

# AI Empowered Exploration of Innovative Teaching Reform Model for International Students in “Interchangeability and Technical Measurement”

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## Abstract

With the continuous expansion of the scale of international students in China, the quality of their education has become a key measure of the level of internationalization in higher education. "Interchangeability and Technical Measurement," as an important foundational course for mechanical engineering majors, faces systemic challenges when teaching international students, including language barriers among faculty, low adaptability of teaching materials, weak practical components, and a single assessment method. The development of artificial intelligence (AI) technology offers new pathways to address these issues. This paper aims to explore the model of AI-enabled teaching reform for this course and proposes an intelligent teaching framework that encompasses three dimensions: teaching resources, practical environments, and evaluation systems. It analyzes the challenges faced during the implementation of this framework, including the transformation of teacher roles, technological sustainability, and data ethics. Furthermore, it presents prospects for future empirical research, knowledge graph construction, and exploration of human-computer collaboration models, providing insights for improving the quality of education for engineering international students.

**Keywords:** international students, artificial intelligence (AI), teaching reform, education for engineering

## 1. Introduction

International student education in China has grown significantly alongside the country's increasing global influence and economic globalization, becoming an integral component of China's higher education internationalization strategy <sup>[1]</sup>. This endeavor not only cultivates globally competent professionals but also promotes cross-cultural understanding through educational exchanges <sup>[2]</sup>.

Mechanical engineering, as a core field supporting the development of modern manufacturing, is one of the popular directions chosen by international students studying in China<sup>[3]</sup>. The "Interchangeability and Technical Measurement" course serves as a foundational technical course for mechanical and related disciplines, aiming to enable students to systematically grasp the core knowledge of interchangeability, standardization, and measurement technology. However, this course presents particular challenges for international students due to its abstract concepts and practical requirements. From a theoretical perspective, these challenges align with principles of cognitive load theory <sup>[4]</sup>. The abstract nature of concepts like "tolerance zones" and "fits" creates intrinsic cognitive load for all learners. For international students facing additional language barriers and cultural differences, this cognitive load becomes exacerbated, potentially overwhelming their working memory capacity and hindering effective learning <sup>[5]</sup>.

The prevailing teaching model, which relies on "textbooks + blackboard + limited experiments," suffers from two major shortcomings. On one hand, the teaching tends to emphasize theoretical instruction, with relatively weak practical components, making it difficult for students to establish intuitive understanding. On the other hand, for international students who encounter language barriers, cultural differences, and varying measurement unit backgrounds (e.g., imperial versus metric), comprehending these abstract concepts becomes exceedingly challenging. Consequently, they often struggle to construct spatial models of precision design in their minds and fail to understand the far-reaching impacts of tolerance selection on product performance, cost, and

manufacturability. This approach fails to provide the contextualized learning experiences essential for constructing meaningful understanding—a key principle of constructivist learning theory [6].

To overcome this teaching bottleneck, it is essential to find teaching methods that can visualize abstract concepts, operationalize complex principles, and provide personalized guidance across languages. The rapid advancement of artificial intelligence technology, alongside successful explorations in the educational field, offers a new and promising pathway to address the aforementioned challenges<sup>[7-9]</sup>. Compared to traditional multimedia or online teaching, AI technologies such as large language models, virtual simulations, and learning data analytics possess core advantages including powerful situational awareness, personalized interaction, and intelligent content generation. These capabilities enable precise responses to the linguistic, practical, and evaluative challenges in teaching international students.

Therefore, this paper proposes a novel model of intelligent teaching reform centered on artificial intelligence technology in response to the systemic challenges in the course. The aim is to facilitate a fundamental shift in teaching methods from "uniform instruction" to "tailored teaching" by constructing personalized learning pathways, virtual simulation laboratory platforms, and intelligent assessment feedback systems. This approach is intended to effectively stimulate the initiative of international students in their learning processes and comprehensively enhance their engineering practice and innovation abilities.

## 2. Current Deficiencies

The teaching of "Interchangeability and Technical Measurement" to international students presents systemic challenges across instructional delivery, learning resources, and assessment practices. These interconnected issues collectively hinder educational effectiveness in three primary domains.

### 2.1 Faculty Linguistic and Instructional Limitations

English-medium instruction is a prerequisite for achieving cross-cultural knowledge transfer; however, it poses significant challenges to faculty members' language proficiency, particularly in terms of real-time spoken expression and interaction in the classroom. Firstly, there are barriers in language expression. Many instructors possess solid subject knowledge but struggle with fluency in spoken English, mispronunciation of technical terms, and vague classroom instructions, making it difficult to accurately explain complex concepts such as "geometric tolerances" and "measurement uncertainty." Secondly, understanding students' expressions can be challenging. The diverse accents of international students from different countries further exacerbate communication barriers. As a result, educators, despite their deep professional expertise, find themselves constrained by linguistic mediums, unable to effectively transform and convey their knowledge. This often leads to insufficient depth in teaching and superficial understanding. For instance, when explaining the difficult concepts of "tolerance zone" and "maximum material conditions," if instructors cannot articulate their physical meanings and application scenarios under different boundary conditions with precision in English, students are likely to become confused about these concepts. Additionally, the comparative explanation of national standards (GB) and international standards (ISO) requires educators to possess a cross-standard teaching perspective, which further amplifies the challenges posed by language barriers. Ultimately, classroom interactions tend to become silent, significantly diminishing the accuracy and depth of knowledge transfer.

### 2.2 Inadequate Adaptation of Learning Resources

At the level of teaching content and methods, the existing teaching system exhibits significant "localization" characteristics, conflicting with the knowledge backgrounds and learning habits of international students. In terms of textbooks, there is a dilemma of "unsuitability." Currently, Translated Chinese textbooks or locally developed English materials often retain content organization and case examples rooted specifically in China's industrial context [10]. For example, when discussing precision design for "keys and splines," if the discussion is solely based on specific domestic enterprise standards without global comparisons, international students will struggle to relate the knowledge to their future careers. Conversely, introducing original foreign textbooks presents additional difficulties due to differences in systems, focus areas, and domestic teaching outlines and competency certification requirements.

Additionally, there exists a "cultural conflict in teaching modes." International students generally favor interactive, inquiry-based classroom cultures and prefer immediate questioning and discussion. The traditional teacher-centered, theoretical instruction model prevalent in China leaves them feeling alienated and passive, resulting in low classroom participation. This conflict extends beyond superficial teaching forms to deeper levels involving engineering thinking and the contextual application of knowledge, leading to disconnection between course learning and the process of solving real engineering problems.

### 2.3 Misalignment of Assessment Practices

International students exhibit distinctive characteristics in their learning habits, such as an active classroom atmosphere and a willingness to ask questions immediately, while showing lower adherence to rigid classroom discipline. This often creates conflicts with conventional domestic teaching management practices. More critically, the current evaluation mechanism is overly simplistic and rigid, relying heavily on attendance rates and final exam scores, which reflect a typical assessment model that emphasizes "results over processes, memorization of knowledge over application of skills." This model fails to effectively capture and measure the true performance and growth of international students in diverse scenarios such as problem-solving, teamwork, experimental innovation, and classroom interaction.

Thus, on one hand, it cannot objectively and comprehensively reflect students' knowledge mastery and skill levels. For instance, a student who performs poorly in the final exam may have demonstrated remarkable spatial imagination and problem-solving abilities in virtual simulation experiments, yet the existing system overlooks this. On the other hand, this evaluation mechanism fails to positively motivate proactive learning; instead, due to its disconnection from actual competencies, it becomes a negative screening tool, losing its intended diagnostic, feedback, and motivational functions, ultimately restricting the cultivation of students' innovative thinking.

### 3. Exploration of Teaching Reform Pathways Based on AI

To address the deficiencies inherent in the aforementioned teaching models, this paper deeply integrates artificial intelligence technology into the teaching of the course "Interchangeability and Technical Measurement," thereby constructing a new teaching paradigm centered around students that transcends the limitations of time, space, and resources. The reform pathways primarily encompass three core dimensions: teaching resources, practical environments, and evaluation systems, aiming to form a closed-loop intelligent teaching solution, as shown in Figure 1.

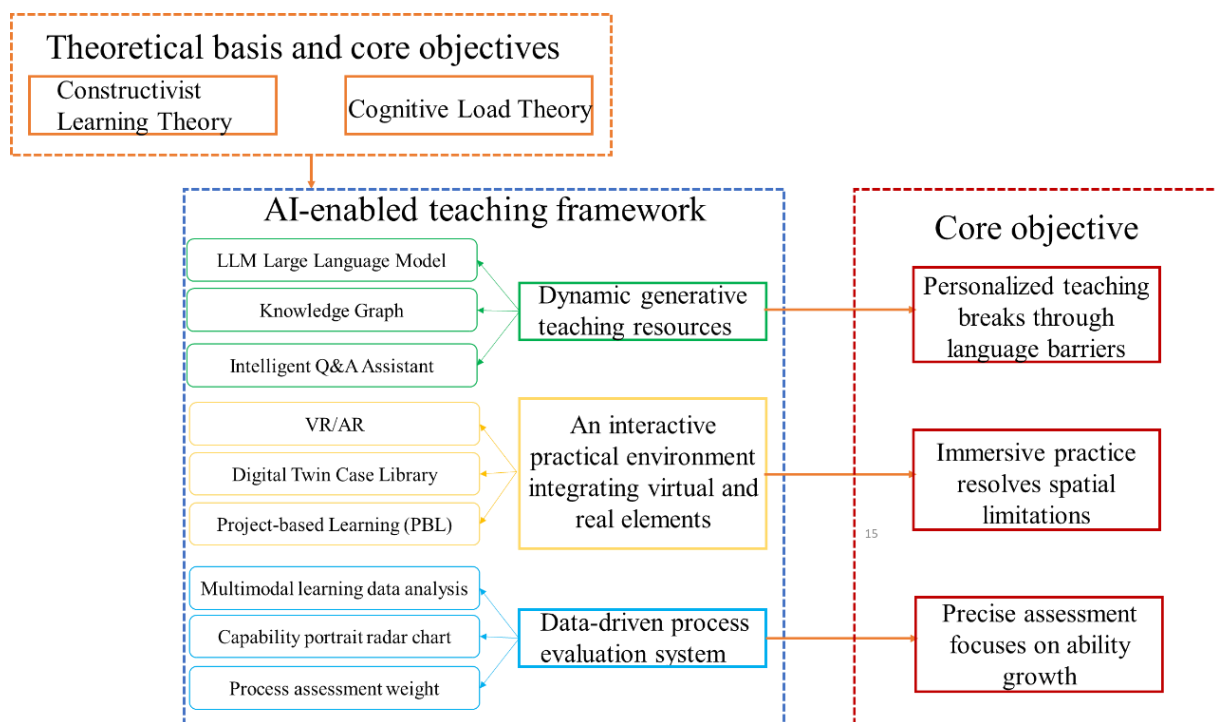


Figure 1. AI-enabled smart teaching framework

#### 3.1 Dynamic and Adaptive Learning Resources

Cognitive load theory emphasizes optimizing the presentation of information to facilitate schema acquisition. For international students facing disconnections between textbook content and language comprehension barriers, dynamic generative AI technology provides an effective solution. The core idea is to deploy large language models to "atomize" course knowledge points, constructing fine-grained knowledge graphs and thereby achieving intelligent analysis and personalized reconstruction of teaching content.

The system can dynamically generate multiple versions of English handouts with varying levels of detail and language difficulty based on students' pre-test scores, interaction history, and learning preferences. For instance, in the chapter on "Tolerances and Fits," students with foundational weaknesses will receive a simplified version of the handout that includes basic terms, codes, and diagrams of preferred fits, while advanced learners can access supplementary materials that analyze differences between ISO and ASME standards and provide case studies on tolerance optimization based on cost and performance. Additionally, the system's one-click translation function offers students native language references, significantly reducing the cognitive load associated with non-native learning.

Furthermore, an interactive tutoring assistant could be developed and embedded within the course platform, similar to the "Learning Companion" used at Tsinghua University. This assistant leverages deep semantic understanding rather than simple keyword matching. When a student asks, "Why is the hole-basis system more widely applied?" the system can provide explanations from multiple perspectives including standardization, cost, and manufacturability, while also displaying comparative animations and guiding students to consider the applicable scenarios for shaft-basis systems, thereby realizing heuristic tutoring.

In this model, the role of teachers shifts from being unidirectional transmitters of knowledge to optimizers of learning resources, supplemental AI tutors, and guides for higher-order thinking, with their focus transitioning towards auditing AI-generated content, designing deeper questions, and organizing thematic discussions.

### *3.2 Creating a Virtual-Real Fusion Interactive Practical Environment*

"Interchangeability and Technical Measurement" is a highly practical course; however, traditional experimental teaching is limited by equipment availability, spatial constraints, and operational safety, making it challenging for every international student to gain sufficient hands-on experience. To thoroughly resolve this predicament, an interactive practical environment that integrates virtual reality (VR/AR), digital twin technology, and AI guidance can be constructed, facilitating a transition from "observational verification" to "immersive training."

First, high-fidelity virtual measurement laboratories can be constructed using VR/AR technology to accurately simulate the operating procedures and physical feedback of various measuring instruments from basic tools to coordinate measuring machines (CMMs). In primary modules, the focus will be on virtual operation training for traditional tools such as calipers and micrometers. Utilizing computer vision technology and physics engines, the AI system can capture and evaluate students' operating postures, simulated measurement forces, and reading methods in real-time, providing immediate visual and auditory prompts to correct common errors such as "excessive measurement force causing tilt" or "measuring instrument not orthogonal to the workpiece." In advanced modules, the complete detection process of CMMs will be highly simulated, requiring students to establish part coordinate systems, plan probe scanning paths, execute measurements, and process point cloud data in the virtual environment. The system will introduce random errors to simulate real measurement uncertainties and require students to analyze sources of error, ultimately generating an engineering-compliant inspection report, allowing students to deeply grasp the complex connotations of "measurement accuracy" and "uncertainty" through practice.

Secondly, a digital twin case library of key assemblies will enable students to dynamically adjust tolerance parameters and observe in real-time their impact on product assembly performance and kinematic characteristics. This method of transforming abstract design principles into visual causal relationships can greatly deepen students' understanding of precision design concepts and is pivotal for overcoming the challenges in teaching "precision design." Using a typical "single-stage gear pump" as a digital twin object, students can directly manipulate sliders in simulation models, dynamically adjusting the fit tolerances between the gear shaft and pump housing, transitioning from clearance fits to interference fits. Simultaneously, the right interface of the system will display key performance parameters in real-time, including volumetric efficiency curves, outlet pressure fluctuation graphs, and temperature rise curves due to increased friction. This immediate, visual causal feedback between "design parameters and product performance" transforms abstract textbook principles of precision design into an intuitive, trial-and-error engineering decision-making experience, unmatched by any traditional two-dimensional diagram explanation or limited physical demonstration.

Building upon this foundation, AI is embedded as an intelligent analytical tool within project-based learning, enabling students to verify, question, and optimize preliminary tolerance schemes generated by AI. This process cultivates their critical thinking and innovation capabilities in collaborating with intelligent tools to address complex engineering problems. For instance, in the final phase of the course, students can be grouped to perform tolerance annotation and optimization on an actual reducer assembly drawing. AI may first generate an initial tolerance scheme based on general design rules. Students are then required to validate and critique this proposal

using digital twin simulations, and further refine it through multi-objective trade-offs—considering factors such as cost, performance, and manufacturability. Such an approach not only enhances students' ability to collaborate with AI in solving complex engineering challenges, but also strengthens indispensable competencies such as critical thinking and decision-making confidence when interpreting AI-generated outputs.

### *3.3 Data-Driven Process Assessment*

A scientific assessment system is essential for evaluating teaching outcomes and providing feedback to optimize the teaching process. To fundamentally shift away from the overreliance on final written examinations as the sole evaluation method, it is necessary to leverage AI technologies to establish a data-driven processual assessment system. This system should be capable of constructing a comprehensive and dynamic multi-source data perception and evaluation framework that reflects students' competency profiles.

The implementation of this system relies on the in-depth collection and intelligent analysis of data throughout the entire learning process. Data collection covers all learning scenarios, including virtual experiments, AI interactions, online discussions, and project collaborations. Beyond basic behavioral data such as login duration and video completion rates, the system prioritizes the collection of deep behavioral data that reflects cognitive processes and competency levels. Examples include the number of repeated attempts and strategy optimization paths in virtual experiments to achieve precise measurements; the quality, depth, and frequency of questions raised in AI-assisted Q&A sessions; the logic, accuracy, and helpfulness demonstrated in replying to peers in online discussion forums; and version iteration records of design proposals submitted during team projects. Through the analysis of such data, the system can generate a multi-dimensional, visual competency radar chart that dynamically displays students' strengths and weaknesses across various dimensions, such as "mastery of core knowledge," "proficiency in experimental operations," "engineering decision-making ability," "team collaboration effectiveness," and "inclination for innovative application." This big data-based assessment approach provides a solid and objective foundation for transitioning from summative "knowledge testing" to process-oriented "competency evaluation."

In terms of specific assessment mechanisms, the weight of processual evaluation in the overall grade should be significantly increased, recommended to reach 60% or higher. Processual assessment should comprehensively incorporate factors such as the quality of classroom interactions, virtual experiment reports, project design documentation, and collaboration performance records. Correspondingly, the final assessment should undergo a paradigm shift, focusing more on students' ability to integrate course knowledge and apply it in complex scenarios. This can be achieved by substantially increasing the proportion of comprehensive case analyses and open-ended precision design tasks, while reducing the emphasis on memorization of isolated knowledge points. Such an approach not only enables a fairer and more comprehensive evaluation of international students' genuine learning outcomes but also, through continuous feedback, guides students to shift their focus from passive exam preparation towards daily active exploration and competency accumulation. Ultimately, this fosters a virtuous cycle of mutual enhancement between teaching and learning, driven by continuous improvement.

## **4. Research Design for Empirical Validation**

To validate the proposed framework, a mixed-methods study was designed, incorporating both quantitative and qualitative approaches. The research will be implemented in the Fall 2025 semester with international mechanical engineering students enrolled in "Interchangeability and Technical Measurement."

### *4.1 Participants and Procedure*

Approximately 80 international students will be recruited and randomly assigned to experimental (AI-enabled instruction) and control (traditional instruction) groups. The study will employ a pre-test/post-test control group design to isolate the impact of the AI interventions.

### *4.2 Data Collection*

A combination of quantitative and qualitative data collection instruments will be employed to comprehensively evaluate the effectiveness of the AI-enabled teaching framework. Quantitative measures include pre- and post-intervention conceptual knowledge tests to assess learning gains, and practical skills assessments conducted within the virtual laboratory environment, which will generate metrics on operational accuracy and procedural competence. To capture student perceptions and cognitive experiences, validated surveys will be administered to measure levels of learning engagement, perceived cognitive load, and overall satisfaction with the instructional approach. Complementing these quantitative data, semi-structured interviews will be conducted with a subset of participants to gather in-depth qualitative insights into their learning experiences, perceived challenges, and the perceived utility of the AI-based resources, thereby providing a rich, multi-faceted dataset for analysis.

### 4.3 Data Analysis

Quantitative data will be analyzed using appropriate statistical methods. Qualitative data will undergo thematic analysis to identify patterns in student experiences and outcomes.

## 5. Discussion and Conclusion

This study systematically analyzes the main challenges in teaching the "Interchangeability and Technical Measurement" course to international students and proposes a theoretically grounded framework for AI-enabled teaching reform. By addressing critical challenges in language comprehension, practical training, and competency assessment, the proposed approach demonstrates significant potential to enhance educational effectiveness, moving beyond traditional models that exhibit shortcomings in faculty resources, teaching materials, and assessment methods. Theoretically, this framework extends existing research by explicitly connecting AI applications with established learning theories; its alignment with constructivist principles demonstrates how AI can create active learning environments, while its incorporation of cognitive load theory highlights a deliberate design to manage learning complexity. From a practical perspective, the framework offers implementable strategies: the dynamic resource generation system provides a scalable solution to the challenge of culturally accessible materials, the virtual practice environments address resource limitations while maintaining educational quality, and the data-driven assessment framework promotes authentic competency evaluation.

However, the implementation of this smart teaching system faces several challenges and limitations. Teachers are required to transition from knowledge transmitters to learning designers and proficient users of AI tools, necessitating comprehensive training and institutional support. On the technical front, issues such as platform development costs, algorithm accuracy, and system integration must be addressed to ensure sustainability. Simultaneously, data privacy and ethical guidelines cannot be overlooked when utilizing learning analytics. Furthermore, it is crucial to acknowledge the current limitations of AI technology itself, particularly in deep reasoning and innovative breakthroughs, which means it cannot replace the professional insight and experience of human teachers. Therefore, the integration of AI and education must be viewed as an ongoing evolutionary process, adhering to the principle of teacher-led, technology-enabled enhancement.

Future research should extend beyond the current conceptual proposal and limited course context. Longitudinal studies are needed to examine the long-term effects on professional competency development, while investigations into cross-cultural adaptations for diverse student populations and applications to other engineering disciplines would enhance the framework's generalizability. Additionally, research should explore optimal implementation strategies for institutions with varying resource levels. In conclusion, the integration of AI technologies represents a promising direction for enhancing the quality and accessibility of international engineering education. By combining solid theoretical grounding with practical applications, this research contributes to the ongoing transformation of engineering education, advocating for a future built on effective human-AI collaboration.

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