

Article

Not peer-reviewed version

Theory, Technology and Teaching Exploration of Curriculum Chains

[Peng Liu](#)^{*}, [Xuhui Zhang](#), [Xiangang Cao](#), [Xuechao Duan](#), Qiao Xinzhou

Posted Date: 27 October 2023

doi: 10.20944/preprints202310.1812.v1

Keywords: social needs; curriculum chains; curriculum energy efficiency space; student ability space; dynamic evolution; control



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

Theory, Technology and Teaching Exploration of Curriculum Chains

Peng Liu ^{1,2,*} Xuhui Zhang ¹, Xiangang Cao ¹, Xuechao Duan ² and Qiao Xinzhou ¹

¹ Shaanxi Key Laboratory of Mine Electromechanical Equipment Intelligent Detection and Control, Xi'an University of Science and Technology, Xi'an 710054, China; liupeng@xust.edu.cn (P.L.); zhangxh@xust.edu.cn (X.Z.); caoxg@xust.edu.cn (X.C.); qiaoxinzhou@xust.edu.cn (X.Q.)

² Key Laboratory of Ministry of Education for Electronic Equipment Structure Design, Xidian University, Xi'an 710000, China; xchduan@xidian.edu.cn (X.D.)

* Correspondence: liupeng@xust.edu.cn;

Abstract: Curriculum teaching is the basic unit to realize the cultivation and achievement of students' ability in undergraduate colleges, and it is very important to investigate the influence mechanism of the curriculum system on the achievement states of students' ability. This paper first puts forward the theoretical system and framework of curriculum chains, and constructs a "double-energy and double-space" (DEDS) which consist of the curriculum energy efficiency space and student ability space respectively. Investigating the space-time transformation relationship of curriculum chains in the DEDS, the forward transformation model, inverse transformation model and the rheological model of the achievement states in the curriculum energy efficiency space and student ability space are established. Studying the dynamic evolution mechanism of curriculum chains within the DEDS, the dynamic evolution model, which presents the relationship between achievement states of curriculum energy efficiency/students' ability and curriculum/students' dynamic potential, are established; the control methods of courses/students' dynamic potential based on the proposed dynamic evolution model are developed to ensure the achievements of the graduates' social ability; the evaluation and detection methods of achievement states of curriculum chains in DEDS are proposed to obtain the actual achievement states of curriculum energy efficiency and students' ability, and this will provide effective input for the control of curriculums/students' dynamic potential; the planning and design methods of curriculum chains facing social needs are presented, which can provide theoretical basis for the formulation of the talent training scheme and curriculum system in colleges and universities.

Keywords: social needs; curriculum chains; curriculum energy efficiency space; student ability space; dynamic evolution; control

1. Introduction

Advanced undergraduate teaching plays the role for cultivating applied talents in universities under the background of new engineering, and it is also an important highland for cultivating talents. Undergraduate teaching is mainly composed of course teaching, experimental teaching and practical teaching. Among them, the course teaching is the basic unit to realize the training and achievement of students' abilities, and there is a certain sequence and continuity among the courses. Generally speaking, from the point of view of teaching time, general education courses are firstly taught, and then professional education courses are taught. Many courses with time sequence and continuity constitute the curriculum system [1–3], and students can achieve the expected abilities to meet social needs through studying the curriculum system, so it is very important to investigate the influence mechanism of the curriculum system on the achievements of students' abilities. Facing the social needs, the national higher education vigorously implements the OBE education concept [4–9] to realize the graduates' abilities meeting the social needs. The social demands for graduates' abilities is multidimensional (12-dimensional ability for professional certification of engineering education), and each course of the curriculum system, in fact, contributes to certain dimensions of students' abilities, such as integrating ideological and political elements into the course teaching process

[10,11]. The course teaching process can adopt diversified ways and means, such as the integration of competition and teaching [12], the combination of virtuality and reality [13], and the online and offline mixed teaching [14–17]. However, there are some key issues in the teaching process of higher education, such as how to determine the required graduates' abilities of higher education and formulate a complete curriculum system, how the curriculum system affects the graduates' abilities, how the curriculum/student's dynamic potential affects the curriculum/student's achievement states, how to control the dynamic potential of curriculum/student to obtain the achievement states meeting the requirements, how to evaluate and measure the achievement states. However, there, as far as the authors concerned, is no report on the quantitative model between the achievements of curriculum energy efficiency and students' abilities.

Generally speaking, colleges and universities have formulated training objectives and training programs for their respective majors according to the presented talent training objectives of colleges and universities, and formulated a systematic and complete curriculum system to promote the achievement of graduates' abilities. There is a coupling relationship between each course in the training scheme and curriculum system, and the curriculum system, in fact, can be simplified as a typical series system. The curriculum system determines the achievement states of students' abilities when they graduate, and plays a vital role in cultivating students' comprehensive literacy and application abilities. At present, in the teaching process of higher undergraduate courses, the problems have not been well solved, such as how the teaching effect of the preceding courses affect the teaching practice of the succeeding courses, whether the teaching practices of the succeeding courses can strengthen the achievements of the preceding courses, and whether the temporal and sequential distribution of courses is reasonable. Therefore, this paper innovatively puts forward the theoretical system and structure of curriculum chains, and proposes the DEDA consisting of curriculum energy efficiency space and student ability space. And moreover, this work reveals the space-time transformation relationship of curriculum chains, and establishes the space-time transformation and rheological model of curriculum chains. With regard to curriculum energy efficiency space, the curriculum teaching is the basic unit of curriculum energy efficiency space, and the achievement states of curriculum energy efficiency (achievement trajectory, achievement speed and achievement acceleration) directly depends on the curriculum dynamic potential (teaching content and methods, students' learning input and initiative, etc.); while with respect to student ability space, the achievement states of students' abilities (achievement trajectory, achievement speed and achievement acceleration) directly depends on students' dynamic potential (students can contribute to the society or the social needs for graduates). And the curriculum dynamic potential has a decisive influence on the students' dynamic potential. Therefore, investigating the relationship between the curriculum teaching and the achievements of students' abilities, this paper innovatively puts forward the concepts of curriculum energy efficiency/students' ability achievement states and curriculum/students' dynamic potential, reveals the dynamic evolution mechanism of curriculum chains within DEDS and establishes the dynamic evolution model of curriculum chains.

Undergraduate colleges and their majors have formulated a relatively complete talent training scheme and curriculum system according to the social expectation and demand (achievement states students' abilities), and rely on certain curriculum/student dynamic potential to ensure that students can achieve the abilities to engage in social work when they graduate. However, with the rapid development of society, the social demands for graduates' abilities will change to some extent. Therefore, it is very important that how to control the curriculums/students' dynamic potential to narrow the deviation between the actual achievement states of students' abilities and the social demands so as to achieve the expected social demands (the achievement states of students' abilities). To the best of the author's knowledge, no previous work on curriculum chains has discussed the control of the curriculums/students' dynamic potential. Therefore, this paper proposes a control method of the curriculums/students' dynamic potential based on the dynamic evolution model in the DEDS. Through the adjustment of course dynamic potential, the deviation between the actual achievement states and the expected achievement states of course energy efficiency/students' ability can be reduced, and finally the graduates' abilities meeting social demand can be ensured.

In order to control the dynamic potential of the curriculum/student, it is necessary to evaluate and detect the actual achievement states of curriculum energy efficiency/students' abilities. Nevertheless, the study on the evaluation and testing method of actual achievement states for curriculum energy efficiency/students' ability, to the finest of the authors' knowledge, isn't considered in past investigates. Therefore, this paper puts forward the evaluation and detection method of the achievement states for curriculum chain in the DEDS to obtain the actual achievement states of curriculum energy efficiency/students' abilities and provide effective input for the curriculums/students' dynamic potential.

The training of talents in colleges and universities is oriented to the social demands and the output of achievements, meanwhile the social demands put forward strict requirements for the graduates' abilities. But for every student, social needs are a series of specific jobs. It is very important for cultivating high-level talents meeting social needs to establish a quantitative relationship between social needs and students' abilities in colleges and universities, and to plan and design a reasonable talent training scheme and a strict curriculum chain. To our knowledge, there is no work has been proposed for investigating the relationship between social needs and students' abilities. Therefore, this paper presents the planning and design method of curriculum chains facing social needs, which can provide theoretical guidance for the formulation of talent training scheme and curriculum system in colleges and universities.

To sum up, inspired by the theory, technology and application of industrial robots [18–21], this paper first puts forward the theoretical concept and basic configuration of curriculum chains (Figure 1), deeply studies the influence mechanism of curriculum chains on the achievement states of students' abilities, and constructs the DEDA including the curriculum energy efficiency space and student ability space. This paper discusses the relationship and model of space-time transformation of the proposed spaces, the dynamic evolution mechanism and model of curriculum chains in the DEDA, the dynamic control method of curriculums/students' dynamic potential based on the proposed dynamic evolution model, the evaluation and detection method of the achievement states in the DEDA, and the planning and design method of curriculum chains facing social needs. The key scientific problems, such as the dynamic coupling mechanism of between adjacent courses of curriculum chains, the influence mechanism of social time-varying demands on talent training scheme and curriculum chain configuration, are presented; and the key technical problems, such as the dynamic modeling technology of curriculum chains and the evaluation and detection technology of the achievement states within DEDA employing the multi-means and multi-information fusion, are put forward in this paper. The research in this paper can provide theoretical basis and practical guidance for the planning and design of the curriculum system, controlling the achievement states of students' abilities and course efficiency, and the evaluation method of achievement states of course efficiency and students' abilities, which is helpful to comprehensively improve students' comprehensive literacy and abilities to adapt to society and lay a solid theoretical foundation for cultivating high-level academic talents.

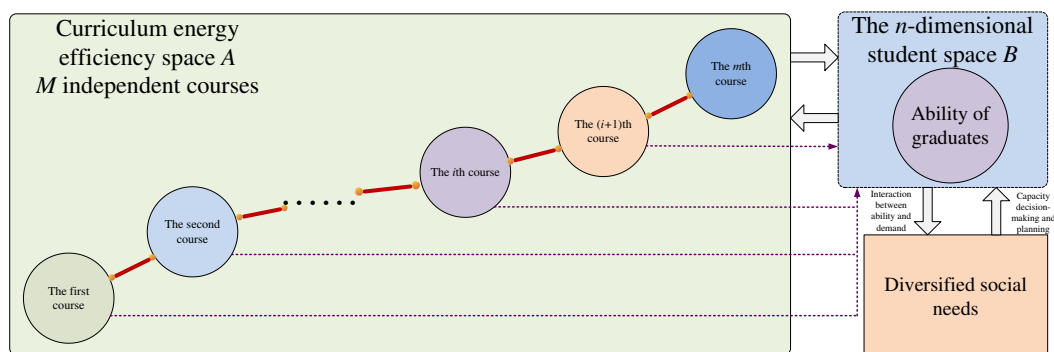


Figure 1. Concept and basic configuration of curriculum chains.

2. Theoretical system and overall framework of curriculum chains

The time-varying society needs put forward higher requirements for the graduates' abilities, and the achievement states of graduates' abilities mainly depends on the achievement of curriculum objectives. Curriculum teaching is the basic unit to realize the cultivation and achievement of students' abilities, and it is very important to report the influence mechanism of curriculum chains on the achievement of students' abilities. The theoretical system and overall framework of curriculum chains are shown in Figure 2.

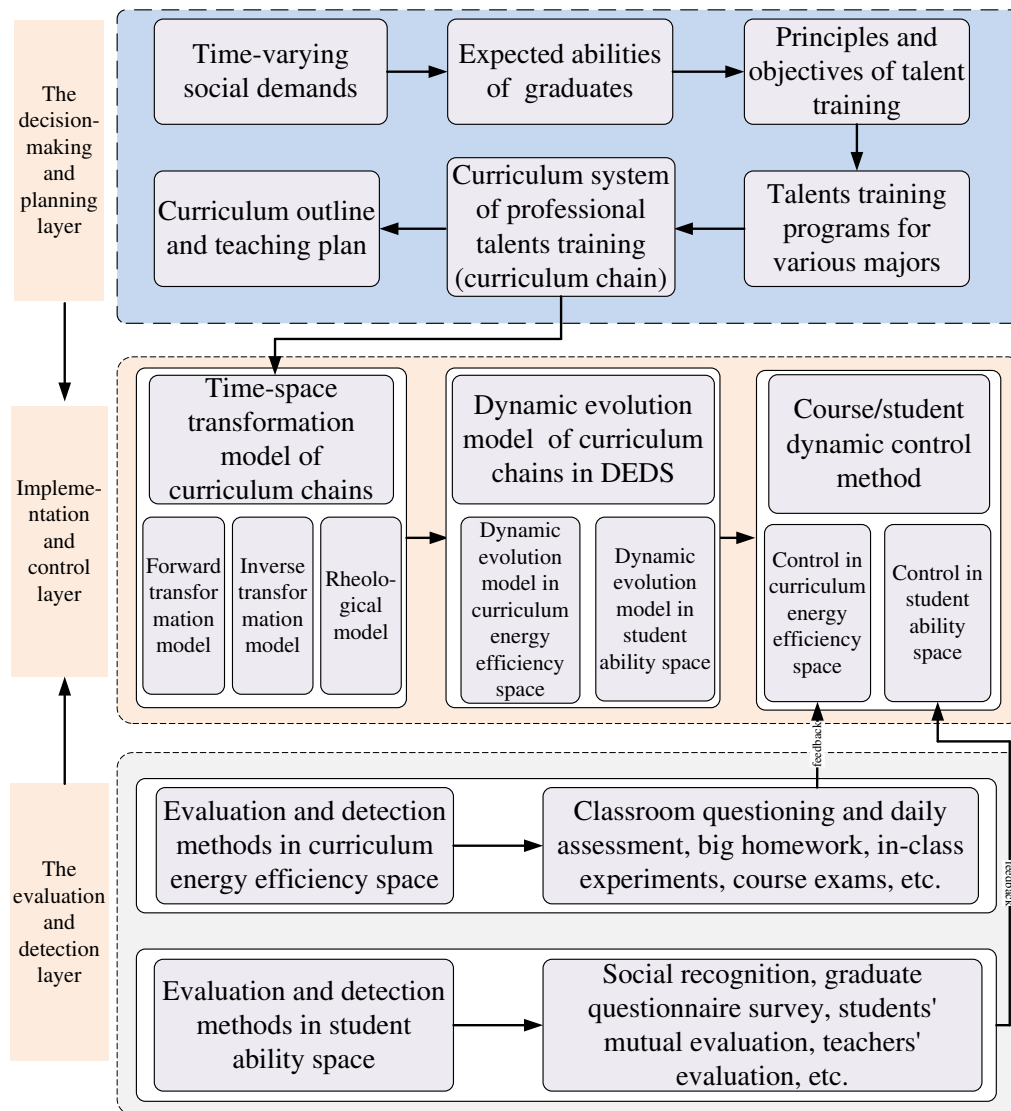


Figure 2. Theoretical system and overall framework of curriculum chains.

3. The main research content and technical scheme

There are some factual issues in undergraduate teaching that the relationship between the achievements of graduates' abilities complying with social expectation and the configuration of curriculum chains is unclear, leading to the lack of graduates' abilities. In this paper, a new concept, curriculum chains, is established. And moreover, the influence mechanism of curriculum chains on the achievement of students' abilities is deeply investigated, and the DEDES including the curriculum energy efficiency space and students' ability space is constructed, further forming the core theory, method and key technology of curriculum chains. The main research content and technical scheme of curriculum chains are shown in Figure 3.

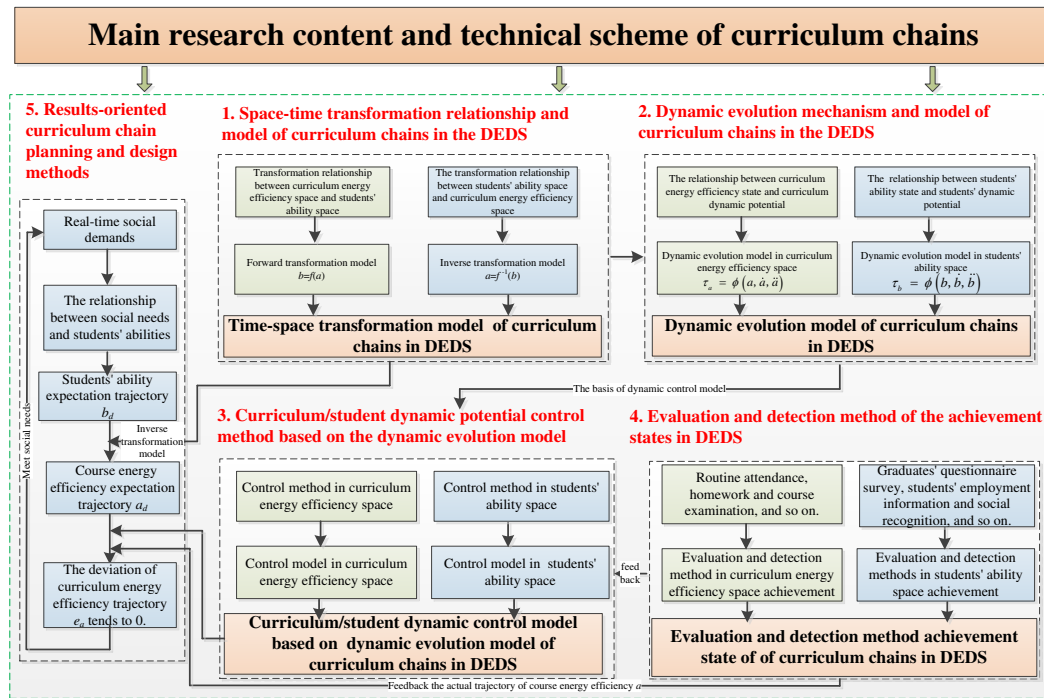


Figure 3. Main research content and technical scheme of curriculum chains.

3.1. Time-space transformation relationship and model of curriculum chains in the DEES

As mentioned above, there is a coupling relationship between the courses in the teaching and training program and the curriculum system for colleges and universities, which can be simplified as a series system, and the courses determine the achievement states of students' abilities. In this paper, the curriculum system with the relationship between predecessor and successor is defined as curriculum chains, and the space formed by each course is called the curriculum energy efficiency space denoted by A . For example, the curriculum chains of the training program for the major of mechanical and electronic engineering in the school of mechanical engineering of Xi'an University of Science and Technology includes the basic principles of Marxism, an introduction to Mao Zedong Thought, advanced mathematics, physics and other courses. The social expectations and requirements for students' abilities are multidimensional, and the multidimensional ability space that students can achieve when they graduate is called student ability space denoted by B in this paper. For example, the requirements for the achievements of students' abilities proposed by engineering education professional certification include 12 dimensions [22–24], such as engineering knowledge, problem analysis, design/development solutions, research, use of modern tools, engineering and society, environment and sustainable development, professional norms, individuals and teams, communication, project management and lifelong learning.

For the curriculum energy efficiency space A , there is an interaction between the two adjacent courses of curriculum chains. This paper proposes to describe the relationship by using the curriculum correlation transformation matrix, and it can be expressed as follows:

$$X_{i+1} = T_i^{i+1} X_i, i = 1, 2, \dots, m \quad (1)$$

in which, the vectors X_i and X_{i+1} represent the energy efficiency achievement trajectories the i th course and the $(i+1)$ th course respectively; T_i^{i+1} represents the correlation transformation matrix from the i th course to the $(i+1)$ th course of course chains; m is the number of independent courses of curriculum chains in energy efficiency space.

The achievement states of students' abilities depend on the achievement states of energy efficiency of each course, and the achievement states of each course of course chains jointly determine

the abilities that students can achieve when they graduate. This paper puts forward a positive transformation model from the achievement trajectory of course energy efficiency space to the achievement trajectory of student ability space, which can be expressed as follows:

$$\mathbf{b} = f(\mathbf{a}) \quad (2)$$

where the vector $\mathbf{a} \in \mathbb{R}^{m \times 1}$ represents the achievement trajectory of course energy efficiency, while the vector $\mathbf{b} \in \mathbb{R}^{n \times 1}$ represents the achievement trajectory of students' abilities; m is the number of independent courses in curriculum chain in energy efficiency space, and n is the dimension of student ability space; f represents the mapping function from the curriculum energy efficiency space to the student ability space.

In order to meet the needs of society, students must have certain personal qualities and abilities when they graduate, and the cultivation and formation of the abilities must rely on curriculum chains. Therefore, in order to achieve students' expected abilities, the achievement status of each course of course chains must meet certain requirements. This paper puts forward an inverse transformation model from the achievement trajectory of student ability space to the achievement trajectory of course energy efficiency space, which can be expressed as follows:

$$\mathbf{a} = f^{-1}(\mathbf{b}) \quad (3)$$

At the same time, the energy efficiency achievement speed of each course in the curriculum energy efficiency space will have an important impact on the achievement speed of students' abilities in the student ability space. Taking the derivative of time on both sides of Eq. (2), the quantitative relationship between them can be expressed as follows:

$$\dot{\mathbf{a}} = \frac{df^{-1}}{dt} \dot{\mathbf{b}} = \mathbf{J}(\mathbf{b}) \dot{\mathbf{b}} \quad (4)$$

where $\dot{\mathbf{a}} \in \mathbb{R}^{m \times 1}$ represents the achievement speed of the curriculum energy efficiency; $\dot{\mathbf{b}} \in \mathbb{R}^{n \times 1}$ denotes the achievement speed of students' abilities; $\mathbf{J}(\mathbf{b})$ denotes the Jacobian matrix of achievement speed, which represents the achievement speed ratio from the curriculum energy efficiency space to the student ability space.

3.2. Dynamic evolution mechanism and model of curriculum chains

With regard to the curriculum energy efficiency space A , the achievement states of curriculum energy efficiency directly depend on the curriculum dynamic potential, and the quantitative relationship between them is defined as the dynamic evolution model within the proposed curriculum energy efficiency space, and it can be expressed as:

$$\tau_a = \phi(\mathbf{a}, \dot{\mathbf{a}}, \ddot{\mathbf{a}}) \quad (5)$$

where \mathbf{a} represents the achievement trajectory of the course energy efficiency; $\dot{\mathbf{a}}$ indicates the achievement speed; $\ddot{\mathbf{a}}$ indicates the achievement acceleration; τ_a indicates the dynamic potential of curriculums; ϕ denotes the mapping function from the achievement states of curriculum energy efficiency space to dynamic potential of curriculums.

While with regard to student ability space B , the achievement states of students' abilities depends directly on students' dynamic potential, and the quantitative relationship between them is defined as the dynamic evolution model in the student ability space, which can be expressed as:

$$\tau_b = \varphi(\mathbf{b}, \dot{\mathbf{b}}, \ddot{\mathbf{b}}) \quad (6)$$

where \mathbf{b} represents the trajectory of the students' abilities; $\dot{\mathbf{b}}$ indicates the achievement speed of the students' abilities; $\ddot{\mathbf{b}}$ indicates the achievement acceleration of students' abilities; τ_b indicates

students' dynamic potential; φ represents the mapping function from the achievement state of the student ability space to students' dynamic potential.

Meanwhile the dynamic potential of curriculums has a decisive influence on the students' dynamic potential, and in more detail, the dynamic potential of curriculums determines the students' dynamic potential. The relationship between them can be expressed as follows:

$$\boldsymbol{\tau}_a = \mathbf{J}^T(\mathbf{b}) \boldsymbol{\tau}_b \quad (7)$$

where $\mathbf{J}^T(\mathbf{b})$ is the transposed matrix of the proposed Jacobian matrix $\mathbf{J}(\mathbf{b})$.

3.3. Proposed control method of course/student dynamic potential

According to the training scheme, each major has formulated curriculum chains to promote the achievement of graduates' abilities. For curriculum energy efficiency space A , the mathematical relationship between the dynamic potential of curriculums and the achievement states in the curriculum energy efficiency space is established using Eq. (5). While for student ability space B , the mathematical relationship between students' dynamic potential and the achievement states in the student ability space is established with Eq. (6).

However, for different students, there is a certain deviation of initial abilities when they enter the school. How to ensure the students' expected abilities when they graduate through the adjustment of curriculums/students' dynamic potential is very important. In view of this, this paper puts forward a control method of the dynamic potential of curriculums to narrow the difference between the actual achievement states and the expected achievement states for curriculum energy efficiency; and while this paper puts forward a control method of students' dynamic potential, so as to narrow the difference between the actual achievement states of students' abilities and expected achievement states.

The achievement trajectory error of course energy efficiency is defined as follows:

$$\mathbf{e}_a = \mathbf{a} - \mathbf{a}_d \quad (8)$$

where \mathbf{a} denotes the achievement trajectory of course energy efficiency; \mathbf{a}_d indicates the expected achievement trajectory of the course energy efficiency.

While the achievement speed error of course energy efficiency is define as follows:

$$\dot{\mathbf{e}}_a = \dot{\mathbf{a}} - \dot{\mathbf{a}}_d \quad (9)$$

In the curriculum energy efficiency space, the goal of control method for the curriculum dynamic potential is to design curriculum dynamic control law $\boldsymbol{\tau}_a$, so that the trajectory error \mathbf{e}_a and speed error $\dot{\mathbf{e}}_a$ reach zero.

In the same way, the achievement trajectory error of students' abilities is defined as follows:

$$\mathbf{e}_b = \mathbf{b} - \mathbf{b}_d \quad (10)$$

where \mathbf{b} denotes the achievement trajectory of the course energy efficiency; while \mathbf{b}_d denotes the expected achievement trajectory.

And moreover, the achievement speed error of students' abilities can be defined as follows:

$$\dot{\mathbf{e}}_b = \dot{\mathbf{b}} - \dot{\mathbf{b}}_d \quad (11)$$

In the student ability space, the goal of the control method for students' dynamic potential is to design the control law of students' dynamic potential $\boldsymbol{\tau}_b$, so that the trajectory error \mathbf{e}_b and the achievement speed of students' abilities $\dot{\mathbf{e}}_b$ tend to zero.

The control scheme of course/student's dynamic potential is shown in Figure 4. Through the analysis of social needs, all majors in colleges and universities determine the various abilities and

their achievement status that students need to have when they face social employment b_d , and obtain the expected trajectory of curriculum space a_d through the proposed inverse transformation model; using the evaluation and detection method in the curriculum energy efficiency space, the actual achievement trajectory in the curriculum energy efficiency space a is obtained, and there is bound to be a deviation e_a between the expected achievement trajectory and the actual achievement trajectory. The linear combination of the deviation generates the control law in the curriculum energy efficiency space τ_a , which is input into the student-classroom dynamic system, and the deviation e_a tends to zero through the presented control law meeting the stability condition.

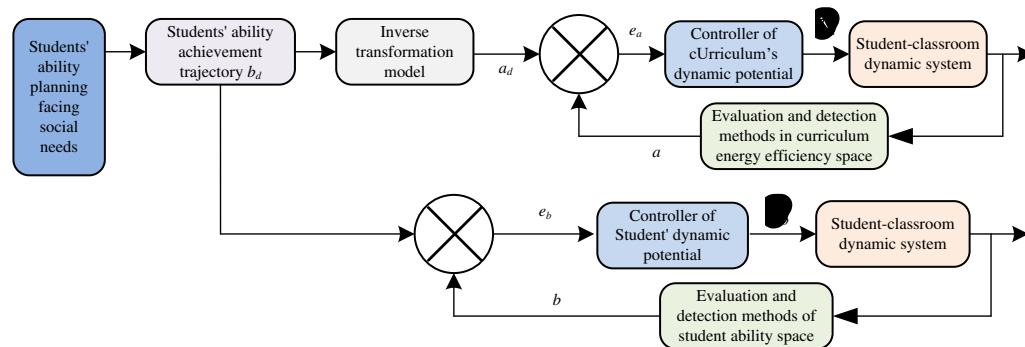


Figure 4. Control scheme of curriculum/student's dynamic potential in the DEDS.

3.4. Evaluation and detection method of achievement states for curriculum chains in DEDS

In order to realize the control of the curriculums/students' dynamic potential based on the proposed dynamic evolution model, it is necessary to evaluate and detect the actual states of curriculum energy efficiency/students' abilities, and provide effective input for the control of the dynamic potential. The evaluation methods and means of achievement states within the curriculum energy efficiency space include daily course assessment, classroom questioning, big homework, mid-term assessment and course examination, and so on. Through the examination of students in each stage of each course, each major dynamically adjusts the dynamic potential of the curriculum to ensure the minimum deviation between the factual achievement trajectory and the expected value for curriculum energy efficiency. While the evaluation methods and means of achievement states in student ability space include students' mutual evaluation, teachers' evaluation, graduates' questionnaire, employers' questionnaire, social recognition and so on. Through the assessment of students' abilities in each stage, each major dynamically adjusts students' dynamic potential to ensure that the minimum deviation between the factual achievement trajectory and the expected value for students' ability.

3.5. Planning and design method of curriculum chains facing social needs

The cultivation of high-level talents is the fundamental mission of colleges and universities, and the achievement and promotion of high-level talents' abilities mainly depends on the course teaching and its achievement. However the time-varying needs of society put forward higher requirements for the graduates' abilities, and in more detail, the time-varying needs of society determine the abilities of talents trained by colleges and universities. The relationship between them can be expressed as follows:

$$\mathbf{b} = g(\mathbf{q}(t)) \quad (12)$$

where the vector \mathbf{q} represents the time-varying needs of society; the vector \mathbf{b} represents the achievement trajectory of students' abilities; the function g represents the transformation relationship between the time-varying needs of society and the achievement trajectory of students' abilities.

4. Key scientific problems and key technical problems

4.1. Key scientific problems of curriculum chains

The curriculum teaching is the basic unit to realize the cultivation and achievement of students' abilities in undergraduate colleges, and it is very important to investigate the influence mechanism of the curriculum system on the achievement of students' abilities. To the best of our knowledge, this is the first time that the theoretical system and framework of curriculum chains are developed. In addition, this is the first time that the DEDS consisting of the curriculum energy efficiency space and student ability space is established. There are, however, many problems concerning the proposed curriculum chains need be solved. For this reason, the key scientific problems of curriculum chains are presented as follows:

(i) The coupling mechanism between adjacent courses of curriculum chains.

Colleges and universities make a complete curriculum chain according to the talent training scheme to promote students' abilities while they graduate through curriculum teaching. The curriculum chain is composed of many courses in series, and there is a coupling relationship between the adjacent courses, which is mainly reflected in the interaction between the dynamic potential and the achievement states. Clarifying the coupling mechanism between adjacent courses can provide an accurate model for the control method of dynamic potential for course/student. Therefore, the coupling mechanism between adjacent courses of curriculum chains is the first key scientific problem to be solved urgently.

(ii) The influence mechanism of time-varying social demands on talent training scheme and curriculum chain configuration.

The goal of talent training in colleges and universities is to educate people for the country and the party. Therefore, it is the fundamental mission of colleges and universities to cultivate high-level talents who can serve social development and progress. The achievement and promotion of high-level talents' abilities mainly depends on curriculum teaching and its achievements. However, with the in-depth development of science and technology, the social needs are diversified and changing rapidly, which poses an unprecedented challenge to the talent training scheme and curriculum chain configuration of colleges and universities. As a result, the influence mechanism of time-varying social demands on the talent training scheme and curriculum chain configuration is another key scientific problem to be solved urgently.

4.2. Key technical problems

And as mentioned above, while the key technical problems of curriculum chains are presented as follows:

(i) Modeling technology of dynamic evolution for curriculum chains in the DEDS.

For a specific major, many courses with the coupling relationship between predecessor and successor form a curriculum chain, and the abilities of graduates can be achieved through the achievements of the expected objectives of the curriculum chains. The dynamic potential of curriculums and students are the power sources of students' ability achievement, which determine the achievement states of curriculum energy efficiency space and students' ability space. In order to realize the control of dynamic potential of the curriculums/students, it is very important to establish the evolutionary relationship between the dynamic potential and achievement states within DEDS for curriculum chains. However, at present, there is a lack of relevant modeling methods and technologies. Therefore, the modeling technology of dynamic evolution for curriculum chains in the DEDS is the first key technical problem in constructing the theoretical system of curriculum chains.

(ii) The evaluation and detection technology of achievement states with multi-means and multi-information fusion.

It is necessary to obtain the achievement status in the curriculum energy efficiency space and student ability space with the help of certain technologies and means, and provide an effective feedback for the control of the dynamic potential for the curriculums/students based on the presented dynamic evolution model. However, at present, there is no effective way to integrate the above

information to obtain the actual achievement states in the DEDES. Therefore, evaluation and detection technology of achievement states with multi-means and multi-information fusion is another key technical problem so as to construct the theoretical system of curriculum chains.

5. Theory Features and Innovations

Facing the new engineering background and engineering education professional certification, deeply investigating the configuration of curriculums and its time-space transformation relationship, the present paper models the teaching process of higher education curriculum as a typical series system-curriculum chain, constructs the DEDES including the curriculum energy efficiency space and student ability space, and explores the influence mechanism of curriculum chains on students ability achievement. In summary, the main contributions of this work include the following aspects:

(i) Proposing the theoretical system and basic framework of curriculum chains, and constructing a DEDES consisting of curriculum energy efficiency space and student ability space, which can be employed to investigate the influence mechanism of curriculum chains on the achievement of students' ability.

(ii) Revealing the space-time transformation relationship of curriculum chains within the proposed DEDES, and establishing the space-time transformation model and rheological model; while revealing the dynamic evolution mechanism of curriculum chains within the proposed DEDES, and establishing the dynamic evolution model in the curriculum energy efficiency/student ability space respectively.

(iii) Developing a control method of dynamic potential within the proposed DEDES, so as to reduce the deviation between the actual achievement states and the expected achievement states of curriculum energy efficiency/students' ability and to ensure the achievements of graduates' social demand abilities.

6. Conclusions

With the in-depth development of science and technology, the time-varying needs of society put forward higher requirements for the graduates' abilities from colleges and universities. Meanwhile curriculum teaching is the basic unit to realize the cultivation and achievement of students' ability, and it is very important to study the influence mechanism of curriculum system on the achievements of students' ability. Facing the background of new engineering and the professional certification of engineering education, this paper firstly models the course teaching process of higher education as a typical series system-course chain by deeply analyzing the course configuration and its time-space relationship. And moreover the paper proposes the theoretical system and framework of course chains and constructs the DEDES including the course energy efficiency space and student ability space. Furthermore, the five main aspects of the theoretical research of course chains are presented, and the key scientific problems and key technical problems of the theoretical research for course chains are reported in this paper. The research of this paper provides theoretical basis and practical guidance for the planning and design of curriculum chains facing the time-varying needs of society, the controlling of the achievements of students' ability and curriculum efficiency, and the evaluation method of the achievement states for curriculum energy efficiency and students' abilities.

In addition, with regard to the proposed curriculum chains, the theory and technology are presented in this paper. However, the practical application of the proposed theory and technology of curriculum chains not obtained. As a result, there are several topics for future work that can be executed in the investigation of the curriculum chains. One possibility is to employ the theory and technology of curriculum chains to a particular major. Another potential area of future work is to plan and generate a curriculum chains meeting social needs for a particular major, such as the major of mechanical and electronic engineering.

Author Contributions: Conceptualization, P.L.; methodology, P.L.; software, P.L.; validation, P.L.; formal analysis, X.C.; investigation, P.L.; resources, X.D.; data curation, X.C.; writing—original draft preparation, P.L.;

writing—review and editing, P.L., X.D., X.Z., X.C. and X.Q.; supervision, X.Z.; project administration, X.C.; and funding acquisition, X.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by special project of “student-centered” teaching reform of Xi’an University of Science and Technology under Grant No. JZ22022 and JZ 22027, and key project of Shaanxi education and teaching reform research project under Grant No. 21BZ040.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon request.

Acknowledgments: In this section, you can acknowledge any support given which is not covered by the author contribution or funding sections. This may include administrative and technical support, or donations in kind (e.g., materials used for experiments).

Conflicts of Interest: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

1. SeoKyoungHye, S.-A. Yu, and 정진영, “An Analysis of the 7th Korean National Elementary School Mathematics Curriculum : Focusing on the Continuity, Sequence, and Integration of Mathematical Content,” *The Journal of Elementary Education*, research-article vol. 16, no. 2, pp. 159-184, 2003 2003.
2. S. Yang, “Analysis on the Continuity and Sequence of the Educational Contents in the Nuri Curriculum for 3 to 5 Year Olds and Elementary School Curriculum,” *Korean Journal of Child Education and Care*, research-article vol. 14, no. 4, pp. 261-294, 2014 2014.
3. Y. Yu and J. Kim, Eun, “Analysis of the continuity and sequence in the science education curriculums for kindergarten, elementary school, and middle school,” *Korean Journal of Early Childhood Education*, research-article vol. 33, no. 4, pp. 241-265, 2013 2013.
4. Y. Huang, H. Guo, and Y. Li, “Study on the construction and practice of blended teaching mode of emergency first aid specialty based on OBE concept,” *Medicine*, Article vol. 102, no. 28, Jul 14 2023.
5. Y. Liang *et al.*, “Online Education Plight and Countermeasures for MBBS in Chinese Regional Medical Schools Based on the OBE Concept During COVID-19 Pandemic,” *Frontiers in Public Health*, Article vol. 9, Jan 21 2022, Art no. 806809.
6. Y. Qiao and H. Fu, “Study on OBE Teaching Concept in the Context of Deep Learning for the Construction of University Mathematics Microcourses,” *Computational Intelligence and Neuroscience*, Article vol. 2022, Jun 30 2022, Art no. 6860842.
7. H. Xiong and M. Talha, “A Study on the Optimization Mechanism of the Civic OBE Concept for a Computational Thinking-Oriented Basic Programming Course,” *Mathematical Problems in Engineering*, Article vol. 2022, Feb 11 2022, Art no. 6983942.
8. H. Yang, H. Zhu, W. Luo, and W. Peng, “Design and practice of innovative practice workshop for new nurses based on creativity component theory and outcome based education(OBE) concept,” *Bmc Medical Education*, Article vol. 23, no. 1, Sep 26 2023, Art no. 700.
9. W. Zheng, S. T. Wen, B. Lian, and Y. Nie, “Research on a Sustainable Teaching Model Based on the OBE Concept and the TSEM Framework,” *Sustainability*, vol. 15, no. 7, Apr 2023, Art no. 5656.
10. R.-L. Cai *et al.*, “Implication and implementation path of the ideological and political elements in acupuncture- moxibustion courses,” *Zhongguo zhen jiu = Chinese acupuncture & moxibustion*, vol. 41, no. 1, pp. 99-102, 2021-Jan-12 2021.
11. C. Lin, X. Zhi-Peng, J. Min-Jun, and W. Guan-Ling, “Thinking on integration of ideological and political education into Human Parasitology teaching,” *Zhongguo xue xi chong bing fang zhi za zhi = Chinese journal of schistosomiasis control*, vol. 31, no. 4, pp. 431-433, 2019-Aug-08 2019.
12. K.-L. Cheong, M. Wang, L. Zheng, X. Xie, B. Teng, and Y. Liu, “Application of micro-teaching in life sciences courses based on the “National Universities Micro-teaching Competition of Life Sciences” analysis,” *Sheng wu gong cheng xue bao = Chinese journal of biotechnology*, vol. 37, no. 8, pp. 2947-2955, 2021-Aug-25 2021.
13. C. Xu and L. Zhang, “Application of XR-Based Virtuality-Reality Coexisting Course,” *Intelligent Automation and Soft Computing*, Article vol. 31, no. 3, pp. 1843-1855, 2022 2022.
14. H. Ding, “Online and Offline Mixed Teaching Mode Based on Multimedia Computer-Aided Music Lessons during the Epidemic,” *Mobile Information Systems*, Article vol. 2022, Oct 3 2022, Art no. 1642790.

15. S. Guo, Q. Chai, and M. Wang, "Evaluation Model of Online and Offline Mixed Teaching Quality in Colleges and Universities Based on BP Neural Network," *Scientific Programming*, Article vol. 2022, Jan 20 2022, Art no. 7560227.
16. W. Guo and Y. Niu, "Interactive Teaching System of Basketball Action in College Sports Based on Online to Offline Mixed Teaching Mode," *Mobile Information Systems*, Article vol. 2021, Apr 22 2021, Art no. 9994050.
17. M. Yanfei, "Online and Offline Mixed Intelligent Teaching Assistant Mode of English Based on Mobile Information System," *Mobile Information Systems*, Article vol. 2021, Jul 26 2021, Art no. 7074629.
18. H. Gao, S. Lu, and T. Wang, "Motion path planning of 6-DOF industrial robot based on fuzzy control algorithm," *Journal of Intelligent & Fuzzy Systems*, Article vol. 38, no. 4, pp. 3773-3782, 2020 2020.
19. K. Li and X. Cheng, "Design of a Conflict Prediction Algorithm for Industrial Robot Automatic Cooperation," *Mobile Networks & Applications*, Article vol. 27, no. 2, pp. 535-546, Apr 2022.
20. P. Wenger and D. Chablat, "A Review of Cuspidal Serial and Parallel Manipulators," *Journal of Mechanisms and Robotics-Transactions of the Asme*, Review vol. 15, no. 4, Aug 1 2023, Art no. 040801.
21. D. Zhang, Z. Peng, G. Ning, and X. Han, "Positioning Accuracy Reliability of Industrial Robots Through Probability and Evidence Theories," *Journal of Mechanical Design*, Article vol. 143, no. 1, Jan 1 2021, Art no. 011704.
22. X. M. Guan, W. L. Song, J. W. Zhang, and T. B. Wang, "Research on engineering student training mode of forestry colleges under the background of new engineering and engineering education professional certification," *Basic & Clinical Pharmacology & Toxicology*, Meeting Abstract vol. 126, pp. 180-181, Mar 2020.
23. Y. Y. Li, "Study on the ethical dimension of engineering education accreditation," Dissertation/Thesis Jan 01 2011.
24. D. Wang, F. Han, Q. Zhao, and Y. Lv, "Teaching Practice of Engineering Management Course for Engineering Education Certification under Background of Artificial Intelligence," *International Transactions on Electrical Energy Systems*, Article vol. 2022, Oct 6 2022, Art no. 3106491.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.