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ORIGINAL ARTICLE

International perspectives on cultivating high-quality bachelor's degrees in vocational education: Insights, experiences, and practices from overseas universities

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ABSTRACT

Cultivating high-quality technical and skilled professionals is essential for building a modern economic system and ensuring there is a balance between workforce supply and demand. Currently, there are various challenges associated with pilot programs offering undergraduate-level vocational education in China, including unbalanced training structures, limited curricular diversity, and inadequate systemic coordination. To address these issues, in this study, we employed a comparative case study methodology to examine the practices of several esteemed overseas universities in developing high-quality, undergraduate-level programs in vocational education. We systematically analyzed the training objectives, curriculum design, and support systems of these programs and categorized the associated practices as research-oriented, practice-oriented, and integration-oriented models. Drawing on the valuable insights revealed by this study will support China's goal of developing a skilled workforce that meets the demands of a rapidly evolving economy.

Key words: vocational education, training objectives, curriculum design, support system, comparative case study

INTRODUCTION

In January 2019, the State Council of the People's Republic of China issued the "National Vocational Education Reform Implementation Plan", which explicitly emphasized that "vocational education and general education are two different forms of education, both of equal importance".[1] This policy clarified the status of vocational education in China and proposed the development of a "high-level applied talent cultivation system, piloting vocational education at the undergraduate level".[2] By June 2019, the Ministry of Education had upgraded 15 private higher vocational colleges to create the first batch of pilot vocational undergraduate institutions in the country. Subsequently, more institutions were upgraded or restructured. As of February 2021, there were 27 pilot vocational undergraduate colleges in China, of which six were public and 21 were private institutions.[3] After receiving approval from the Ministry of Education, these institutions were officially renamed "vocational universities" and began offering undergraduate-level vocational education with the aim of cultivating high-quality technical and skilled professionals to meet regional economic and social development needs, further highlighting the distinguishing characteristics of higher education, vocational education, and regional development.[4] The term "high-quality technical and skilled professionals" refers to individuals who possess not only robust professional and technical skills but also

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the capacity for innovation, adaptability, and continuous learning, which are essential for meeting the demands of modern industries and contributing to economic growth and societal progress. Vocational undergraduate education or undergraduate-level vocational education, on the other hand, is a form of higher education that focuses on equipping students with specialized technical skills and practical knowledge, with an emphasis on hands-on training and direct application of skills in real-world contexts.

Although most of the new pilot vocational colleges originated from former higher vocational colleges and have developed basic operational models through a period of exploration, they still face numerous and significant obstacles. These challenges are multifaceted and stem from the rapid transformation that these institutions have undergone within a relatively short period of time. This accelerated evolution has led to a range of disparities, including differences in educational philosophies, systems, available resources, and the overall scale of operations. For instance, some institutions have struggled to align their educational goals with the needs of modern industries, which has led to a lack of uniformity in educational quality across these colleges. Moreover, this rapid transition has not allowed sufficient time for the establishment of well-defined theoretical and practical frameworks that are essential for guiding the development of these institutions. As a result, the educational outcomes have been inconsistent, with some programs failing to achieve the goals expected to be reached by implementing the reforms. This inconsistency has created a challenging predicament, often metaphorically described as "crossing the river by feeling the stones, "[5] with institutions navigating uncertain terrain without a clear and tested path. In many cases, this has led to institutions merely upgrading existing programs to undergraduate programs without implementing the substantial transformations necessary to ensure the quality and relevance of vocational education at the undergraduate level. These issues underline the need for more structured guidance and support to achieve the intended goals of the reforms.

Previous studies on the reform of vocational education have highlighted the importance of aligning educational objectives with industry needs to ensure that graduates are adequately prepared for the workforce. For example, Xiao and Xiang emphasized the role that industry-academia collaborations play in enhancing the practical relevance of vocational education programs.[6] Similarly, Li discussed the challenges associated with implementing vocational undergraduate education in China,[7] particularly the need for a more systematic approach to curriculum design and teacher training. However, there are relatively few reports in the literature of analyses conducted to compare international practices in vocational education. Therefore, the aim of this study was to address this issue by examining successful models implemented in other regions or countries. Optimizing the cultivation of high-quality technical and skilled professionals during the pivotal period of high-quality development in China's higher education landscape is crucial for the sustainable growth and advancement of vocational undergraduate education. In light of this, in the present study, we endeavored to: (1) explore the values inherent in nurturing such professionals within the Chinese context, highlighting their crucial role in driving economic progress and societal development; (2) identify key insights and lessons from the successful practices of cultivating high-level technical and skilled professionals in overseas settings and examine how these can be adapted and applied to the Chinese context; and (3) propose prospective directions for the future development of vocational undergraduate education in China, based on a comprehensive understanding of current challenges and opportunities.

The value of cultivating high-quality technical and skilled professionals

Cultivating high-quality technical and skilled professionals as a necessity for building a modern economic system

In the rapidly evolving landscape of information technology, emerging technologies such as big data, the Internet of Things (IoT), and artificial intelligence (AI) are profoundly reshaping not only manufacturing processes and industrial requirements but also our lifestyles and societal operation models. Consequently, it has become a priority to cultivate high-quality technical and skilled professionals who can drive industrial upgrades and construct a vibrant, modern economic system.[8] The "Made in China 2025" strategic initiative underscores this imperative, emphasizing the escalating demand for individuals proficient in the skills required by a cutting-edge manufacturing industry.[9] Amid the expansion of enrollment in vocational colleges, there lies a pressing need to refine and optimize talent training programs. This endeavor necessitates not just revamping curricula but also fostering deeper industry-academia partnerships. Taking such actions will help produce a workforce that is equipped to meet the swiftly evolving economic and societal demands and thus contribute effectively to the development of a robust, future-ready economy.

Cultivating high-quality technical and skilled professionals as a response to the imbalance between supply and demand in enterprises

A pivotal challenge confronting vocational education today revolves around addressing the supply-demand imbalance that exists between the personnel needs of

enterprises and the output of talent training programs.[10] The demand for technical and skilled professionals is escalating, and there is a preference for individuals with the ability to both excel in a current role and adapt to evolving positions, embrace continuous learning, and embody a craftsmanship mindset.[11] The ideal high-quality technical and skilled professionals possess not only robust technical skills but also innovative thinking, a strong learning capacity, and exceptional professional attributes.

To produce such individuals, vocational colleges must comprehensively and innovatively reform many of the factors that contribute to their educational offerings, such as their training programs, curriculum design, teaching methodologies, and in-school and extracurricular practical experiences. This transformation is imperative to cultivate graduates who genuinely align with the demands of enterprises. It necessitates updating educational philosophies and fostering robust partnerships with industry partners to ensure that educational content closely aligns with market requirements.[12] Furthermore, enhancing students' practical skills is paramount to boosting their employability and equipping them with the skills needed to navigate the rapidly changing job landscape. By implementing such changes, vocational colleges can effectively contribute to the development of a skilled workforce that is competent, adaptable, innovative, and poised to drive the modern economic system forward.

Cultivating high-quality technical and skilled professionals as a key task in deepening the reform of undergraduate-level vocational education

In October 2021, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued a document entitled "Opinions on Promoting the High-Quality Development of Modern Vocational Education",[13] which clearly stated the overall requirement to "build a skill-based society, promote the craftsman spirit, and cultivate more high-quality technical and skilled professionals, skilled craftsmen, and great craftsmen to provide strong talent and skill support for the comprehensive construction of a socialist modern country". During the "14th Five-Year Plan" period, the country faces multiple strategic transitions, such as comprehensively constructing a modern socialist country, forming a new development pattern, addressing the main social contradictions present in the new era, and advancing rural revitalization, all of which are closely linked to vocational education.[14]

Thus, there is a need for China's vocational educational system and programs to be modernized, standardized, adaptable, and actively integrated into the comprehensive modernization transition to produce high-quality technical and skilled professionals that can enhance the nation's strength and self-reliance.[15] It must also be noted that the creation of a modern vocational educational system needs to be guided by "human modernity" and thus consider modern talent cultivation goals and modern economic and cultural influences. As China's economy embarks on a new era of high-quality development, the labor market is in need of skilled, versatile, and well-rounded technical professionals. This necessitates the cultivation of a new breed of professionals who are not only proficient in hands-on skills but also adept at management and possess a holistic understanding of their field. In response, the adjustment and optimization of vocational educational structures must be expedited, and this must involve reforming educational content and teaching approaches to produce graduates for the evolving economic and industrial landscapes.[16]

RESEARCH METHODS

We employed a comparative case study methodology to analyze the vocational educational practices of selected high-level overseas universities. The research methodology was designed to enable the exploration and categorization of the distinct approaches taken by these institutions to cultivate high-quality technical and skilled professionals. The process involved several key steps, which are described below.

Criteria for selecting overseas universities

The selection of the overseas universities was based on the following criteria.

1. Reputation and ranking: universities were chosen based on their global rankings and recognition for excellence in technical and vocational education.

2. Focus on vocational education: the selected institutions emphasize practical training and industry partnerships, which align with the goals of vocational undergraduate education.

3. Geographical diversity: universities from different global regions (Europe, North America, and Asia) were included to ensure a comprehensive analysis of various educational models.

4. Availability of data: institutions with sufficient and accessible data and information on their educational practices, curricula, and outcomes were prioritized.

Data collection

The data collection step involved conducting a thorough review of the academic literature, institutional reports,

and official publications from the selected universities. Additionally, case studies and detailed program descriptions provided by the universities were analyzed. We gathered information on various aspects of the universities' vocational education programs, including the curriculum design, teaching methods, industry partnerships, and student outcomes. The following universities were selected for this study.

1. Hong Kong Polytechnic University (Hong Kong, China). A research-oriented university known for combining cutting-edge research with vocational training, particularly in engineering and the applied sciences.

2. Baden-Württemberg Cooperative State University (Germany). A leading institution that exemplifies the practice-oriented model through its dual education system, blending academic learning with hands-on industrial experience.

3. University of Birmingham (United Kingdom). An institution that has adopted the integrated model, balancing strong research components with practical applications, particularly in its AI and computer science programs.

4. Olin College of Engineering (United States). A research-focused institution that emphasizes project-based learning and interdisciplinary collaboration, preparing students for both academic research and industry challenges.

The inclusion of research-oriented universities, namely Hong Kong Polytechnic University and Olin College of Engineering, was purposeful and critical to this study. While these institutions are not traditionally classified as vocational universities, their strong focus on combining research with practical education offers valuable insights into how vocational education can benefit from a research-driven approach. These universities demonstrate how undertaking advanced research can enhance students' technical skills, foster innovation, and prepare graduates for complex challenges in both industrial and academic settings. By including these institutions, we were able to more broadly examine how different educational models can contribute to the cultivation of high-quality technical and skilled professionals than if we had only included institutions with traditional vocational education frameworks.

Research framework

Before we compared the overseas universities of applied science with Chinese technical and vocational education and training universities, it was crucial to establish a robust comparative framework grounded in educational theories to ensure that the comparison was systematic, comprehensive, and revealed meaningful insights and valid conclusions. The research framework utilized in this study is structured around three key dimensions: talent development objectives, curriculum structure, and resource assurance measures.

The talent development objectives dimension focuses on the goals and outcomes that each educational institution aims to achieve in developing high-quality technical and skilled professionals. It includes an examination of how different universities define and prioritize the competencies, skills, and knowledge that graduates should possess. In this study, we analyzed the alignment between these objectives and the industrial and societal needs of both overseas universities and Chinese universities.

The curriculum structure dimension evaluates the design and organization of educational programs. This includes analyzing the balance between theoretical knowledge and practical training, the integration of interdisciplinary studies, and the use of project-based learning. The dimension also considers how curricula are tailored to meet the specific demands of various industries and how they prepare students for the workforce. By examining these elements, we assessed the effectiveness of different curriculum models in achieving the talent development objectives.

The resource assurance measures dimension examines the resources and support systems in place to ensure the successful implementation of educational programs. It includes the availability and quality of faculty, the infrastructure for practical training (*e.g.*, laboratories and workshops), and partnerships with industry. In this study, we also considered the extent of internationalization and collaboration with global institutions. These resource assurance measures are critical for maintaining high standards of education and for fostering an environment in which students can thrive.

Analysis and categorization of practices

The data analysis involved systematically reviewing the collected data to identify common themes and distinctive features in the educational practices of the selected institutions. The universities were then categorized as adopting one of the following three types of primary models.

Research-oriented model

Universities that adopt this model emphasize the blending of research activities with vocational training. They focus on developing their students' ability to innovate and preparing them for advanced roles in research and development. Hong Kong Polytechnic University adopts a research-oriented model.

Practice-oriented model

Universities in this category prioritize hands-on training

and direct industry engagement. The curriculum is designed to equip students with practical skills that are immediately applicable in the workforce. A notable example is Baden-Württemberg Cooperative State University.

Integration-oriented model

Universities that adopt this model combine research and practical elements to prepare their students for versatile roles in both academic and industrial settings. The University of Birmingham's programs in AI and computer science exemplify this integrated approach.

The categorization was achieved by analyzing how each university structures its programs, the extent of industry involvement, and the balance between theoretical and practical components. This structured analysis allowed for a clear distinction between the three models, providing valuable insights into how these practices could inform and enhance vocational undergraduate education in China.

RESULTS

The research-oriented model: the aviation engineering program at Hong Kong Polytechnic University and Olin College of Engineering

In this section, we present two institutions, Hong Kong Polytechnic University and Olin College of Engineering, as exemplary cases of institutions that have adopted the research-oriented model for their undergraduate vocational educational offerings. Hong Kong Polytechnic University is a world-class research university located in Hong Kong, China, renowned for its robust academic research, exceptional professional education, and impactful community service. Its engineering disciplines are consistently ranked among the best in the world, which reflects the university's deep commitment to excellence in both theory and practice.[17] Likewise, Olin College of Engineering is distinguished by its innovative educational philosophy that prioritizes interdisciplinary learning and practice-oriented teaching methodologies. By emphasizing practical experience and innovation, Olin College of Engineering engages students in real-world engineering projects, empowering them to solve pressing challenges. Furthermore, it encourages an entrepreneurial spirit, teamwork, and interdisciplinary collaboration, underpinning its commitment to holistic student development. The curriculum at Olin College of Engineering is centered on practical applications, with an emphasis on extensive project work and laboratory experience.[18] In general, both institutions have adopted a research-oriented approach. Their overall curriculum systems are depicted in Figure 1.

Educational objectives

In engineering education, the traditional approach often falls short by being overly narrow and constraining students to merely respond to predetermined queries rather than nurturing their ability to independently identify and address problems. This approach also fails to effectively bridge the divide between the laboratory and the real world, hindering students' ability to translate theoretical knowledge into tangible solutions. However, the training objectives of Hong Kong Polytechnic University and Olin College of Engineering focus on cultivating engineers who are equipped with interdisciplinary skills, innovative thinking, and an entrepreneurial spirit and can spearhead future industrial advancements. In alignment with their educational vision, each of these institutions aspires to produce engineering leaders who possess a solid foundation in engineering principles and professional knowledge and a broad understanding of the societal implications of engineering. They emphasize the importance of creativity in proposing novel solutions to contemporary engineering challenges, and they highlight the entrepreneurial mindset needed to transform ideas into reality. Both universities underscore the significance of understanding human needs, values, and the societal roles of engineering. Students are encouraged to learn how to conceptualize engineering innovations that can transform society and serve its needs. Hong Kong Polytechnic University, for example, emphasizes that it "provides students with a high-quality, holistic education aimed at nurturing 'leaders of tomorrow' who embody a strong national identity, global perspective, and social responsibility" and that it "prioritizes impactful innovation and interdisciplinary research to tackle the world's most pressing challenges, with a focus on knowledge transfer and fostering an entrepreneurial culture that transforms research into practical applications."[19]

Curriculum system

In terms of curriculum design, both institutions underscore the importance of open-ended, project-based, and hands-on teaching and learning experiences. In this section, we take Olin College of Engineering as a prime example to elucidate this point. First, its open-ended approach is prominently demonstrated through its commitment to providing interdisciplinary learning experiences. The college aims to forge robust connections not only between the basic sciences, including mathematics and engineering, but also across the arts, humanities, social sciences, and technology-related disciplines. Furthermore, Olin College of Engineering actively seeks to equip students with business acumen and entrepreneurial skills in addition to knowledge of engineering technologies, preparing them for the multifaceted challenges of the modern world. This interdisciplinary focus is evident in the freshman

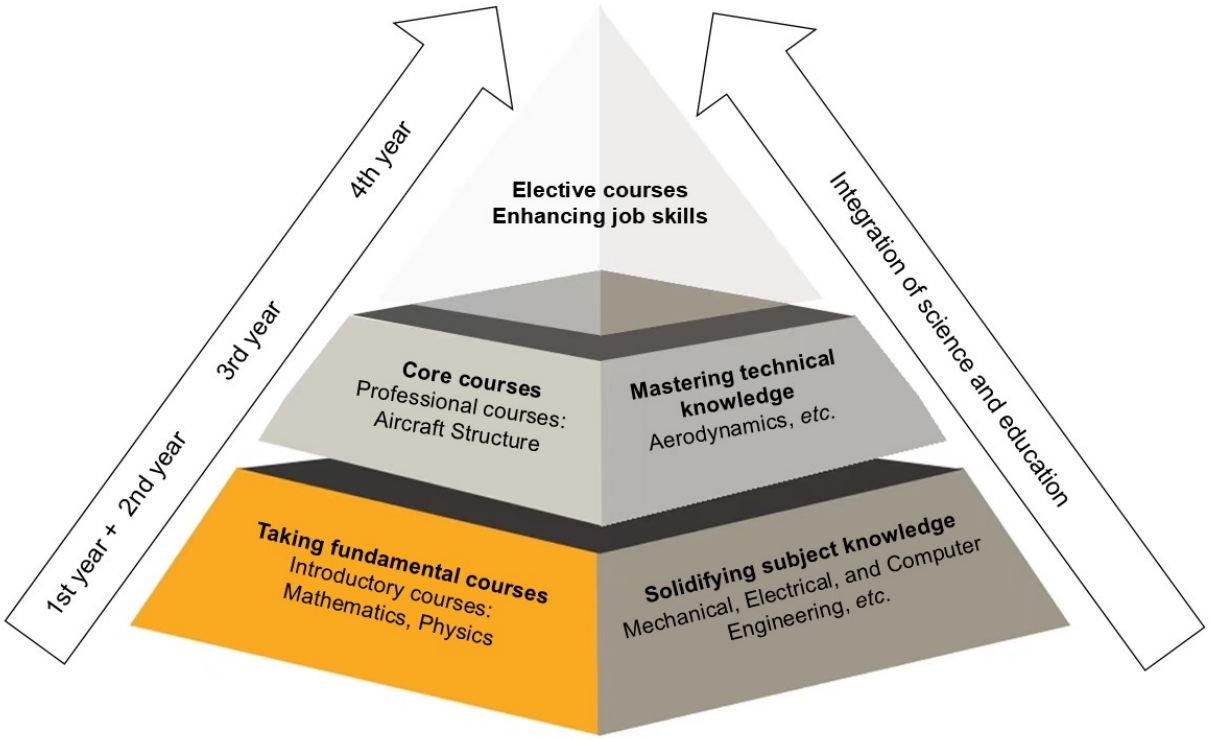

Figure 1. The "pyramid" curriculum system of the aviation engineering program at Hong Kong Polytechnic University and Olin College of Engineering.

curriculum, which incorporates engineering, calculus, and physics modules and thus invites students to delve deeply into these interconnected subjects and develop a comprehensive understanding of their interrelationships.

Olin College of Engineering prioritizes developing the ability to integrate engineering into real-world applications as early as possible. Rather than undertaking two years of theoretical study without practical exposure, students at Olin College of Engineering are immersed in project-based work within college-affiliated factories in their first-year courses. This creates a learning environment in which theory meets practice. Students enrolled in majors in mathematics, science, engineering, and other disciplines have the opportunity to gain hands-on experience in modeling and simulation. This approach allows students to not only develop skills in experimental design and prototype creation but also to utilize advanced instruments, which enhances their understanding and proficiency in these areas.

Olin College of Engineering's open-ended projects ultimately converge in a pivotal capstone research design project that spans two semesters. This ambitious undertaking involves thoroughly researching, designing, and working on genuine, real-world projects sourced from reputable industry partners. The "Capstone Design Project" is mandatory for fourth-year students and encompasses two distinct components. In the first component, the "Engineering Senior Consultancy Project", teams are handpicked by companies, nonprofit organizations, or venture capital firms to embark on authentic engineering endeavors. In the second component, the "Humanities, Arts, and Social Sciences" or "Entrepreneurship Capstone Project", students are required to conceive a design project or a startup blueprint that aligns with their academic major.[20]

Resource assurance measures

The analysis of the resource assurance measures in both institutions revealed two significant features. First, both institutions have established an internationally diverse faculty. For instance, Hong Kong Polytechnic University has assembled a high-caliber, global faculty comprised of members from top universities, including Harvard University, the Massachusetts Institute of Technology, the University of Cambridge, and Stanford University. Almost all faculty members possess international academic backgrounds, with many having conducted groundbreaking research in renowned scientific and industrial laboratories or exhibiting diverse disciplinary expertise. Employing such illustrious faculty members supports the cultivation of interdisciplinary professionals.[21]

Second, both institutions have established robust interdisciplinary research and management platforms, with three distinct aspects. The first is the presence of dedicated organizations tasked with overseeing interdisciplinary curriculum affairs. These organizations consist

of esteemed professors from diverse faculties and focus on designing interdisciplinary courses that offer students a broad spectrum of learning opportunities and encourage participation in cross-disciplinary research projects. This approach ensures that students gain a multifaceted education that includes the development of their innovation and critical thinking skills. The second aspect is that both institutions have established numerous interdisciplinary research centers, which fosters a collaborative environment in which researchers from different faculties can work together. Members of these teams hold "dual appointments", allowing them to maintain their primary teaching responsibilities within their respective faculties while engaging in collaborative research activities within the centers. This approach fosters cross-disciplinary collaboration and innovation, driving advancements in various fields. The third aspect is that both institutions have made significant efforts to promote the translation of interdisciplinary knowledge. Recognizing the importance of protecting and applying interdisciplinary intellectual property, they have implemented comprehensive achievement transformation and intellectual property management systems. These systems have been instrumental in facilitating numerous interdisciplinary knowledge translation projects, furthering advancements and innovations across various fields.[22] By fostering a culture of collaboration and innovation, these institutions are poised to make significant contributions to the global academic landscape.

The integration-oriented model: university of Birmingham

This section focuses on the bachelor's degree in AI and computer science offered by the University of Birmingham as an exemplar of the use of the integration-oriented model. Renowned for its harmonious blend of research and practical components, the University of Birmingham has a long-standing commitment to supporting local economic development. As a prestigious "red brick" university and a leading member of the Russell Group, it achieved a ranking of 13th in the most recent Research Excellence Framework.

With the rapid advancements in next-generation information and communication technologies (ICTs), including AI, big data, cloud computing, and the IoT, there is a growing demand in the UK for skilled professionals adept in modern high-tech applications. To address this need, the University of Birmingham offers a four-year bachelor's degree in AI and computer science under the auspices of the College of Engineering and Physical Sciences. This program is designed to foster the development of versatile professionals through an integrated theoretical and practical application model that is unique to the University of Birmingham. It provides a comprehensive framework for nurturing students into graduating as well-rounded professionals prepared to contribute to the dynamic world of AI and computer science.[23]

Educational objectives

The educational objective of the four-year bachelor's degree in AI and computer science at the University of Birmingham is evident in its aspiration to cultivate individuals who possess a robust theoretical foundation, coupled with strong professional adaptability and job readiness skills. This program aims to provide students with a balance of theoretical knowledge and practical experience, as well as job-specific competencies and versatile general capabilities. This program emphasizes the application of theoretical research findings to tackle societal challenges and is thus distinct from vocational skills-based education programs, which primarily focus on the skills needed to undertake practical problem-solving within specific job roles. This comprehensive approach to capability development necessitates not only the mastery of practical skills but also a profound understanding of theoretical concepts.[24] Leveraging its reputation as a research-intensive institution, the University of Birmingham prioritizes the nurturing of individuals with advanced research capabilities. It meticulously integrates theoretical teaching and learning to meet stringent theoretical standards, and subsequently supports the development of practical skills. This two-pronged strategy aligns perfectly with the educational goal of providing students with a "solid theoretical foundation + application capability", thereby ensuring that graduates are well-equipped to make meaningful contributions to the AI and computer science landscape.

Curriculum system

After conducting a thorough review of the pertinent documents and policies, we concluded that the curriculum system for the four-year bachelor's degree in AI and computer science program adheres to a set of principles that underscore skill enhancement, a seamless industry-academia relationship, holistic student development, and sustainability. Notably, this program adopts a "sandwich" model (Figure 2); it is characterized by a cyclical progression of "theory-practice-theory", which results in a unique talent development trajectory. It is underpinned by robust teaching and operational mechanisms, which are collaboratively supported by the university, government, and industry partners. Furthermore, the program boasts a comprehensive competency assessment system that underscores the importance of "university-enterprise cooperation" and "industry-academic alliances". The program's strategic partnerships with industry players not only ensure that students receive cutting-edge theoretical knowledge but

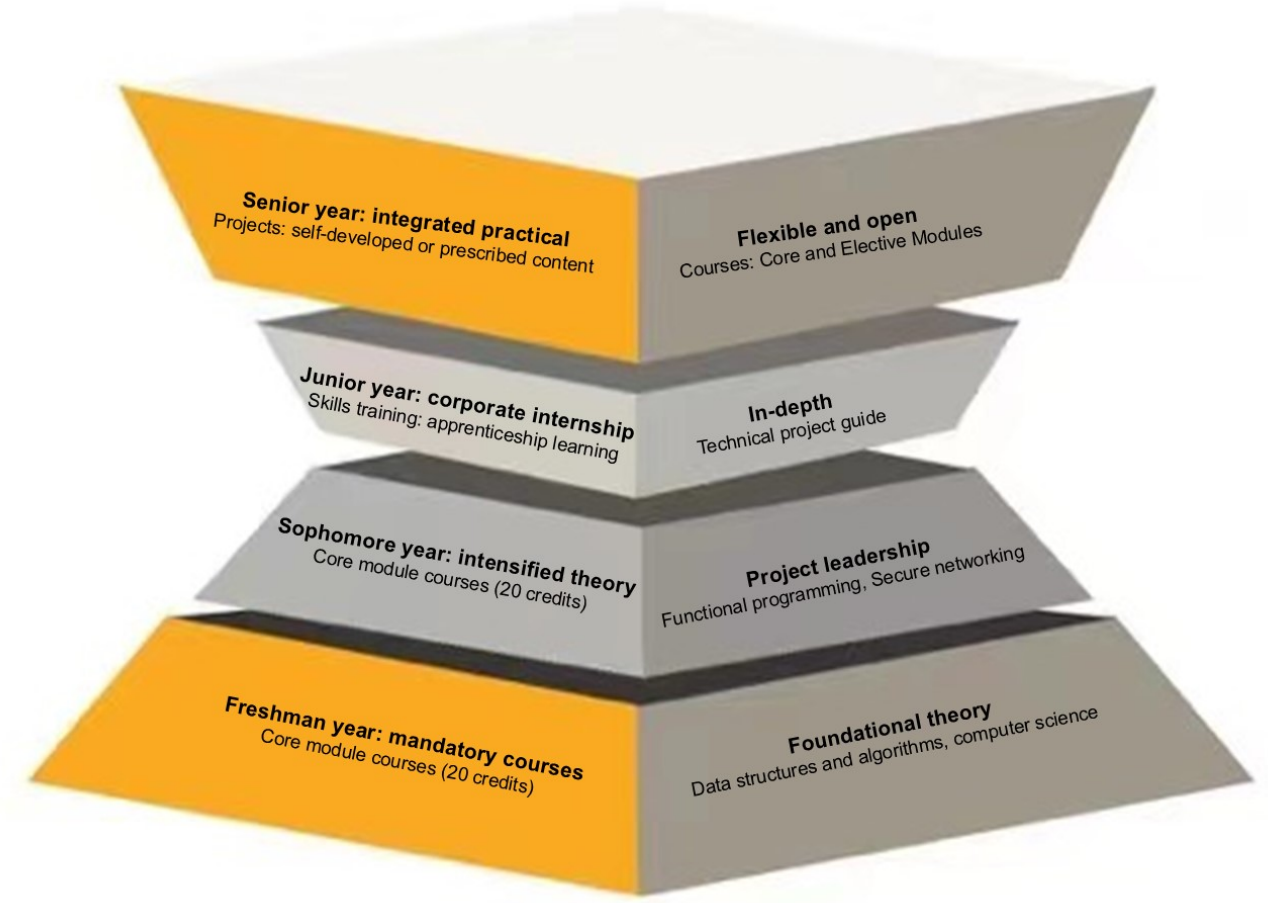

Figure 2. The "sandwich" curriculum system of the University of Birmingham.

also have ample opportunities to apply their skills in real-world settings, thereby bridging the gap between academia and industry.[25]

In the first two years, students focus on developing their theoretical knowledge. During the first year, students take compulsory courses that primarily cover cognitive theories, technology for intelligent behavior generation, fundamental computer science principles (*e.g.*, AI), data structures and algorithms, full-stack application development, mathematical and logical foundations of computer science, and object-oriented programming. In the second year, students delve deeper into foundational topics in computer science, including databases, formal foundations of graphics, programming languages, and other supporting technologies. Additionally, students are required to complete an AI-based team project to gain experience in collaboratively developing software. The knowledge gained from these modules is expected to enhance the student's comprehension and ability to complete the final year project.

The third year is dedicated to undertaking an industrial internship consisting of projects that reinforce the students' theoretical knowledge. During this time, students are immersed in real-world scenarios and gain real-world knowledge. The university has long-standing cooperative relationships with numerous enterprises and government departments that host the students. Student placements and internship positions are jointly determined by enterprise recruitment standards and school recommendations, paving the way for a year-long industrial internship. The university collaborates with the host enterprises to design the internship plans and content, oversee the training process, and conduct joint assessments. The internship comprises both skills training (approximately 40%) and technical project work (approximately 60%). This internship year provides students with firsthand industrial experience, bridging theory and practice. It deepens students' understanding of their profession, enhances their practical skills, and allows them to develop a deeper understanding of society through practical work. Furthermore, it sharpens students' skills in teamwork, expression, communication, and collaboration, ultimately enhancing their overall competency.

During the final year, students spend one-third of their time working independently on a major project, which primarily involves the development of large-scale software. The project topic can be proposed by either the supervisor or the student. During the remaining two-thirds of the fourth year, students complete advanced courses. They choose their courses from over 20 courses available that cover a range of topics, including specialized AI topics, such as intelligent robotics, neural computing, and advanced natural language processing. The topics taught in these courses are at the forefront of the fields of AI and computer science. Thus, the students who take these courses must have a solid theoretical foundation and practical experience. In turn, taking these courses enhances the students' abilities to think and combine theory with practice.[26]

Resource assurance measures

In terms of faculty resources, each student is assigned a personal tutor upon enrollment who acts as a companion throughout their university journey, offering comprehensive support for the student's academic, personal, and professional development. The college further offers a selection of group tutorials and mentorship programs, where students can seek guidance from experienced tutors and peers on any academic challenges they encounter.

As part of its commitment to faculty development, the university maintains partnerships with leading global enterprises, which enables students to benefit from mentorship by accomplished industry professionals during their industrial placement year. When recruiting school tutors, the university selectively hires outstanding educators from around the world who are renowned for their exceptional research and teaching prowess. Furthermore, to bolster the employability of its graduates, the university and its constituent colleges offer tailored career services, providing personalized career guidance to help students navigate their professional aspirations. This comprehensive network of support, which encompasses personal tutors, school tutors, industry mentors, career advisors, and senior peers, transcends the limitations of singular guidance and thus ensures that students receive multifaceted yet complementary information tailored to their unique needs.[27]

In terms of resources and facilities, the college strives to foster group collaboration and continuous teacher-student interaction. It provides ample collaborative spaces throughout its buildings, cultivating a comfortable and conducive environment for communication between and among teachers and students. As a world-renowned research university, the University of Birmingham offers students access to cutting-edge practical platforms and equipment. More specifically, it is a premier hub for AI teaching and research in Europe, housing high-tech laboratories focused on medical imaging, intelligent robotics, human-computer interaction, and security research. Furthermore, the university boasts a comprehensive computer science library, robotics teaching laboratories, and dedicated computing laboratories tailored exclusively for and catering to the specific needs of computer science majors. In addition, recognizing the importance of real-world experience, the university maintains robust partnerships with leading enterprises, offering students international and domestic internship opportunities, all guided by seasoned industry mentors. This holistic approach ensures that students receive a well-rounded education grounded in theory and enriched by practical experience.[28]

The practice-oriented model: Baden-Württemberg Cooperative State University

The "dual system" utilized by universities of applied sciences represents a distinctive and innovative model used in the German higher education landscape, it effectively combines the resources of academia and industry. Baden-Württemberg Cooperative State University, located in Stuttgart, Baden-Württemberg, is the pioneer institution in Germany that seamlessly blends academic research with on-the-job training, setting the benchmark in Germany. Stuttgart, renowned for its robust and innovative ecosystem and prominent position in the German economy, provides an unparalleled geographical advantage and a high-quality training ground for technical professionals. The educational model adopted by Baden-Württemberg Cooperative State University is rooted in the dual system, which is possible due to the formation of intimate collaborations between vocational colleges and industry partners. In this system, theoretical learning is interwoven with hands-on practical training, ensuring that students receive a comprehensive and meaningful education.[29]

"Dual spiral" talent development objectives

At the core of Baden-Württemberg Cooperative State University's Bachelor of Mechanical Engineering program is a practice-oriented talent development model. The overarching goal of the program is to cultivate graduates who possess both profound theoretical knowledge of mechanical engineering principles and practical application expertise. The program's educational objectives have been meticulously crafted and specify that students can expect to gain a deep understanding of mechanical engineering fundamentals and advanced-level competencies (*e.g.*, engineering structural analysis) so that they are ready to navigate the challenges that exist in the field. Crucially, the objectives are strategically aligned with the ever-

evolving demands of the industry; thus, graduates from this program have a competitive edge and are highly sought-after. By aligning the objectives with future employers' demands, this program aims to provide its graduates with a myriad of career prospects and avenues for their professional advancement and opportunities to make meaningful contributions to the field of mechanical engineering and beyond.

"1 + 1 + 1 + 1" curriculum structure

The Bachelor of Mechanical Engineering program at Baden-Württemberg Cooperative State University embraces a distinctive and innovative "1 + 1 + 1 + 1" curriculum structure. This structure meticulously integrates core, general, and regional modules and corporate internships, creating a "dual spiral" curriculum design (Figure 3). Core modules (the first "1") that encompass essential content form the foundation of the program. They are enriched with practical elements and are mandatory for all students, regardless of their future specialization. These modules are predominantly offered during the first two years. General modules (the second "1") are typically introduced during the second and third years. These compulsory modules span diverse specializations and broaden students' horizons, fostering a holistic understanding of the engineering landscape. Complementing the core and general modules are the regional modules, which are tailored to address local economic needs and are unique to each campus. These specialized modules enrich the curriculum and ensure that the educational offering is relevant and responsive to regional issues. Central to the program's philosophy is its alternating semester structure that seamlessly blends internships and academic study. In the internship semester (another "1"), students gain practical work experience and invaluable hands-on skills. This is followed by a semester of intensive academic study (the final "1"), in which students further develop their theoretical mechanical engineering knowledge, reinforce their understanding, and apply practical insights gained during their internships.[30]

The successful implementation of this curriculum structure necessitates a highly specialized and integrated educational arrangement. The program's educational framework is built upon two pivotal aspects that synergistically enhance student learning. First, students engage in academic study in classrooms, and this involves theoretical knowledge acquisition and academic guidance. Second, students undertake practical learning during their internships, and this transforms working environments into dynamic learning venues. Here, students apply their theoretical knowledge, hone their professional skills, and gain invaluable practical experience. Internships at esteemed partner companies across Germany offer students a unique opportunity to gain insights into industry practices, positioning them favorably for future career endeavors.[31] Furthermore, because the mechanical engineering program incorporates the dual system, its students continually alternate between studying at the university and working in practical settings, which creates a seamless connection between theory and practice. This approach not only deepens students' comprehension of theoretical knowledge but also cultivates their problem-solving abilities, preparing them to tackle the complex challenges of the mechanical engineering industry.

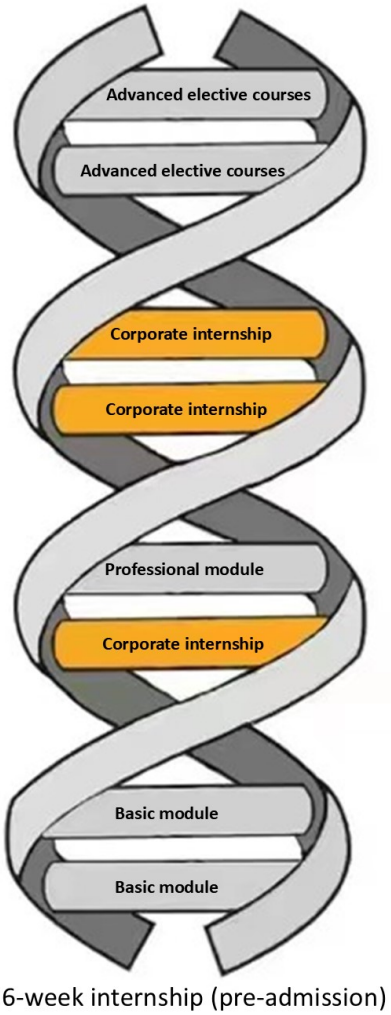

Figure 3. The "dual spiral" curriculum structure of Baden-Württemberg Cooperative State University.

In summary, the Bachelor of Mechanical Engineering program at Baden-Württemberg Cooperative State University emphasizes practical education and close collaboration with enterprises. By employing a dual-system approach, the university provides students with rich practical and academic experiences and a solid foundation for their future career development. The aim of implementing this curriculum structure is to cultivate graduates equipped with extensive mechanical

engineering knowledge and practical application skills.

Rigorous assurance system

Baden-Württemberg Cooperative State University has a comprehensive assurance system for the development of vocational and technical skills that emphasizes three pivotal aspects: faculty expertise, practical training platforms, and course quality assurance mechanisms. This approach guarantees that students receive superior education and training.

First, the university sets rigorous standards for its faculty members. Professors are required to possess a doctoral degree and have accumulated over five years of professional experience in their respective fields, with at least three of those years spent gaining hands-on experience in enterprises. This criterion ensures that faculty members have a strong academic foundation and practical work experience and can thus seamlessly blend theoretical knowledge with practical insights to provide students with valuable information. Moreover, the university actively cultivates a robust academic community by engaging a diverse array of industry experts as part-time and guest lecturers. Their invaluable contributions significantly enrich the curriculum by infusing it with cutting-edge content that is intricately tied to current industry demands and trends.

Second, the university offers a wide range of practical opportunities tailored to empower students and foster their growth. Among these are industry projects and case studies, which serve as powerful platforms for students to translate their classroom knowledge into real-world solutions. These immersive experiences encourage collaboration with industry professionals, enabling students to refine their practical working abilities and develop a deep understanding of industry dynamics. Implementing a practice-oriented approach is paramount to supporting the students' future career development, as practice-oriented programs equip students with the skills and knowledge necessary to excel in work environments. Moreover, collaborating on industry projects and engaging with professionals allows students to develop their professional networks, which are instrumental to their future employment prospects.

Finally, the university uses a series of rigorous quality assurance measures to ensure course quality. The Educational Quality Assessment Committee oversees teaching quality assurance, and its responsibilities include setting quality standards, evaluating the teaching process, collecting student feedback, and proposing improvements. Establishing this type of committee ensures that the quality of the education provided is continually monitored and supervised. Furthermore, a quality monitoring platform is in place to conduct regular professional development quality assessments of courses. This involves reviewing and evaluating course content and teaching methods to ensure they meet the latest industry standards and requirements. These measures also support ongoing improvements and updates to the curriculum.[32]

DISCUSSION

The findings of this study highlight the effectiveness of different educational models employed by overseas universities of applied science in cultivating high-quality technical and skilled professionals. Examining the use of these models, categorized as research-oriented, practice-oriented, and integration-oriented, has provided valuable insights for enhancing vocational undergraduate education in China. To further substantiate these findings, it is important to consider them in the context of the existing literature on vocational education and training.

First, our findings on the use of the research-oriented model, in which research activities are combined with vocational training, align with the findings of Wu,[33] who argued that integrating research into vocational education can enhance students' innovative capacities and better prepare them for high-level technical roles. Our findings support this view, with the analysis of Hong Kong Polytechnic University showing that incorporating a substantial research component can significantly contribute to the development of students' problem-solving skills and technical expertise.

Second, our findings on the use of the practice-oriented model, in which hands-on training and industry engagement are prioritized, are consistent with the conclusions drawn by Willert *et al.*,[34] who emphasized that close collaboration between educational institutions and industry bodies is essential for equipping students with the practical skills required in the workforce. Baden-Württemberg Cooperative State University serves as a prime example of how such collaborations can lead to the successful blending of theory and practice, ensuring that graduates are well prepared for their professional careers.

Third, our findings on the use of the integration-oriented model, in which theoretical knowledge is balanced with practical application, resonate with those of Cao,[35] who highlighted the importance of a holistic approach to vocational education that includes both rigorous academic training and real-world experience. The University of Birmingham's strategy of combining theoretical studies with industrial internships supports this perspective, demonstrating that a well-rounded curriculum can produce graduates who are both academically proficient and practically skilled.

However, our findings also reveal areas where existing models could be further refined. For instance, while applying the research-oriented model offers significant advantages in terms of fostering innovation, Lucas *et al.* argued that an overemphasis on research might detract from the development of practical skills, which are equally crucial for vocational education.[36] This observation underscores the need for a balanced approach, as seen in the integration-oriented model, where equal importance is placed on both research and practice.

In conclusion, the findings of this study are consistent with and support the findings described in the existing literature on vocational education, which underscores the importance of aligning educational practices with industry needs, fostering innovation, and ensuring that students are equipped with both theoretical knowledge and practical skills. These insights not only validate the models identified in this study but also offer a roadmap for refining vocational undergraduate education in China, ensuring that it meets the evolving demands of the modern economy.

Implications for undergraduate-level vocational education in China

Strategic choices in educational ecology: balancing practical and research orientations

Undergraduate-level vocational education is relatively new in China—it has been in place for only five years—and the need for this type of education stemmed from the pragmatic requirements of our ever-evolving society. Despite still being at an embryonic stage of growth, the undergraduate-level vocational education sector in China has a solid foundation, and there is immense potential for it to evolve and adopt a holistic, integration-oriented model. This transformation will require a gradual shift toward a more research-intensive approach to foster critical thinking, problem-solving skills, and an intellectual curiosity that complements practical training.

In China, advancing vocational undergraduate education will involve finding the equilibrium between external factors, including national and societal imperatives, and internal educational dynamics. It must also seamlessly align with national strategic development priorities, and play a role in driving the transformation and upgrading of the industrial sector. Furthermore, the component programs must be based on a market-responsive approach and consist of strategically crafted curricula that resonate with the needs of emerging, future, and pillar industries. Concurrently, closing the academia-industry gap is paramount. This will entail strengthening university–enterprise partnerships, nurturing collaborations that transcend traditional boundaries, and ensuring that theory and practice are seamlessly intertwined. Taking such steps will not only enhance the relevance and applicability of the education provided but also ensure that graduates are equipped to adapt and respond in innovative ways to the ever-changing industrial landscape.[37]

Talent cultivation positioning: distinguish technical from skill-based modes

According to the guidelines published by the Ministry of Education,[38] the aim of providing vocational undergraduate education is to develop high-level technical and skilled professionals. This educational objective is to be achieved by combining vocational and professional training at the bachelor's level to effectively transcend the dichotomy of technical and skill-based training modes. Consequently, an integrated framework that encompasses bachelor's, professional master's, and professional doctoral degrees in vocational education should be developed and implemented to collectively foster the production of advanced technical and skilled professionals suited to the evolving demands of modern society and industrial progress. This integrated mode of talent development emphasizes the comprehensive development of students to produce professionals who are innovative, technically adept (in terms of their knowledge and skills), understand the principles underlying technologies, and are capable of collaborating across disciplines.[39]

Talent cultivation standards: equal emphasis on theoretical and practical knowledge

Institutions that offer vocational undergraduate education ought to adhere to a set of standards that ensure their graduates possess robust foundational knowledge, a comprehensive understanding of technical principles, proficiency in technologies, interdisciplinary knowledge, and a pronounced innovative mindset. Standards should also be implemented to ensure that graduates are adept in innovative thinking and have a creative spirit and entrepreneurial abilities. Institutions should also be required to provide their students with a harmonious blend of coursework and exposure to technical research and development.

This type of education transcends the mere augmentation of vocational training with undergraduate courses; institutions must offer students opportunities to acquire comprehensive knowledge (including theoretical knowledge), sophisticated professional competencies, and a robust technical skillset. There must be an emphasis on gaining hands-on experience in industrial frontline practices, tool utilization methodologies, and product manufacturing techniques, as well as on examining and developing innovative solutions for the real-world issues encountered during internships and

placements. Vocational undergraduate education is centered on imparting technical knowledge, mastering underlying principles, and refining technical competencies through a blend of theory and practice. More specifically, engineering programs should produce engineers who are adept at onsite engineering, have knowledge of applied technologies, and can combine theoretical learning with practical experience.[40] This approach underscores the importance of scenario-based practical teaching, tailored to real-world work contexts, thereby ensuring graduates are well-equipped to contribute effectively to the engineering profession.

Educational process: boosting industry-academia integration

Based on the above analysis, it is clear that vocational undergraduate education programs should seamlessly integrate training in industry-specific professional skills, align the content of courses with industry needs, and infuse classrooms with realistic workplace scenarios. The teaching methodologies utilized should also mirror the methods used in workplaces to further minimize the gap between academia and industry. Analyzing job posts and core technologies and establishing partnerships with enterprises could enable the development of not only teaching and learning processes that better reflect those in workplaces but also symbiotic university–enterprise relationships. Taking such steps can help to provide more learning opportunities inherently linked to the practical application of knowledge.[41]

Faculty construction: balancing the master craftsmen and expert models

Institutions offering vocational undergraduate education should adopt the dual-teacher model. In this model, industry-specific expertise is combined with academic proficiency. Teachers must possess considerable professional theoretical knowledge, a wealth of practical experience, an international perspective, and exceptional technical innovation abilities. To enhance the effectiveness of their programs, institutions offering vocational undergraduate education must prioritize employing teachers with applied research technical competencies, practical teaching skills, and the capacity to mentor students in areas such as technological innovation, research and development, and the translation of achievements into practical applications. Additionally, it is imperative to establish mechanisms that allow faculty to conduct enterprise-based research and undertake continuing professional development through on-the-job learning.[42] Institutions that adopt the dual-teacher model will be well positioned to produce high-caliber technical and skilled professionals, as the quality of their educational offerings will align with industry standards and they will be responsive to the evolving social and economic development needs.

CONCLUSION

The study provides valuable insights into the practices of esteemed overseas universities in cultivating high-quality bachelor's degrees in vocational education. By analyzing the training objectives, curriculum design, and support systems of these programs, the study identified three distinct models: research-oriented, practice-oriented, and integration-oriented. These models offer a range of approaches that can be adapted and implemented in China to address the challenges faced by pilot programs offering undergraduate-level vocational education. By incorporating these insights and practices, China can develop a skilled workforce that is better equipped to meet the demands of a rapidly evolving economy. Ultimately, this study contributes to the ongoing effort to improve the quality and relevance of vocational education in China and globally.

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Author contributions

Li RJ: Conceptualization, Methodology, Writing—Original draft. Zheng YQ: Data Curation, Formal Analysis, Writing—Review and Editing. Ren KX: Investigation, Resources, Supervision. Huang DY: Software, Validation, Visualization. Zhao HL: Funding acquisition, Project administration. Sun J: Data curation, Formal analysis. Zhang W: Methodology, Supervision. Mei XX: Writing—Review and Editing, Visualization. Yang Z: Conceptualization, Project Administration, Writing—Review and Editing. All authors have read and approved the final version of the manuscript.

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The author has no conflicts of interest to declare.

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