

Deep Integration of German Language Teaching and Mechanical Engineering Knowledge: A Curriculum Reform Practice in Sino-German Cooperative Education Programs

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Abstract: Against the background of the integration between the “Made in China 2025” strategy and Germany’s “Industry 4.0” initiative, mechanical engineering programs in Sino-German cooperative education urgently need to address the separation between language education and professional training. Based on the concept of Content and Language Integrated Learning (CLIL), this study incorporates constructivist learning theory, intercultural communication competence theory, and Outcome-Based Education theory to explore approaches for deeply integrating German language instruction with mechanical engineering education. A three-stage progressive and modular curriculum framework consisting of “foundation-core-advanced” was developed. Meanwhile, localized teaching guidelines and case databases were developed, and a collaborative teaching mechanism involving professional instructors and German language teachers was established. In response to challenges such as institutional barriers and resource constraints, corresponding strategies, including the supervision of joint teaching committees and comprehensive support throughout the educational process, were proposed. The proposed reform approach facilitates the simultaneous development of students’ language proficiency and professional understanding, strengthens their ability to solve complex engineering problems in German, and provides a practical framework for transforming international cooperative education from a “simple combination” toward “deep integration.”

Keywords: Sino-German cooperative education; Content and Language Integrated Learning; Curriculum framework development; Collaborative teaching; Mechanical engineering

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1. Introduction

In the context of the profound restructuring of global industrial chains and increasingly intense technological

competition, the cultivation of internationally oriented engineering professionals has become a key strategic factor for enhancing national industrial competitiveness and innovation capabilities. As two major contributors to advanced manufacturing worldwide, China and Germany have gradually expanded their cooperation beyond traditional technology toward collaborative innovation in educational concepts and talent development systems. The alignment between the “Made in China 2025” strategy and Germany’s “Industry 4.0” initiative is not only reflected in the integration of emerging technologies such as smart manufacturing and the Internet of Things, but also places greater emphasis on achieving “soft connectivity” within talent development systems. Against this background, Sino-German cooperative education programs, as pioneering models of internationalized higher education, undertake the important mission of cultivating interdisciplinary engineering professionals with global perspectives and advanced technical knowledge to support China’s industrial transformation and upgrading. However, current practices in Sino-German cooperative mechanical engineering programs are facing a critical transition from “scale expansion” to “quality-oriented development”^[1]. In particular, the separation between “language learning” and “professional education” in traditional curricula has resulted in a disconnect between theoretical learning and engineering practice, which further affects students’ understanding of core professional knowledge and weakens their competitiveness in future scenarios such as international teamwork and engineering innovation^[2]. Therefore, exploring systematic approaches for the deep integration of German language teaching and mechanical engineering knowledge has become a critical issue for overcoming the quality bottlenecks of cooperative education and achieving sustainable development.

Currently, domestic research on Sino-German cooperative education and bilingual integrated teaching mainly focuses on three areas: macro-level policy and educational model exploration, professional German language teaching, and the introduction and application of Content and Language Integrated Learning (CLIL). These studies indicate a gradual shift from macro-level discussions toward more practical teaching-oriented research. However, the mechanisms, implementation pathways, and long-term evaluation systems for achieving “deep integration” remain insufficiently developed. In the field of professional language education, relatively mature discipline-based discourse teaching approaches have been established for teaching professional German to non-native speakers. Nevertheless, most international studies are developed within their own educational contexts, and systematic research specifically targeting German professional education for Chinese students in mechanical engineering remains limited. Therefore, promoting the deep integration of German language teaching and mechanical engineering knowledge represents an essential approach for Sino-German cooperative education programs to respond to national strategic demands, overcome developmental challenges, and achieve high-quality development with enhanced educational value.

The main research contents of this paper include the theoretical framework and demand analysis of deep integration, the design of a “progressive-modular” integrated curriculum system, and the practical reform of major teaching elements. By applying and further extending the CLIL educational concept within localized professional engineering education in China, this study aims to establish an operational CLIL practice framework for mechanical engineering education. The proposed framework contributes to the enrichment and development of intercultural engineering education theories and provides a new interdisciplinary perspective for research on internationalized higher education curriculum development.

2. Theoretical foundations and definition of core concepts

Mechanical engineering programs within Sino-German cooperative education refer to degree-oriented educational programs jointly established by Chinese and German universities in China under the approval of Chinese educational authorities, with a focus on mechanical engineering and related disciplines. These programs are characterized by the introduction of high-quality German curricula, educational resources, and quality assurance standards, the joint development of talent cultivation schemes, and a strong emphasis on engineering practice and university-industry collaborative education^[3,4]. Their primary objective is to develop engineering professionals who possess both a strong commitment to Chinese industrial development and the capability to compete in an increasingly globalized engineering environment. Sino-German cooperative education programs represent more than the transnational transfer of educational resources. They constitute an integrated institutional framework that combines educational philosophies, pedagogical approaches, and academic quality standards from both countries. Therefore, the essence of such programs lies not only in resource sharing but also in the systematic integration of educational concepts and talent development models.

As the theoretical foundation for curriculum development, learning theories play a fundamental role in facilitating the integration of language learning and professional knowledge. In this study, the theoretical framework is established based on constructivist learning theory, intercultural communication competence theory, and Outcome-Based Education (OBE) theory^[5]. Constructivist learning theory views learning as an active process in which learners construct knowledge through interactions between their existing experiences and surrounding social environment. Within the context of Sino-German cooperative mechanical engineering education, this theory provides essential guidance for designing integrated learning experiences^[6,7]. Specifically, it highlights three important principles. First, learning should be embedded in authentic engineering contexts, where German language skills are acquired naturally through participation in engineering problem-solving activities. Second, students should be regarded as active participants in knowledge construction rather than passive receivers of information. Third, professional instructors and German language teachers should form a collaborative learning community, in which technical communication and disciplinary discussions conducted in German promote students' cognitive development. From this perspective, constructivist learning theory provides the psychological and pedagogical foundation for developing student-centered integrated teaching models.

However, language and professional knowledge integration alone cannot fully meet the requirements of international engineering education. For engineers trained in Sino-German cooperative programs, intercultural communication competence represents another essential dimension of curriculum development^[8]. In this study, intercultural communication competence refers primarily to students' ability to understand communication norms within the German engineering context, appropriately adjust communication strategies, and establish meaningful connections between Chinese and German engineering cultures^[9]. It also involves developing an open attitude toward cultural differences while maintaining critical cultural awareness. This perspective emphasizes that integrated education is not simply a process of transferring linguistic knowledge and skills. Instead, it aims to develop students' ability to communicate, collaborate, and make responsible decisions effectively within a global engineering environment^[10,11]. Therefore, the cultivation of intercultural competence represents a crucial cultural dimension of curriculum reform. Different from constructivist learning theory and intercultural communication competence theory, OBE theory emphasizes that curriculum

design should begin with clearly defined learning outcomes and be systematically developed backward from the competencies students are expected to acquire. In this study, the introduction of OBE theory ensures that the deep integration of professional knowledge and language learning is not an isolated teaching innovation, but an outcome-driven and continuously improvable educational system. It provides a clear logical framework for curriculum design, implementation, and quality evaluation.

Overall, the above theories and concepts jointly establish the theoretical foundation of this study. Within this framework, the CLIL “4Cs model” including content, communication, cognition, and culture, serves as the operational framework for implementing integrated teaching. Constructivist learning theory supports the creation of inquiry-based learning environments; intercultural communication competence theory expands the cultural and ethical dimensions of integration; and OBE theory ensures that curriculum reform remains systematic, measurable, and oriented toward learning outcomes. Through the interaction of these theoretical perspectives within the 4Cs framework, this study provides theoretical guidance for curriculum development and the exploration of practical pathways for deep integration in Sino-German cooperative mechanical engineering education.

3. Development of the curriculum framework and implementation pathways for deep integration

Bridging the gap between theoretical conceptualization and practical implementation represents a critical challenge in curriculum reform. Therefore, this study adopts a systematic design approach to translate theoretical principles into actionable reform strategies. A collaborative curriculum reform framework is developed, centered on students’ comprehensive competency development and extending throughout the entire process of engineering talent cultivation^[12]. The framework consists of four interconnected dimensions. First, the overall design philosophy and fundamental principles of curriculum reform are established. Second, the structure and implementation of the integrated curriculum system are presented. Third, supporting elements, including teaching resources and learning environments, are explored. Finally, the development of a collaborative “dual-instructor” teaching mechanism is discussed. Together, these components form a complete implementation framework that connects educational concepts with teaching practices, integrates macro-level planning with micro-level implementation, and transforms static curriculum structures into dynamic learning processes.

3.1. Overall design philosophy and principles of curriculum reform

The curriculum reform proposed in this study follows the principle of “goal integration as guidance, content reconstruction as support, collaborative implementation as the process, and integrated evaluation as feedback.” Rather than making incremental adjustments to existing courses, the reform adopts the OBE philosophy and reconstructs the curriculum system based on the target competency of enabling students to solve complex engineering problems through German-mediated communication. The curriculum design is guided by five fundamental principles. First, the outcome-oriented principle ensures that curriculum modules and teaching activities are consistently aligned with the expected learning outcomes. Second, the systematic principle emphasizes the establishment of a comprehensive reform framework covering curriculum planning, implementation, assessment, and continuous improvement. Third, the collaborative principle enhances the

development of a teaching community involving professional instructors and German language teachers, facilitating interdisciplinary cooperation and knowledge co-construction between teachers and students. Fourth, the progressive and contextualized principle follows learners' cognitive development and language acquisition patterns by designing hierarchical learning tasks from basic knowledge acquisition to advanced engineering applications. Fifth, the cultural integration principle incorporates German engineering culture, professional norms, and technical standards as implicit curriculum components throughout the educational process.

3.2. Design of the integrated curriculum system

To achieve deep integration between German language education and mechanical engineering education, this study develops a three-stage progressive and modular curriculum framework: "language foundation development, professional knowledge enhancement, and comprehensive engineering application." Each stage corresponds to different levels of competency development, forming a continuous pathway from fundamental language preparation to advanced engineering practice.

3.2.1. Stage I: Foundation Integration Module

The foundation integration module aims to establish students' basic German language competence, develop an initial professional vocabulary system in mechanical engineering, and reduce language barriers during early-stage disciplinary learning. To achieve this goal, the traditional *Comprehensive German* course is redesigned around mechanical engineering themes, incorporating fundamental topics such as *Materials Science* and *Mechanics*. Authentic engineering-related materials are introduced to establish an initial connection between language acquisition and professional knowledge development. In parallel, the course *Introduction to Mechanical Engineering German* is established to introduce the formation principles of mechanical engineering terminology, the structure of German technical documents, and effective strategies for reading professional literature. This course provides students with a systematic framework for understanding engineering-related German. Furthermore, introductory courses such as *Engineering Drawing* and *Computer-Aided Design (CAD)* adopt a bilingual transition model. Key technical terms, classroom instructions, and assignment requirements are presented in both Chinese and German ^[13]. Through continuous exposure to German within professional contexts, students gradually adapt to German-based engineering education while developing fundamental disciplinary knowledge, providing essential linguistic and cognitive preparation for subsequent CLIL-based professional courses.

3.2.2. Stage II: Core Integration Module

The core integration module focuses on enabling students to acquire mechanical engineering knowledge through German as a medium of instruction while developing the ability to communicate and document engineering concepts in German. At this stage, core professional courses, including *Mechanical Design*, *Theory of Machines and Mechanisms*, and *Hydraulic and Pneumatic Technology*, are selected for CLIL-based instruction. Course materials, textbooks, and classroom communication are primarily conducted in German, while Chinese explanations are only provided for complex concepts. This approach allows students to develop professional knowledge and language competence simultaneously within authentic disciplinary contexts. To provide additional linguistic support, courses such as *Technical German* and *Academic Writing*

are offered alongside professional courses. These courses specifically target engineering communication skills, including technical descriptions, experimental report writing, and project presentations. Additionally, German engineering project workshops are organized for 1–2 weeks each semester. Students are required to integrate professional knowledge and language skills through engineering projects, completing the entire process from project conception to final presentation in German. Through the coordinated mechanism of “professional knowledge input, language support, and engineering application output,” students progressively develop the ability to apply German in professional engineering contexts.

3.2.3. Stage III: Advanced Integration Module

The advanced integration module aims to enable students to independently apply German in complex engineering practices, including technical information acquisition, international teamwork, and engineering outcome presentation. Within this stage, the course *Internship and Practice in German Enterprises* incorporates both preparation and reflection components. Before entering German enterprises, students receive intensive German training to improve their ability to adapt to professional environments. Students are required to prepare internship reports in German and to review a certain proportion of German academic literature that is cited in the *Graduation Project*. Meanwhile, Sino-German joint graduation projects are developed in collaboration with German partner universities. Through jointly established engineering projects, students participate in cross-border cooperation and complete design tasks together with international partners. This stage ultimately establishes a comprehensive competency development pathway integrating industrial practice, academic research, and international collaboration, promoting the practical application of German as a working language in engineering contexts.

3.3. Development of teaching resources and learning environment

The effective implementation of integrated teaching requires carefully designed teaching resources and immersive learning environments, which together provide essential facilitation for sustainable curriculum reform. Rather than serving as supplementary components, these resources constitute fundamental conditions for facilitating the deep integration of language learning and professional education. To establish a comprehensive resource system, a *CLIL Teaching Guide for Core Mechanical Engineering Courses* is developed to provide structured guidance for the implementation of CLIL-based instruction. The guide specifies unit-level learning objectives, key professional language elements, representative teaching activities, and corresponding assessment approaches, thereby supporting the systematic integration of language and disciplinary content. Meanwhile, an *Engineering German Case Database* is developed based on authentic materials collected from German engineering practices, including enterprise product documentation, technical standards, and academic publications. These resources are classified according to thematic categories and language proficiency levels, enabling their flexible application in classroom instruction, project-based learning, and autonomous learning activities. Beyond resource development, an immersive learning environment is created through the integration of digital platforms and physical learning spaces. Open educational resources, including foreign language MOOCs and virtual simulation platforms, are introduced as extended learning resources. In addition, an *Engineering German Workshop* is established as a dedicated learning space equipped with original German engineering textbooks, software, and collaborative discussion areas. This environment provides students with continuous exposure to professional German

beyond formal classroom settings. Furthermore, an inter-university collaboration platform is established through sustained communication with German partner institutions. Regular online seminars and academic exchanges are organized to advance interaction between students, teachers, and international partners. These initiatives collectively provide the necessary resource foundation and environmental support for the sustained implementation of integrated teaching.

3.4. Development and collaboration mechanism of the “dual-instructor” teaching team

The successful implementation of deep integration ultimately depends on the active participation and collaborative competence of teachers. Therefore, this curriculum reform places particular emphasis on developing a dual-instructor teaching model and establishing a sustainable mechanism for faculty collaboration. For professional instructors, systematic training programs on introductory German teaching methodologies are provided, with emphasis on German classroom communication strategies. In addition, targeted funding is provided to support short-term pedagogical training in Germany, enabling professional instructors to gain international teaching experience and enhance their capacity for bilingual engineering education. For German language teachers, professional development activities are organized to strengthen their understanding of mechanical engineering disciplines. These activities include lectures on mechanical engineering fundamentals, observation of core professional courses, and visits to engineering laboratories. Through these experiences, German language teachers are able to develop a deeper understanding of disciplinary knowledge structures, engineering practices, and authentic professional learning contexts. To ensure sustainable collaboration between the two groups of teachers, a joint curriculum development mechanism is established. Professional instructors and German language teachers collaboratively design course syllabi, develop teaching units, and define both disciplinary and linguistic learning objectives. Through the coordinated development of teaching resources, learning environments, and collaborative faculty mechanisms, a comprehensive support system is established for deep integration. This three-dimensional framework provides a stable and sustainable pathway for integrating German language education with mechanical engineering education in Sino-German cooperative programs.

4. Challenges, strategies, and sustainable development perspectives

4.1. Major challenges in the implementation of deep integration reform

Although deep integration provides a promising pathway for improving the quality of Sino-German cooperative engineering education, its implementation involves complex challenges arising from institutional structures, resource systems, and stakeholder adaptation. These challenges need to be systematically addressed to ensure the long-term sustainability of curriculum reform. The first challenge concerns institutional coordination and management compatibility. Differences between Chinese and German higher education systems exist in educational structures, academic calendars, curriculum organization, and assessment mechanisms. In particular, the German approach emphasizes modularized curriculum structures and continuous assessment, which may not always align with the Chinese assessment model that traditionally relies on final examinations. Moreover, the performance evaluation for collaborative teaching activities between professional instructors and German language teachers remains insufficiently standardized, which may weaken teachers' motivation. The second challenge involves the sustainable development and allocation of teaching resources. The availability of original German teaching materials remains limited, and the

development of localized CLIL teaching resources requires interdisciplinary cooperation between language education and engineering disciplines. In addition, maintaining an immersive German engineering learning environment requires continuous institutional investment. These factors may become significant constraints, particularly during the early implementation stages of curriculum reform. The third challenge relates to the adaptation of teachers and students to integrated learning environments. For students, the simultaneous demands of foreign language learning and professional knowledge acquisition may increase cognitive load and generate learning anxiety. Differences in students' language backgrounds and learning approaches may further result in heterogeneous learning outcomes. For teachers, professional instructors need to develop the ability to communicate complex engineering concepts in German, while German language teachers need to acquire sufficient disciplinary knowledge to participate productively in engineering education. Establishing effective interdisciplinary collaboration therefore requires continuous interaction, adjustment, and professional development.

4.2. Strategic approaches for sustainable implementation

To address institutional challenges, a long-term Sino-German joint teaching committee should be established as a coordination mechanism between participating institutions. The committee can provide systematic guidance on bilingual/German-taught course standards, assessment approaches, procedures for dual-instructor collaboration, and workload recognition mechanisms. Such institutional arrangements can facilitate the transition of curriculum integration from individual initiatives toward sustainable organizational practice. In addition, university management should incorporate contributions to integrated curriculum reform into existing faculty evaluation and incentive systems. Recognition in areas such as promotion evaluation, teaching awards, and professional development opportunities can encourage teachers to actively participate in interdisciplinary teaching innovation. Regarding teaching resources and learning environments, a diversified development strategy combining resource introduction, collaborative construction, and localized development should be adopted. Cooperation with German enterprises should also be strengthened by transforming authentic industrial cases, technical documents, and engineering projects into educational resources. This approach can enhance the authenticity of learning materials and improve students' understanding of real-world engineering contexts. For student and faculty development, a comprehensive support system covering the entire learning process should be established. For students, learning strategy workshops and peer-support mechanisms can be introduced to help them develop effective learning approaches within CLIL environments. Differentiated learning support should also be provided according to students' language proficiency levels and individual learning needs. For teachers, structured professional development pathways should be established through interdisciplinary teaching workshops, collaborative course development activities, and opportunities for teaching observation and professional training in Germany. These initiatives can gradually enhance teachers' capacity to integrate language education with engineering knowledge.

4.3. Future perspectives for sustainable development

The future development of deep integration in Sino-German cooperative education should focus on continuous expansion in both disciplinary scope and educational approaches. First, integration should gradually extend beyond traditional mechanical engineering toward emerging interdisciplinary areas. In response to technological developments in intelligent manufacturing, industrial robotics, and advanced

engineering systems, future curriculum reform should explore new models combining German language education with emerging engineering technologies. Second, digital technologies will provide new opportunities for advancing integrated education. With the support of artificial intelligence and big data technologies, learning analytics can be applied to monitor students' learning behaviors and provide evidence-based support for instructional adjustment and personalized learning. Finally, future research should move beyond individual case practices and develop more generalizable theoretical and methodological frameworks. The development of an integration evaluation indicator system and a CLIL-based curriculum design framework may provide systematic tools for assessing and promoting deep integration. Through these efforts, Sino-German cooperative education can gradually evolve from structural alignment toward genuine educational integration, contributing to the internationalization and high-quality development of engineering education in China.

5. Conclusion

This study investigates the deep integration of German language teaching and mechanical engineering education within the context of Sino-German cooperative mechanical engineering programs. Through the establishment of a theoretical framework, the design of an integrated curriculum system, and the analysis of practical implementation pathways, this study provides both theoretical insights and practical implications for the reform of international cooperative engineering education. The findings indicate that transforming the relationship between language education and professional training from a “simple combination” toward “deep integration” is an important approach for improving the quality of engineering talent development in Sino-German cooperative programs. By integrating language learning with disciplinary education, students' intercultural communication competence and professional competitiveness can be enhanced, enabling them to better adapt to international engineering environments. Furthermore, the progressive and modular curriculum framework proposed in this study provides a structured pathway for achieving the coordinated development of language competence and professional knowledge. Through the three-stage model of foundation integration, core integration, and advanced integration, the framework supports students' gradual transition from basic engineering German acquisition to professional knowledge application and comprehensive engineering practice. The implementation of deep integration is not dependent solely on curriculum redesign, but also requires coordinated support from institutional mechanisms, teaching resources, and faculty development. Accordingly, this study proposes corresponding strategies involving institutional optimization, collaborative resource development, and the establishment of professional development mechanisms for teachers. These measures provide practical references for promoting the sustainable implementation of integrated education models in Sino-German cooperative programs. Future research may further focus on developing quantitative assessment tools to evaluate the degree of curriculum integration and exploring the potential of emerging technologies. Such efforts may further enrich theoretical studies and practical approaches for promoting the quality-oriented development of international cooperative education.

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