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From "Skills Learning" to "Employment Matching": The role of CTE in reshaping and reforming the U.S. Vocational Education System

Introduction

In the early 20th century, the goal of vocational education in the United States was mainly to train blue-collar workers and focus on skills training (e.g. agricultural machinery and home appliance repair). These courses were seriously disconnected from core subjects (e.g. Mathematics, Foreign Languages, History, etc.) and students lacked the necessary cultural literacy. This has led to vocational education being regarded as "Low-end Education" (Fletcher et al., 2013) for a long time, exacerbating educational inequality. At the end of the 20th century, a large number of emerging industries (e.g. Electronic Information, Health Care, etc.) developed rapidly. The employment market urgently needed compound talents (professional skills + comprehensive abilities) and the traditional vocational education system faced transformation.

Carl D. Perkins Career and Technical Education Act (2006) first proposed the concept of CTE (Career and Technical Education), which is "a systematic education model that can provide students with diversified learning paths from secondary school to higher education by integrating academic knowledge, technical skills and vocational practice so that they can be qualified for high-demand industry positions or continue their studies(Carl D. Perkins Act, 2006, P. 3)". Its core concepts include: Career Pathways and College and Career Readiness and Earn and Learn. Strengthening Career and Technical Education for the 21st Century Act (Perkins V, 2018) further promotes the connection between CTE and the job market, focusing

on fairness and innovation.

The reason why this article chooses CTE as the research topic is that the introduction of CTE has fundamentally changed the training goal of vocational education in the United States: from "Training Skilled Practitioners" to "Cultivating Compound Social Talents" (Perkins V, 2018, P. 3). It breaks the rigid concept of "University is the only option"(Kidwai, 2011)and provides diversified employment channels for low-income families and minority students (Zirkle, 2011; Manley, 2011; John, 2013). The fairness clause in Perkins V (2018) requires that the salary level of vocational school students in high-income industries should be increased (not less than \$1,500 per month). At the same time, CTE effectively connects middle schools, community colleges and enterprises through Career Pathways, studying how its workers can update their skills and learn in continuous work. Apart from these, CTE provides feasible suggestions for some communities with serious aging (Zamzam et al, 2024; Lambeth et al, 2018). In addition, CTE draws on the vocational education development plans of other countries(e.g. The German Dual System and Singapore's "Skills for the Future"), studying how to balance the connection between localization and internationalization (Kidwai, 2011; Cannon et al., 2024; Porreca, 2019) and cultivate skilled talents with an international perspective.

Since the proposal of CTE, various states in the United States have shown diverse responses due to differences in local economy, education system, market demand, etc. Supportive states particularly California have independently established CTE courses according to the industrial needs of each state, forming a "Vocational Cluster Regionalization" model (Karandjeff and Schiorring, 2011, P. 11-12); but agricultural states

led by Alabama have developed slowly due to resource constraints.

Research Questions

The article sets research questions around the two aspects of Vocational Education System and Job market connection.

- How does CTE education change the traditional vocational education system in the United States? What are the differences between the two?
- How does CTE education alleviate the shortage of skilled talents and promote school-enterprise cooperation?

The research on these issues also provides guidance on policy formulation and teaching strategies for state education departments and relevant teachers who teach CTE courses.

Research Methodology

- Clarify research questions and understand the CTE theoretical system and the current situation of vocational education in the U.S.

The main question of this study is how CTE promotes the transformation of the American vocational education system from single skill learning to job market connection. Firstly, by consulting federal laws and related documents, we understand the legal background and implementation status of CTE. Secondly, we should clarify the core concepts and implementation objects of CTE and understand the current status of vocational education in the U.S., accurately understanding some social problems that CTE needs to solve.

- Literature selection and optimization

Because CTE was proposed in 2006 and optimized in 2018, the literature selection is mostly concentrated on books and journal articles after 2006. After 2018, CTE courses pay more attention to docking with the labor market and the setting of CTE courses in various states and specific practices have become the focus of literature selection. According to the above time range, search for keywords (e.g. CTE 2013-2024, CTE and Market, Vocational Education in the United States, etc.) on academic websites particularly Google Scholar, UWTSD Library and SpringerLink. We should selectively read literature based on public data sources and methodological designs, especially core journals of vocational education (e.g. Journal of Vocational Education & Training \ Vocation, Technology & Education etc.).

- Determine the methodology and theoretical framework

The research adopts the literature review method and case analysis method. By analyzing the journal articles of relevant CTE research and taking California and Alabama as examples, the transformation of the American vocational education system from "Skills Learning "to "Employment Matching "is revealed. At the same time, modern vocational education theories e.g. Pragmatism Education Theory (Dewey, 1908), Social Cognitive Career Theory (SCCT, Greene and Ephross, 1991), Constructivist Learning (Wilson, 1996) and Self-Determination Theory (SDT, Murrell and Harget, 1972) are used to ensure the balance between theoretical analysis and empirical research.

- CTE and employment market demand (case analysis)

According to the different educational structures of each state, the article selects two representative typical case analyses: the IBM P-TECH project in California (a model of

School-Enterprise cooperation) and the "Rural Broadband and Digital Skills Program" in Alabama (basic talent construction) for comparative research. By analyzing the theoretical literature and research results of different scholars, we can systematically understand the reshaping and optimization of the American vocational education system by CTE. And make a critical evaluation of its achievements and future development.

- Controversy and challenges of the CTE system

Since CTE was proposed in 2006, it has basically formed a complete vocational education training system after nearly 20 years of development. However, the fair construction, curriculum structure and external environment challenges faced by the CTE system also need to be continuously improved. Read journal articles and dissertations in vocational education, teacher education and other majors, adopt the suggestions in a targeted manner, and effectively respond to the difficulties and challenges of the development of the US CTE system.

- Draw conclusions

Integrate research contents and answer these two research questions raised. Critically analyze the multi-faceted impact of CTE on the US vocational education system. At the same time, compare it with the vocational education systems of other countries and focus on development of US CTE education from an international perspective. Due to the factors of length and research time, this study has some limitations. How should it be improved and perfected in the next step.

Literature Review

1.Related research on CTE

1.1 CTE theory system

CTE was first proposed by Carl D. Perkins Career and Technical Education Act (2006) and supplemented by Perkins V (2018). It aims to help students prepare for specific career fields or further studies through a model that combines academic knowledge and skill training, enhancing students' employment competitiveness and lifelong learning ability(Perkins V, 2018). The CTE theory system includes Pragmatism Education Theory (Dewey, 1908), Social Cognitive Career Theory (SCCT, Greene and Ephross, 1991), Constructivist Learning (Wilson, 1996) and Self-Determination Theory (SDT, Murrell and Harget, 1972). CTE integrates multidisciplinary theoretical systems e.g. pedagogy, sociology, and psychology to respond to the needs of the employment market through educational practice (Mobley et al., 2017).

1.2 The dilemma of traditional vocational education in the United States

The traditional vocational education system in the U.S. faced multiple structural transformation challenges at the end of the 20th century. The Smith-Hughes National Vocational Education Act (1917) create conditions for traditional vocational education. Its core goal was to train factory workers and agricultural laborers, which led to vocational education being regarded as a forced choice for "non-academic students" for a long time (Dortch, 2014). The Vocational Education Amendments (1968) divided students into "Academic Track" and "Vocational Track" according to their grades based on standardized tests. Walsh (1974) conducted a systematic analysis of the vocational education curriculum of

the Handicapped and conducted on-site evaluations of 92 disabled education programs in 24 eastern states, providing a strong reference for the establishment of vocational education curriculum for disabled people in various states; Barr et al. (1989) made a detailed discussion on the obligations that vocational education administrators should fulfill under the law and students should be classified according to many factors.(e.g. health status, academic performance, cultural background, etc.) in order to distinguish between academic high schools and vocational high schools in the U.S. However, because American society has long advocated the "College-for-all" culture (Zajacova and Lawrence, 2021), society generally believes that vocational education is a "choice for poor students." Bailey and Berg (2009) conducted a survey on the acceptance of vocational education in 48 states in the U.S.in 2001. The survey showed that only 11.4% of parents were willing to let their children give priority to vocational education.

More importantly, the traditional vocational education course cycle in the U.S. is as long as 10-15 years, which cannot adapt to the rapid industrial upgrading. Vocational education teachers are mostly retired industry practitioners, lack of systematic teacher training, resulting in serious aging of the teaching staff (Dougherty, 2023; Chen et al., 2023). According to the National Center for Education Statistics (2020), the average age of vocational teachers in the United States in 2019 was 52-54 years old, much higher than the average age of academic teachers. The long course cycle and aging teaching staff are problems that the U.S. vocational education system urgently needs to reform.

These difficulties of traditional vocational education are essentially a reflection of the structural contradiction between the education model and social needs after the industrial

revolution. Entering the 21st century, US states have tried to reform these ills through the "academic + career" integration model. Breiman (2017) suggested introducing dynamic skills to enhance employment competitiveness in his study of the path of young people's transition from secondary education to the workplace; Shah (2017) analyzed in detail the obstacles to setting up CTE courses in US public colleges and universities, pointing out that the available information on course quality and insufficient funds are the main problems in the completion rate of CTE courses. Therefore, the goal of CTE courses is to promote educational equity and improve employment competitiveness.

1.3 Comparison between the traditional vocational education system and CTE system

There are significant differences between the traditional vocational education system and CTE system in the United States in terms of training objectives, curriculum design, market connection, policy support and funding allocation. As shown in the table 1 below.

Dimensions	Traditional vocational education system	CTE system
Training Objectives	To cultivate artisans or blue-collar workers in specific positions(e.g. carpenters, bakers etc.)	To cultivate compound talents with "Academic + Skills" who can adapt social changes
Course Design	Long cycle, out of touch with market demand	Deep integration of knowledge learned with job market
Market Connection	High short-term employment rate but slow salary growth, poor staff mobility, easy to be replaced by AI	High employment rate of STEAM positions, fast salary growth, breaking class solidification(Latinos and minorities enter high-tech fields), skill system upgrade(robot maintenance replaces manpower)
Policy Support	Smith-Hughes Act(1917) focuses on training blue-collar workers, low corporate acceptance	Perkins V(2018)focuses on training compound talents, high corporate participation
Fund Allocation	Evenly distributed according to the number of schools, lack of KPI incentive system	Implement "Apprenticeship System", companies independently choose salary structure and provide internships

Table 1: Comparison between the traditional vocational education system and CTE system

From the comparison in the above table 1, we can see that the CTE system has reshaped the American vocational education system through policy changes, curriculum integration, school-enterprise cooperation, etc. It has continuously adapted to market demand through long-term capital investment and dynamic management mechanisms. In their study on "whether CTE reduces, replicates or exacerbates socioeconomic inequality", Imperatore and Hyslop (2017, P4) found that CTE implementation in regions with a higher degree of modernization is better, which greatly improves the employment success rate of vocational school students; however, CTE implementation in rural areas is more difficult due to poor hardware facilities. At the same time, Miller (2023) believes that Safety is still an important part of the CTE system. Through interviews with 718 STEAM and CTE teachers in 42 states in the United States, it can be seen that the education department should take measures to effectively ensure the safe implementation of CTE system.

From "out of touch with society" to "integration of academics and skills"(Breiman, 2017), the American vocational education system continues to adapt to changes in the job market and optimize. However, Plasman et al. (2017) pointed out that the US CTE system still faces problems e.g. unbalanced regional resource allocation and insufficient teacher training. The federal government and state governments need to continue to pay attention to the development of CTE and provide strong guarantees for the smooth implementation of CTE courses.

2. CTE and employment market demand

There are relatively many special literatures on empirical research on CTE and employment status, including teaching feedback from front-line teachers and master's and

doctoral theses in majors such as vocational education. Most of these papers analyze the implementation of CTE in a certain state or school. Shulock et al. (2012) fully affirmed the positive role of the CTE system in the organizational structure and funding allocation of vocational schools while analyzing the contribution of community colleges to the training of California's workforce and economic development; Kamin (2023) analyzed the implementation of CTE in 20 immigrant communities in New York State, exploring the differences in CTE access among students of different racial backgrounds. It pointed out that communities with a higher proportion of black and Latino students have the highest CTE access; Yoon and Strobel (2017) explored the changes in enrollment data for STEAM courses in vocational and technical education in Texas from 2008 to 2013, founding that the implementation of CTE has greatly increased students' interest in STEAM courses. More than 74% of students believe that CTE is helpful to their studies. These studies provide us with a detailed reference for a systematic understanding of the current status of CTE implementation in various states in the United States, and they also provide some practical experience for teachers who will engage in CTE teaching in the future.

2.1 CTE creates a new model of school-enterprise cooperation

California, as the most economically developed region in the western United States, has a relatively complete vocational education system. Due to the high proportion of Latino students in California, the fairness of vocational education has received much attention from the government. Lopez (2024) discussed the application of CTE system in public school districts in Southern California and pointed out that CTE system provides solid academic literacy and potential employment opportunities for vocational school students from ordinary

families. Among them, the IBM P-TECH (Pathways in Technology Early College High School) project in California is regarded as a model of school-enterprise cooperation under CTE system.

P-TECH was jointly founded by IBM, the New York City Department of Education and the City Institute of Technology in New York in 2011. It aims to provide an integrated path of "high school-vocational-university" for low-income groups and minority students. The first pilot of the project was selected in the San Francisco Unified School District (SFUSD) in California. The goal is to solve the skill gap in vocational schools and promote educational equity through school-enterprise cooperation (IBM, 2013). Students in the IBM P-TECH program complete high school in four years starting from grade 9 and obtain an Associate Degree through a two-year community college course(IBM, 2013). At the same time, they accumulate industry skills(e.g. IBM certificates and data analysis certificates etc.) to achieve the same academic certification as a university bachelor's degree. Mustain (2018) conducted 60 in-depth interviews and participatory observations with corporate cooperation leaders, front-line teachers and students in three P-TECH model schools in California, analyzing CTE's guidance on the educational goals, teaching strategies and employment directions of the P-TECH model. He also explained the negative impact of CTE system on students' personalized training.

The IBM P-TECH program provides more employment opportunities for students in California vocational schools. SRI International (2017) conducted a survey on the employment rate of graduates from the California P-TECH program. About 60% of students obtained an associate degree within 6 years and some students transferred to CSU (California

State University) through school-enterprise cooperation agreements, far exceeding the state average (42%); Laforest et al. (2019) conducted a systematic investigation of the IBM P-TECH program of the California Career Institute and found that students majoring in welding and auto repair had the highest support for this program, because the program implements the "apprenticeship" training method in the CTE system. Students can also get in touch with their teachers at any time to enhance their professional skills.

The IBM P-TECH program has achieved the "educational equity" and "gender balance" advocated by the CTE system. Barnett (2015) revealed that the enrollment target of the IBM P-TECH program tends to be Asian and African female immigrants from low-income families, effectively guaranteeing the right of women from immigrant families to receive education; Biddix et al. (2023) pointed out that the project aims to cultivate "academic + skills" talents in the CTE system, and IBM and its partner companies provide them with professional skills and employment options guidance to broaden the employment channels for vocational school students. Goracinova (2019) further supplemented Barnett et al. (2015). Her study took the "Girls Who Code" club in the San Diego P-TECH project as the research object, analyzing the significance of establishing a women's technology club and the support of the IBM Innovation Fund for female students. At the same time, female skill mentors were added, so that the proportion of female teaching teachers increased from 13% in 2015 to 35% in 2018.

As an innovative model of vocational education in the United States, the IBM P-TECH project has achieved remarkable results in promoting educational equity and eliminating gender differences, but several problems(e.g. uneven resource allocation,

inadequate protection of student rights and interests, ambiguous corporate roles during implementation) cannot be ignored. Kazis (2016) pointed out that the initial transition of the project relied on IBM and its corporate funding support and schools lacked the awareness of independent training; EdTrust–West (2022) pointed out that the P-TECH project resources were unevenly distributed. Wealthy school districts could obtain advanced technology through corporate cooperation but the gap between low-income school districts widened due to lack of corporate attention. In addition, the curriculum transition relied on IBM's evaluation criteria (Kazis, 2016) and students may be limited in thinking and unable to adapt to the changing workplace needs. Therefore, Kiv et al. (2019) suggested that the federal government and state governments should establish an independent supervision mechanism to limit excessive corporate intervention in CTE courses. Apart from this, governments are bound to add a career conversion course module to reduce reliance on single skill courses.

2.2 CTE helps rural basic talent construction

Unlike the economically developed California, Alabama is located in a mountainous area, where vocational education has long-faced problems such as funding shortages and insufficient teaching staff, resulting in a single and stereotyped vocational education system in Alabama (Norris et al., 2023). Since the promulgation of Perkins V (2018), the state government has formulated the "Rural Broadband and Digital Skills Program" (Connect Alabama Act, 2021) based on its own industrial development priorities, aiming to improve the digital skills of rural residents and expand employment opportunities. The program is centered on CTE theoretical system, making full use of special federal government grants and supporting facilities and cooperating with large telecommunications companies (e.g. C Spire,

T-Mobile US etc.) to establish a "Digital Talent Training Class"(Connect Alabama Act, 2021) to effectively alleviate the shortage of digital talents in rural areas of Alabama.

The course setting of this class revolves around SCCT (Social Cognitive Career Theory) and SDT (Self-Determination Theory) and is divided into basic courses (basic computer operation, Internet security, etc.), advanced courses (business office software, e-commerce, etc.) and industry-customized courses (agricultural digitization, medical and health management, etc.) so that students can fully access multidisciplinary knowledge and broaden their employment channels. Malik et al. (2023) pointed out that three vocational schools in Alabama have opened C language and digital literacy courses, which greatly improved students' professional and technical capabilities; Okonkwo and Ibijola (2021) suggested that the "digital skills certificate" be included in the vocational education credit system to assist enterprises in recruitment. At the same time, an "online network Q&A class" was established to invite professional and technical personnel to provide remote guidance to community residents.

Compared with the IBM P-TECH project in California, Alabama's "Rural Broadband and Digital Skills Program" focuses on cultivating practical talents for rural areas and narrowing the gap between urban and rural development. The former trains skilled talents for emerging industries(e.g. science, technology and medicine) while the latter applies the CTE system to the construction of rural basic talents. Although the two have different training objectives and beneficiary groups, they are both centered on CTE system and pay attention to the right to education of low-income groups and ethnic minorities, implementing a school-enterprise cooperation model. More importantly, Both of them integrate resources

from the government, schools, enterprises and communities and improve the construction of vocational education systems in every state. Mendiola (2025) pointed out that the vocational education systems of every state in the U.S. will be differentiated according to their own conditions. They must not only cultivate professional skilled talents, but also lay a solid foundation for economic development.

3. Controversy and challenges of CTE system

CTE has an important impact on the policy framework, educational goals and curriculum setting of the traditional vocational education system in the United States, promoting its transformation from "Skills Learning" to "Employment Matching". However, it also faces some controversies and challenges in the development process.

3.1 CTE Equity Construction

At the beginning of its establishment, CTE system often faced many problems such as separation of learning and use, racial and gender discrimination (Kim et al., 2021; Alosco et al., 2020), resulting in the inability of CTE system students to receive equal education. Policy lags and insufficient funds also seriously affect the implementation of CTE system. Many experts and scholars have expressed their views on this issue and launched heated discussions.

Good policy intervention and implementation of targeted resource redistribution. Anon (2010) and Stevens (2019) both found that the "Equity Formula" in Perkins V(2018) effectively alleviated the pressure on education funds in rural areas and immigrant communities and CTE courses (cybersecurity, renewable energy, etc.) offered were well-connected to the needs of the job market; Park and Johnson (2019) closely combined the

needs of the labor market with school education to train students with the background knowledge and professional skills required for employment.

To break down gender barriers and develop diversified learning models. Jocson (2008) explained the necessity of establishing gender-neutral courses from the perspective of gender segregation and encouraged female researchers to join the study of AI emerging disciplines ; Solberg et al. (2020) innovatively proposed to let men participate in early childhood education based on Jocson (2008) and add gender awareness sections to CTE courses so that students can be widely exposed to knowledge of different disciplines and ultimately determine their own careers. The two explored different learning models from the perspectives of men and women, which is also a reflection of gender equality in vocational education.

School-enterprise cooperation creates equal employment opportunities. Following the IBM P-TECH project in California, Mississippi, Wisconsin and other states have successively introduced bills to promote school-enterprise employment cooperation. Leu and Arbeit (2020) pointed out that some vocational schools have signed agreements with enterprises to ensure that CTE graduates have fair recruitment opportunities. However, a small number of scholars believe that it is difficult to have a specific measurement standard for the fairness of the CTE system and the so-called "fairness construction" is nothing more than a tool for the government to make profits. Reese (2011) believes that in school-enterprise cooperation, excessive involvement of enterprises in education may lead to the maximization of the interests of teaching goals rather than the overall development of students; DeFeo (2015) also emphasized that public education resources may be used for specific commercial purposes,

weakening the public nature of education. Therefore, the fairness construction of CTE system requires listening to the voices of all parties and making comprehensive judgments.

3.2 Structuring of CTE Courses

The structured design of CTE courses in the United States is a reshaping of traditional vocational education courses (Theobald et al., 2022). It combines academic ability and professional skills through a systematic, modular and diversified curriculum framework, adapting to the needs of the employment market. Since 2006, a large number of experts and scholars have conducted in-depth research on how to reasonably set up CTE courses in vocational schools, which can be roughly divided into the following two aspects.

Stratification and integration of curriculum framework. This is the core issue of structured research. Furey (2025) guided students to understand the current employment situation and complete student interest and ability assessment through the "Career Cluster" model (e.g. information technology, medical health and legal science popularization); Norris et al. (2023) tried to add geometric measurement to the architectural course to improve the core professional ability of engineering students. In addition to the vertical stratification of employment development orientation, horizontal integration of interdisciplinary cross-disciplines is also essential. Lowry and Thomas (2017) integrated gene editing and data analysis into the agricultural CTE curriculum system to form an "agriculture + big data" training model. However, problems such as knowledge fragmentation and insufficient teacher ability caused by interdisciplinary studies are becoming increasingly prominent. Hough (2025) found that in the "green energy courses", environmental science, engineering and economics were taught in independent modules and the ability to solve problems systematically was not

formed.

Personalized training and scenario-based teaching. This is the focus of structured research in recent years. Manley (2011) advocated that vocational schools with conditions should conduct ILP (Individual Learning Plan), recording completion status through learning management systems and flexibly adjusting course progress; Seifert (2019) proposed WBL (Work-Based Learning) on the basis of "apprenticeship"(Gibbs, 2010), in which junior students conduct short-term professional environment experience and senior students implement paid training to reduce practical costs. However, Hayes (2021) opposes scenario-based teaching for all courses. He pointed out that regular maintenance of hardware facilities requires a lot of money especially teacher training is long and expensive; Plasman et al. (2019) pointed out that some vocational schools in Texas are overly idealistic and ignore the ambiguity and uncertainty in the work environment. Therefore, it is necessary to formulate different training programs based on individual differences of students and to adhere to the teaching of basic subjects.

3.3 Challenges of CTE external environment

The development of the US CTE system has formed a relatively complete teaching model and training program. However, with the rapid rise of AI and automation technology, traditional manufacturing and service industries are gradually being replaced and digital skills and cross-industry cooperation have put forward higher requirements for vocational school graduates. Hirschy et al. (2011) have long found that most companies not only need employees with strong professional skills, but also critical thinking, remote office and other abilities are also necessary for employees (Spindler and Greiman, 2013). Online platforms

(e.g. Udacity, etc.) provide flexible and low-cost training for corporate employees and also divert some CTE supporters.

More importantly, CTE system is highly dependent on federal funding from the Perkins Act (2006), but changes in national regimes such as presidential elections and cabinet changes directly affect funding allocation. Schmidtke (2017) pointed out that Arizona reduced its investment in vocational education in 2013 due to the change of state House members. In addition, the American society has long advocated the "four-year undergraduate" university training path and CTE has been mistakenly regarded as a "non-academic path" (Reese, 2011), resulting in low acceptance by parents and students. Therefore, promoting successful cases to enhance social awareness of CTE system is also what the vocational education departments of various states in the United States have been doing in recent years.

4. Conclusion

Since the proposal of Perkins V (2018), CTE has gradually transformed from the traditional vocational education model and the training goal has also changed from "Skills Learning" to "Employment Matching". This transformation has not only reshaped the curriculum design, training methods and policy orientation of American vocational education, but also profoundly affected the whole society's understanding of vocational education.

CTE promotes the goal of vocational education from "single skill" to "integration of career and academics". Constructing the path of "CTE-community college-adult undergraduate-lifelong learning" (Sanchez and McMurray, 2024) fully meets the different learning needs of workers in various industries for undergraduate education; CTE effectively

promotes in-depth cooperation between schools and enterprises. The traditional teaching mode of vocational education in the United States is single, the curriculum is updated slowly and the participation of enterprises is low. The CTE system enables enterprises to directly participate in curriculum construction, which greatly improves the academic employment rate of vocational schools; during the epidemic, 80% of CTE project courses in the United States were taught through online and offline hybrid teaching (Edmunds et al., 2024), realizing the innovation of teaching methods.

CTE has promoted educational equity and class mobility, reshaping the society's perception of vocational education. Emerick and Goldberg (2022) conducted a survey on graduates from 10 vocational schools in Texas and found that 35% of CTE graduates had salaries exceeding the state average within 5 years of graduation. At the same time, more than 20% of CTE graduates work in the STEAM field and the proportion of women and minorities is increasing year by year. At the same time, public awareness of CTE has increased significantly. Anglum et al. (2023) conducted street interviews in downtown Seattle and found that nearly half of parents believed that CTE could provide the same educational value as undergraduate education.

However, the U.S. vocational education system still has shortcomings and limitations. CTE education in rural areas generally faces the problems of aging teaching facilities and teacher shortages. Seifert (2019) pointed out that the teaching equipment in rural vocational schools in Alabama is mostly aging factory machinery from the 1990s, which cannot simulate the real scene of modern factories; CTE course content is difficult to keep up with the rapidly changing industry needs. CTE course updates usually take 2-3 years, but fields such as AI

and new energy are updated very quickly and it takes a long time for CTE courses to match the industry (Edmunds et al., 2023); the aging population structure in the United States restricts the development of CTE. Edmunds et al. (2024) analyzed the changes in the U.S. population structure in the past three years based on the 2023 report and pointed out that by 2050, the U.S. population aged 65 and above will exceed 20% so the decline in social labor and innovation capabilities may have an impact on CTE education system.

The federal government, state governments, schools and businesses should work together to address the risks and challenges that CTE may face in the future. At the same time, we can learn from the experience of vocational education in other countries (Bastgen et al., 2024; Zi et al., 2023) to supplement and improve the US CTE education system so that CTE can better cope with future social development and industry needs.

Due to the influence of research time and region, this study has some limitations. This study focuses on local cases in the United States (California, Texas, etc.) but fails to explore the comparison of international vocational education development in depth. At the same time, due to the limitations of existing resources and conditions, the reform resistance at the school level of vocational schools has not been deeply explored. Therefore, in the subsequent research plan, I will review the latest laws and policies on vocational education in various states and read relevant scholars' literature, conducting in-depth research on the development of critical CTE in the AI era to provide effective reference for the employment of vocational school graduates.

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