement for higher education's comprehensive supply-side structural reform during its universalization phase, aiming to build a high-quality higher education system that supports China's modernization drive. In February 2023, the Ministry of Education and four other departments jointly issued the "Reform Plan for Adjusting and Optimizing Academic Disciplines in Regular Higher Education," which explicitly requires "establishing new disciplines aligned with emerging technologies, industries, business models, and operational modes while phasing out outdated programs that fail to meet socio-economic development needs" [1]. Under this policy guidance, from 2014 to 2024, China's undergraduate programs underwent annual adjustments averaging 5%, resulting in nearly 28,000 program restructurings. During this period, 19,966 new undergraduate programs were established, while 5,290 programs were either revoked or discontinued.According to the data released by the Ministry of Education in March 2024, the adjustment of undergraduate majors involved 3,389 major distribution points, which was the largest in history [2].

China's current dynamic adjustment of academic programs reveals several issues: universities either blindly proliferate similar majors or abruptly phase out specific disciplines. There persists a "new bottles for old wine" phenomenon, where newly restructured programs still rely on outdated faculty teams, training methods, and curriculum resources. University program adjustments consistently lag behind economic development and industrial restructuring. Institutions must proactively establish adaptive adjustment mechanisms to align with economic changes [3].

In recent years, research on dynamic adjustment mechanisms for undergraduate programs in higher education has primarily focused on three categories: First, studies examining program adjustments through the lens of policy evolution [4]; Second, analyses of talent cultivation dynamics within specific disciplines such as Education [5]; Third, investigations into program modifications from perspectives of human capital development and social benefits [6].Existing research has predominantly focused on a single perspective, neglecting dynamic adjustments in complex scenarios. Building upon the application of Complex Adaptive Systems Theory (CAS) across various fields, this study adopts a CAS-based systems thinking approach to examine dynamic adjustments in university undergraduate programs. By exploring the underlying mechanisms of such adjustments, it breaks away from traditional single-perspective approaches and establishes a new methodology that comprehensively reveals the intrinsic connections of program adjustments from micro to macro levels. This research provides scientific theoretical foundations and practical guidance for optimizing academic disciplines in higher education institutions.

1 Dynamic adjustment of undergraduate majors as complex adaptive systems

1.1Overview of CAS

The concept of CAS was formally proposed in 1994 by Professor John Holland at the Santa Fe Institute in the United States. This theory encompasses seven key concepts: aggregation, nonlinearity, flow, diversity and identification, internal models, and three mechanisms (building blocks). Adaptive agents within complex systems follow a "stimulus —— response" model, exchanging information and energy with other adaptive entities under environmental stimuli. Through adaptive behaviors such as information processing, experiential learning, and rule adjustment, these agents continuously optimize their behavioral strategies. Such micro-level nonlinear interactions, through multi-layered and multidimensional coupling effects, ultimately give rise to macro-system characteristics including self-organization evolution, dynamic equilibrium, and creative mutations [7].

CAS emphasizes examining the behavioral patterns of micro-level adaptive agents to reveal the formation pathways and structural mechanisms of macroscopic systems. This approach transforms human understanding of complex phenomena from static "structural analysis" to dynamic "evolutionary generation," not only bridging microscopic behaviors with macroscopic complexity but also deepening our comprehension of the inherent logic within complex systems. The framework provides a systematic analytical approach that illuminates these intricate interactions.

1.2 Interpret the appropriateness of undergraduate major adjustment from the perspective of CAS

The core concept of CAS (Complex Adaptive System) is that adaptability generates complexity, emphasizing the interactions between adaptive agents and their external environment, thereby creating evolutionary dynamics [7]. CAS is applicable to multidisciplinary explorations of complex systems, initially widely used to analyze complex mechanisms in political and social systems. As scholars increasingly recognize the complexity of interactions between micro-level individual behaviors and macro-level policies in educational systems, this theory has now been applied to analyze various phenomena in education.For example, CAS perspective focuses on regional higher education integration, which provides a new perspective and analytical framework for understanding its practical difficulties and solutions [8]; CAS is used to build a dynamic governance mechanism to solve the governance difficulties of higher education [9].To be specific, first of all, the adjustment of undergraduate majors involves multiple adaptive subjects. The adjustment of undergraduate majors is an organic system including government, universities, market, teachers, students and other diverse subjects as well as institutional rules.The government acts as the policymaker and macro-regulator for academic program adjustments, influencing universities 'restructuring decisions through policy guidance, program approval processes, and professional evaluations. Higher education institutions serve as the primary implementers of these changes, yet their implementation remains profoundly shaped by faculty-student interactions. Academic disciplines constitute both scholars' professional identities and career anchors – some actively embrace reforms while others resist or dilute them. Students make major selection decisions based on limited information including personal interests, employment prospects, and social prestige [10].Adaptive entities dynamically coordinate and adapt to each other, fulfilling the foundational requirements of CAS components. These adaptive entities—individuals or units with perception, decision-making, and learning capabilities—align perfectly with CAS systems where multiple stakeholders autonomously organize into behavioral response patterns and information processing mechanisms. Secondly, professional adjustments exhibit emergent properties. Emergence refers to how micro-level entities interacting under relatively simple rules spontaneously generate new, complex patterns or attributes at macro levels. Such novel patterns cannot be predicted through simplistic aggregation of micro-level behaviors. University program adjustments are not precise government or institutional blueprints; they emerge from the interactions between millions of students, parents, universities, and government policies. This process gives rise to both popular majors and unpopular "pit" programs, as well as universities rushing to add new majors or revoke existing ones.

2 Complex adaptation characteristics of dynamic adjustment of undergraduate majors

2.1Agglomeration characteristics

Agglomeration characteristics stem from interactions between entities and their outcomes. The embryonic form of specialized education and higher education institutions originated from medieval chamber of commerce organizers who formed communities based on shared objectives. As society evolved, these groups gradually developed into academic institutions with distinctive professional education features [11]. Building upon this agglomeration within universities, stakeholders including governments, educational institutions, and market entities that align with professional adjustments have collectively created an agglomeration effect.

Higher education institutions conduct comprehensive evaluations of their academic program design and talent development practices, then provide statistical findings to government agencies, market entities, and other stakeholders. After gaining insights into the evolving needs and challenges within academic programs, these external parties offer resource support while simultaneously sending feedback to universities to drive further improvements. This collaborative process ultimately establishes an organic ecosystem characterized by dynamic communication and continuous self-renewal.

2.2 Flow characteristics

Flow refers to the channels of interaction and communication among entities, where the concept vividly illustrates the dynamic process of resource movement between subjects. In CAS (China's Academic and Scientific Community), a flow structure integrating nodes, connectors, and resources exists, with resources encompassing material flow, energy flow, and information flow. Government agencies, universities, markets, and faculty/students each represent nodes within this system. The continuous circulation of materials, information, and energy across these nodes forms a dynamic equilibrium, enabling efficient adjustments in university programs. Within the dynamic adjustment mechanism for undergraduate majors, information technology plays a crucial bridging role. For instance, policy updates, teaching materials, and employment information circulate continuously among the four major nodes [12].

In the process of academic program restructuring, material flow forms the foundation. This includes laboratory equipment, internship facilities, textbooks, and teaching materials for target disciplines. Information flow refers to the transmission of data between entities. The government guides universities in dynamically adjusting undergraduate programs through policy directives and official notices, while media serves as an information conduit by publishing rankings, career trends, and market demands. Notably, Zhang Xuefeng's online posts caused the average minimum admission scores for journalism and communication majors to drop by 15% [13]. Energy flow acts as an invisible driving force for program optimization, facilitated by institutional reforms such as government funding and flexible enrollment policies that enhance educational efficiency [12].

2.3 Diversity features

Diversity refers to the internal transformation and proactive adaptability within a system. Driven by market-oriented policies and digital technologies, the higher education system is undergoing unprecedented changes. Universities must proactively evolve by adjusting academic programs through measures like program additions, reductions, and interdisciplinary integration, ensuring their alignment with contemporary societal needs and technological advancements.

The continuous adjustments in undergraduate programs at universities are achieved through constant adaptation between existing disciplinary foundations and emerging demands. Diversity manifests in three aspects: changes in form, content, and structure. Content-related transformations involve updates and modifications to theoretical frameworks and practical systems. Structural changes include interdisciplinary integration, cross-disciplinary convergence, micro-specializations, and the development of comprehensive discipline-integrated programs. Form-oriented adaptations encompass shifts between experimental and theoretical courses, innovations in educational models, and transitions between academic and professional orientations. By strategically implementing differentiated adjustment strategies based on institutional positioning, external policies, and market needs, universities effectively promote diversified program development.

2.4 Nonlinear characteristics

During the process of academic discipline restructuring, the involvement of multiple stakeholders (government, universities, faculty, and students) and massive information exchange result in evolving role definitions, functional contributions, and deep environmental interactions. As these entities act, they accumulate experience that enables strategic adjustments to their behavioral paradigms and knowledge frameworks, enabling flexible adaptation to changing external challenges. The interactions among stakeholders are not simple cause-effect relationships but nonlinear processes, making the final outcomes of disciplinary restructuring difficult to predict. New policies interact with existing institutional rules, diverse stakeholders, and informal norms in complex, nonlinear ways, generating unpredictable "side effects" and "resistance". For instance, after the Ministry of Education proposed the goal to "optimize and adjust approximately 20% of university academic disciplines by 2025", some program adjustments and cancellations faced resistance from faculty members. In the power struggle between academic autonomy and administrative authority, certain programs continued enrollment and teaching through experimental class formats.

3 The complex adaptation mechanism of dynamic adjustment of undergraduate majors

3.1 Identification mechanism

The essence of institutional branding lies in its distinctive identity and unique attributes that set it apart from other academic entities. Like a strategic banner, this brand carries forward-looking vision and serves as a guiding force. As universities optimize their undergraduate programs, they must proactively adapt to evolving trends and market demands. By establishing innovative and forward-looking "branding" disciplines, institutions can drive comprehensive quality enhancement and ensure sustainable development in education.

The dynamic adjustment mechanism for undergraduate programs should emphasize distinctive characteristics in discipline development, avoiding blind trend-following or homogenization tendencies. This approach highlights unique institutional identities and promotes differentiated development strategies, thereby supporting the establishment of universities with distinct features. In the 1980s, Beijing Union University's College of Applied Arts and Sciences pioneered the "Applied Historiography" program reform concept, transforming traditional history disciplines into specialized programs in cultural heritage and museology. The "Applied Historiography" program has been recognized as a hallmark of Beijing Union University's distinctive development in liberal arts education.

3.2 Building block mechanism

The "building block" mechanism organizes university undergraduate programs into modular structures, akin to interlocking components. These flexible building blocks enable institutions to adapt their academic frameworks and operational behaviors in response to policy shifts and market demands. Within the CAS (Chinese Academy of Sciences) system, individual disciplines—including curriculum resources, educational systems, and faculty teams—function as modular units [14]. At the institutional level, synergistic interactions emerge among government funding, academic governance, market dynamics, and faculty-student relationships. Through strategic combinations and dynamic interactions, these building blocks collectively shape each university's distinctive educational architecture and academic identity.

The modular components within academic disciplines require adaptive adjustments based on market demands, disciplinary trends, and student interests. These components do not simply stack together during program restructuring, as this process involves high complexity and uncertainty, necessitating flexible adjustment strategies [15]. Through mutual interactions and adaptive adjustments among these components, new professional trends emerge. Such evolutionary phenomena may manifest through novel program designations, exemplified by the proliferation of digital technology in the job market, which has driven universities to establish specialized programs like online publishing and new media communication.

3.3 Internal model mechanism

The internal model mechanism of CAS can be abstracted into the "stimulus —— response" model in psychology, which explains the behavioral process of subjects in processing external information inputs and demonstrates their fundamental attributes of self-adjustment and

adaptation. This model consists of three elements: detectors, rule sets, and effectors. The process of university program adjustments essentially represents a continuous transformation in response to changes in external policy environments and market demands [8].

The internal model mechanism of higher education program adjustments under the CAS perspective comprises three key aspects: First, detector perception and response. Universities monitor external changes through government announcements and market research. As an educational institution dedicated to cultivating talents for society, maintaining constant awareness and sensitivity to environmental shifts is essential. Second, rule set learning and adaptation. Undergraduate programs continuously learn and accumulate experience through interactions with their environment, demonstrated not only in information absorption and processing but also in developing adaptive mechanisms for similar information. Third, effector response mechanism. The critical step in program adjustment lies in responding during external exchanges, enabling subsequent entities to better capture signals and activate their "stimulus-response" models, thereby forming a complete organic system.

4 Conclusion and Outlook

With the rapid development of science and technology and ever-changing social demands, various factors force colleges and universities to actively adjust, reform and innovate their disciplines. Based on CAS, the following reform measures are proposed to build a more flexible and efficient professional adjustment mechanism.

4.1Respecting the diverse needs of multiple subjects, "administrative leadership" to "subject collaboration"

From the CAS perspective, the adjustment of undergraduate majors in higher education constitutes a complex ecosystem with long-term and constructive characteristics, involving multiple elements and hierarchical levels. Key stakeholders including governments, universities, market forces, and faculty/students dynamically adapt to promote efficient adjustments under the common goal of promoting dynamic major optimization. The primary objective of this adjustment process is to clarify the ecological niches occupied by governments, universities, and market entities, leveraging their respective strengths while moving beyond the previous single-dimensional administrative dominance. Guided by a collaborative mechanism that addresses diverse stakeholder needs, the adjustment process achieves dynamic equilibrium among all parties, optimizing internal structural frameworks and enhancing the efficiency of communication and collaboration mechanisms through digitalization.

The ideal state of subject synergy lies in clear division of responsibilities: the government acts as the macro-regulatory authority formulating policies, universities serve as autonomous adjustment entities implementing program reforms, students function as self-driven demand subjects, and the market serves as the regulatory mechanism. All parties achieve survival and development through dynamic equilibrium and mutual adaptation to environmental changes. Each entity leverages its unique strengths, fully utilizes existing resources, respects the laws of higher education, considers faculty and student development needs, and continuously improves the professional adjustment mechanism.

4.2 Promote the circulation of information resources among all parties, and shift from "precise prediction" to "agile adaptation"

CAS posits that the continuous exchange of information and energy among key stakeholders forms the internal driving force behind dynamic adjustments in undergraduate academic programs. The current adjustment process faces obstacles due to insufficient communication channels between universities, market entities, and students, as well as significant information asymmetry regarding actual market demands for talent quality, type, and level. Effective information aggregation, flow, and sharing are crucial elements for improving the dynamic adjustment mechanism. Systematizing information presentation serves as a bridge facilitating multi-stakeholder interactions. By leveraging government agencies and IT companies to introduce technological solutions, we can establish collaborative platforms that ensure all adaptive stakeholders receive timely feedback and evaluations from others [16].

CAS maintains that the operational mechanism fundamentally functions through information transmission and execution. This process involves effective information acquisition, decision-making based on relevant data, and feedback mechanisms, which should facilitate resource flow and information circulation while addressing issues like information gaps and uneven resource distribution. By integrating

multi-source information from government agencies, universities, employment markets, and graduate tracking surveys, we aim to comprehensively cover critical areas including policy updates, educational management, student development, labor market trends, and industrial evolution. This will establish a data-driven, adaptable framework featuring flexible training models such as "specialization + micro-specialization" and "major + minor" programs. These innovations expand students' academic choices while implementing dynamic program adjustment mechanisms.

4.3 Actively respond to internal and external environmental factors, establish feedback evaluation and continuous improvement mechanism

To achieve dynamic adjustments in undergraduate programs, it is essential to establish a continuous improvement and feedback evaluation mechanism. This ensures all stakeholders can reasonably express their demands and suggestions, which are promptly received by other parties. Through the "stimulus——response" mechanism, targeted action strategies can be formulated to collectively advance the program adjustment process. Simultaneously, the existing rigid evaluation system must be dismantled, emphasizing a combination of diversified and long-term evaluations. University program adjustments have no "completion date" – we must abandon linear thinking like "one-size-fits-all" or "permanent solutions", instead aligning with policy directions and social needs for continuous development. For instance, establishing close industry-academia collaboration by inviting experts to participate in program establishment, revocation reviews, and talent cultivation plan formulation; creating long-term graduate tracking systems that effectively integrate employment quality and career development feedback into curriculum optimization. Modern information technology greatly facilitates data transmission. Leveraging the advantages of digital platforms, all stakeholders within the program adjustment mechanism can also engage in self-renewal and learning, thereby building and refining a dynamic undergraduate program adjustment framework in higher education institutions.

5 Conclusion

The adjustment mechanism for undergraduate programs in higher education is neither a simple government-led initiative nor purely market-driven. It should be viewed as a complex system involving multiple stakeholders ——the government, universities, market forces, and faculty-student communities-all engaged in dynamic interplay. Rather than passively following directives, these entities proactively adapt strategies to environmental changes. Examples include universities expanding popular majors, students voting with their feet through course selection preferences, and faculty adapting to new disciplinary demands. These adaptive behaviors collectively drive systemic adjustments through information flow, resource reallocation, and feedback mechanisms. From the CAS perspective, this framework not only provides a theoretical foundation for understanding program adjustments but also offers actionable strategies. By respecting the adaptability of system participants and integrating digital technologies to design multi-stakeholder collaborative mechanisms, we can stimulate bottom-up innovation. This establishes a dynamic adjustment mechanism for academic programs that ultimately achieves the educational goal of cultivating virtue and talent. Through aligning program offerings with talent development needs and keeping pace with the times, it enables universities to nurture high-caliber professionals who meet contemporary demands.

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