Engineering Education Review

RESEARCH

A five-in-one framework for international computer graphics education: Design, implementation and assessment

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ABSTRACT

As an important component of computer science curricula, computer graphics education faces unprecedented challenges in meeting the demands of an increasingly globalized technical landscape. The expanding scope of applications has heightened the need for professionals with global competencies and cross-cultural collaboration capabilities. This paper addresses critical challenges in internationalizing computer graphics education, specifically focusing on the systematization of teaching models, development of international course pathways, enhancement of cross-cultural pedagogical practices, and advancement of faculty expertise in global contexts. Computer graphics offers distinct advantages as a platform for international education innovation—its visual-oriented characteristics enable direct communication across different cultural backgrounds, while its immediate visual feedback and shareable graphical results naturally facilitate cross-cultural exchange of ideas. Based on these characteristics, we propose a comprehensive "five-in-one" teaching framework that integrates international faculty team setup, diverse student recruitment, collaborative institutional platforms, cross-cultural competency development, and industry-academia partnerships. Through implementation at leading institutions, this framework has fostered an innovative pedagogical model characterized by the integration of research-based learning and cross-cultural collaboration. Empirical evidence demonstrates significant outcomes: enhanced international recognition of course quality, successful implementation of teaching innovations, and improved student achievement in both academic performance and professional development. The framework's effectiveness is validated through multiple indicators, including recognition from world-class universities, student success in international competitions and research publications, and enhanced career outcomes for graduates. The experience and insights gained from this work not only advance the internationalization of computer graphics education but also provide valuable reference and inspiration for the international teaching reform of other computer science courses.

Key words: computer graphics, internationalized teaching, teaching innovation, cross-cultural learning

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INTRODUCTION

Computer graphics is a significant component of computer science curricula, primarily studying how to represent, generate, process, and display visual information in computers (Marschner & Shirley, 2021). It covers key theoretical technologies including geometric modeling (Botsch, 2010), photorealistic rendering (Haines & Akenine-Möller, 2019; Pharr *et al.*, 2016), physical simulation (Bridson, 2015), and computer animation (Parent, 2012). Computer graphics has been increasingly applied in crucial national economic sectors such as scientific computation visualization (Hansen & Johnson, 2011), computer-aided design and manufacturing (Encarnacao *et al.*, 2012), virtual/augmented reality (Billinghurst *et al.*, 2015; LaValle, 2023), gaming, and visual effects. Particularly, with the rapid development in emerging technologies such as artificial intelligence and digital twins, the cross-integration of computer graphics with deep learning, computer vision, and other fields has given rise to numerous innovative applications, leading to a sustained growth in demand for professionals who can work effectively in global teams. This evolution presents both opportunities and challenges for computer graphics education. The visual and interactive nature of computer graphics provides unique advantages for international education- the visualization and design aspects in areas like user interfaces, character animation, and virtual environments create opportunities for students to understand and appreciate different cultural perspectives through collaborative projects. The immediate visual feedback from graphics programming creates an intuitive learning environment that reduces language barriers, facilitating effective communication in multicultural classrooms. Modern graphics applications often require cross-cultural understanding to create content that resonates with global audiences.

As economic globalization accelerates, there is an increasing imperative to align China's cultivation of engineering talent with global standards (Gu, 2023), and the internationalization of higher education has become an important development strategy for countries worldwide (de Wit & Altbach, 2021). The implementation of national strategies such as "Digital China" has catalyzed unprecedented growth in international technological collaboration, particularly in digital content creation where computer graphics plays a central role. These developments have created new imperatives for educational institutions to adapt their teaching approaches (Qin & Ding, 2024). Traditional graphics education, which often focused primarily on technical competency, must now evolve to encompass broader skills including cross-cultural communication, global project management, and international collaboration practices. This comprehensive skill set has become particularly crucial as graphics technologies increasingly serve as bridges between different cultural contexts and user experiences in our interconnected digital world.

Despite the alignment between computer graphics and international education demands, current internationalization efforts in computer graphics teaching still face several significant challenges. First, existing international teaching models have not yet formed systematic frameworks, making it difficult to effectively support goals of cultivating international talent. Second, the path for international course construction needs to be explored, with existing courses typically lacking complete cooperation mechanisms for sustained international teaching and research exchange. Third, cross-cultural teaching practices need enhancement, particularly in facilitating effective communication and collaboration among students from diverse cultural backgrounds. Finally, developing appropriate faculty expertise presents ongoing challenges, as effective international education demands teaching teams that combine deep professional knowledge with sophisticated cross-cultural communication abilities and innovative pedagogical approaches suited to diverse student backgrounds.

To address these challenges while leveraging the unique characteristics of computer graphics education, we propose a comprehensive "five-in-one" framework for international computer graphics education. This framework deliberately capitalizes on the discipline-specific characteristics of computer graphics while establishing principles that can be adapted to other technical fields. By leveraging computer graphics' visual accessibility and creative aspects, we've designed collaborative learning experiences that naturally encourage multicultural participation and perspective sharing. The framework integrates five essential components: international faculty team setup, diverse student recruitment, establishment of high-caliber cooperation platforms, cross-cultural competency training, and integration of industry, teaching and research. This approach emphasizes developing students' international perspectives and innovation capabilities while enhancing their cross-cultural communication skills through structured group learning experiences that capitalize on the visual and collaborative nature of computer graphics projects. A distinctive feature of our framework is the implementation of multicultural integration through group-based learning methodologies specifically designed for computer graphics education. The methodology leverages the inherent qualities of computer graphics—its visual language, interactive feedback, and creative problem-solving requirements—to facilitate meaningful cross-cultural exchange. In these carefully designed groups, students not only share technical knowledge but also experience different cultural approaches to visualization, user experience design, and problem decomposition. This pedagogical innovation represents a practical manifestation of our framework's theoretical foundations, connecting international faculty expertise with diverse student perspectives through tangible creative projects. Based on over ten years of teaching practice at Tsinghua University and South China University of Technology, this framework has demonstrated significant benefits for both academic achievement and professional development.

This research contributes to the broader discussion of internationalizing computer science education while maintaining rigorous academic standards. The paper is organized as follows: Section 2 presents our "five-in-one" framework for internationalized computer graphics education. Section 3 focuses on introducing course practice measures such as integrating international frontier research into teaching content, industry-academia-research cooperation practice, and reform of diverse assessment and evaluation mechanisms. Section 4 demonstrates the significant outcomes of the teaching framework in enhancing course international recognition, improving teaching quality, and elevating student achievement across multiple dimensions. Section 5 discusses the theoretical foundations and practical implications of the framework, comparing it with traditional approaches while addressing scalability challenges and demonstrating its potential for broader application in engineering education. Section 6 concludes with insights for future development in international computer graphics education and potential applications to other technical fields.

Through systematic analysis of our implementation experience, this research aims to provide valuable reference for institutions seeking to enhance the international dimension of the computer graphics education. The framework offers a structured approach to addressing common challenges in cross-cultural technical education while promoting innovation and academic excellence.

DEVELOPMENT OF INTERNATIONAL EDUCATION FRAMEWORK

The growing demand for internationally competitive computer graphics professionals has necessitated a comprehensive approach to education that addresses both technical competence and global collaboration skills. Therefore, we develop a "five-in-one" framework for computer graphics education that systematically integrates multiple dimensions of international teaching and learning (Figure 1).

Figure 1. The five-in-one framework

"Five-in-one" framework

International faculty team setup

A high-caliber international faculty team brings unique advantages to computer graphics education by leveraging the discipline's inherently visual and creative nature to facilitate multicultural integration and collaborative learning. Computer graphics serves as an ideal platform for cross-cultural exchange precisely because of its universal visual language, and the international faculty team capitalizes on this characteristic in several concrete ways. They can demonstrate how the same graphical concepts—whether in rendering techniques, modeling approaches, or animation principles—are applied differently across cultural contexts. For example, teachers can highlight how cultural aesthetic preferences influence design choices in 3D modeling, helping students understand the cultural dimensions of seemingly technical decisions. The immediate visual feedback that defines computer graphics education allows these cultural nuances to be demonstrated. Moreover, the multicultural faculty team enhances learning by bringing diverse perspectives to evaluating visual outputs. In computer graphics, the assessment of quality often includes subjective elements that are culturally influenced—aspects like visual appeal, character design, or user interface aesthetics. Having instructors from various cultural backgrounds provides students with multifaceted feedback that better prepares them for global professional environments where their work will be viewed through different cultural lenses.

Our cross-cultural group learning methodology specifically leverages the advantages of computer graphics' visual communication. When students from different countries collaborate on graphics projects, their shared visual outputs create a common reference point that transcends language barriers. International faculty members serve as cultural interpreters who can help teams recognize when differences in their approach to graphics problems stem from technical disagreements versus cultural perspectives, transforming potential barriers into opportunities for innovation. Therefore, we have established a multi-tiered faculty structure that optimizes the integration of academic expertise and practical experience, consisting of core teaching team, international advisory team, and industry mentor team.

The core teaching team brings together teachers with strong academic achievements and rich international experience, including a recipient of the National Science Fund for Distinguished Young Scholars, a leader of national first-class undergraduate courses recognized by the Ministry of Education, and an academician of the European Academy of Sciences who is also an Institute of Electrical and Electronics Engineers (IEEE)/ American Association for the Advancement of Science (AAAS) Fellow. Moreover, our team includes distinguished scholars such as a professor from Cardiff University, who brings expertise in computer graphics along with valuable perspectives on UK higher education practices, further enriching our cross-cultural teaching approaches. These faculty members, all holding doctoral degrees from prestigious institutions such as Purdue University and Hong Kong University of Science and Technology, bring extensive international exchange experience to their teaching roles. Their ability to incorporate frontier research developments into teaching ensures that students remain connected to current advances in the field.

To further expand international perspectives, the team has invited several overseas renowned scholars from Nanyang Technological University, Ohio State University, and others as course advisors. These experts provide international perspectives for course construction through various means such as "International Scholars Borderless Lecture Hall", participation in course design, and research project guidance, effectively integrating international quality educational resources. Meanwhile, the team has appointed technical experts from leading companies such as Google and International Business Machines Corporation (IBM) as industry mentors, strengthening the connection between academic training and professional practice

International student recruitment

Cultivating international students is significant for creating authentic cross-cultural communication environments, promoting the productive exchange and integration of diverse cultural perspectives. Our program has provided training to more than 250 international students from over 70 countries across Asia, Africa, Europe, America, and Oceania (Figure 2). In recent years, the proportion of students from developed countries such as Europe and America has continued to rise, exceeding 50% since 2019, providing a good foundation for implementing cross-cultural group learning.

We have implemented an adaptive educational approach that accounts for students' diverse cultural and educational backgrounds. This includes offering differentiated course content based on student preparation levels, providing bilingual instruction in Chinese and English, and utilizing visual learning tools to enhance comprehension. The assessment system combines formative assessment and summative assessment, while project work is structured around mixed-nationality teams to facilitate remote cross-cultural collaboration and communication.

International cooperation platforms

Establishing high-caliber international cooperation platforms is a crucial pathway for advancing course internationalization. International cooperation not only introduces quality educational resources and expands educational horizons but also provides students with opportunities to engage with cutting-edge technology and participate in practical projects, serving as essential support for achieving talent internationalization. Therefore, our teaching team actively expanded international cooperation, establishing long-term teaching and research cooperation relationships with institutions such as Ohio State University, Nanyang Technological University, and the National University of Singapore. Through these high-caliber cooperation platforms, students can deeply participate in international frontier research and understand the latest global technological development trends. Meanwhile, the course has achieved credit recognition with Carnegie Mellon University, marking the recognition of teaching quality by world-class universities.

International competency training

The cultivation of international competency has emerged as a critical objective in contemporary higher education. International competency includes not only professional knowledge and skills but also cross-cultural communication ability, international perspective, and innovative thinking. Our curriculum design emphasizes cultivating students' international competency, integrating scientific spirit through ideological and political education in courses, adopting science-education integration methods to stimulate students' innovation ability, and enabling students to master international frontier theories and technologies. In course teaching, besides teaching basic theories, the latest research results are promptly introduced. Course assessment adopts diverse evaluation methods, incorporating classroom discussion, practical computer work, and group projects into the assessment scope, comprehensively evaluating students' knowledge mastery, practical ability, and cross-cultural communication level.

Integration of industry, teaching and research

The integration of industry, teaching and research mechanism facilitates the alignment between educational

Asia				Africa			
Indonesia	27	South Korea	1	Tanzania	14	Djibouti	1
Pakistan	13			Ethiopia	7	Angola	1
Bangladesh	12	Japan	1	Sudan	4	Mauritius	1
Thailand	7			Congo	4	Madagascar	1
India	5	**Europe**		Zambia	4	Sierra Leone	1
Nepal	4	France	36	Kenya	4	Guinea	1
Kyrgyzstan	3	Russia	8	Jordan	2	Gabon	1
Yemen	3	Germany	6	Zimbabwe	2	Cameroon	1
Malaysia	2	Netherlands	4	Gambia	2	Botswana	1
Singapore	2	United Kingdom	3	Burundi	2	Tunisia	1
Kazakhstan	2	Denmark	2	Ghana	2	Senegal	1
Tajikistan	2	Norway	2	Uganda	2		
Uzbekistan	1	Sweden	1	Togo	2	**Americas**	
Syria	1	Hungary	1	Nigeria	2	United States	13
Vietnam	1	Poland	1	Namibia	2	Canada	7
Israel	1	North Macedonia	1	Rwanda	1	Brazil	4
Macau, China	1			Algeria	1	Mexico	2
Turkmenistan	1	**Oceania**		Chad	1	Ecuador	1
Iran	1	Australia	1	Democratic Republic of the Congo	1	Colombia	1

Figure 2. Distribution of international students taught by our team members across both Tsinghua University and South China University of Technology based on over ten years of teaching practice.

outcomes and industry requirements while enhancing students' practical innovation capabilities. In terms of innovation training, leading technology research is conducted through university-company joint laboratories. Our team has established three on-campus internship bases and thirty-five off-campus internship bases through college cooperation with renowned companies such as Google, Samsung, and Tencent, helping students conduct industry-academia-research internships in international and domestic companies. Through implementing industry-academia-research integration, students' understanding of theoretical knowledge is deepened while cultivating their practical innovation ability in cross-cultural environments. Moreover, students can transform classroom learning into the ability to solve practical problems, achieving coordinated development of knowledge, ability, and quality.

Implementation of cross-cultural group learning

Cultivating outstanding students necessitates fostering students' intrinsic motivation for active learning (Liu *et al.*, 2024). To address the limitations of traditional computer graphics instruction, which often emphasizes theoretical content at the expense of student engagement, we have implemented an innovative cross-cultural group learning model. This approach leverages the diversity of our international student body, encouraging collaboration among students from different cultural backgrounds to enhance both technical learning and cross-cultural competency development (Figure 3).

The implementation focuses on three key aspects: First, we ensure cultural diversity in team composition, with each group including students from different countries and regions. Second, we design open-ended project assignments that allow students to incorporate their diverse cultural perspectives into problem-solving approaches. Finally, we facilitate regular inter-group presentations and discussions to promote broader cross-cultural dialogue and knowledge exchange. This learning model has demonstrated effectiveness in increasing student engagement while developing essential skills for international collaboration. The interaction between students with different cultural backgrounds and problem-solving approaches frequently leads to innovative solutions while fostering global perspective and cultural understanding.

The implementation of cross-cultural group learning in computer graphics education creates unique advantages. The visual nature of graphics assignments allows for immediate shared understanding across language

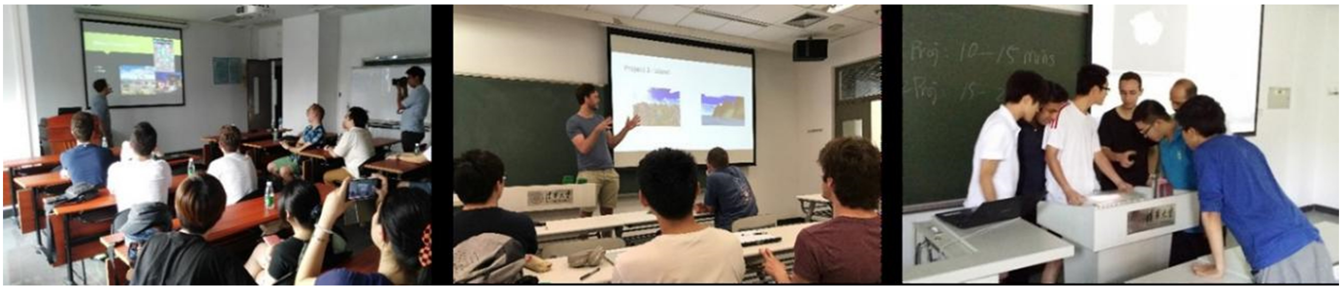

Figure 3. Cross-cultural group learning - students from diverse cultural backgrounds collaborate to complete course tasks.

barriers—students can point to visual elements, demonstrate rendering effects, or sketch modeling concepts even when verbal communication is challenging. Our international faculty deliberately structure group projects to exploit this advantage, creating assignments that require diverse cultural inputs to succeed. For example, character animation projects explicitly benefit from varied cultural perspectives on expression and movement, while game environment design projects naturally improve when incorporating diverse architectural and artistic traditions. Our faculty guide these collaborations by helping students recognize how their cultural backgrounds influence their graphical interpretations and implementations. This approach transforms computer graphics education from merely teaching technical skills to developing intercultural visual literacy—a competency increasingly valued in global digital media industries.

EDUCATIONAL PRACTICE AND INNOVATION

The implementation of our international computer graphics education framework has involved innovative approaches in three key areas: integration of research developments into curriculum content, establishment of industry collaboration mechanisms, and development of comprehensive assessment methods.

Integration of research developments into curriculum

Computer graphics encompasses multidisciplinary knowledge spanning computational geometry, graphics processing, and pattern recognition. The course content contains substantial theoretical foundations and mathematical derivations, requiring students to possess strong mathematical backgrounds and programming capabilities. Traditional instructor-centered teaching approaches often result in limited student engagement and reduced learning autonomy, potentially constraining the development of innovative capabilities. To address this challenge, we have developed an approach that leverages the diverse applications and engaging nature of computer graphics to facilitate active learning. Throughout the teaching process, our team has systematically incorporated research training into regular teaching activities. For instance, in teaching computer animation, beyond introducing fundamental keyframe animation principles, the course presents physics-based simulation techniques and character animation methodologies through practical research cases. Faculty members guide students to identify problems from real-world scenarios and apply their theoretical knowledge to develop solutions, fostering self-directed knowledge construction and innovative thinking capabilities.

To ensure alignment with international standards, the course actively incorporates leading-edge research developments in the field of computer graphics. The original curriculum has been enhanced with interdisciplinary content involving emerging technologies such as artificial intelligence and virtual reality. For example, the three-dimensional modeling unit now includes deep learning-based 3D reconstruction techniques alongside traditional geometric modeling methods, effectively broadening students' knowledge horizons.

The course implements a flexible approach to experimental project design. While faculty members provide structured project options aligned with course objectives, students are also actively encouraged to propose their own research topics based on their interests and cultural backgrounds. This dual-pathway approach to project selection has resulted in a diverse range of applications, from video game characters and animated figures to culturally-specific objects and artistic expressions. Faculty review student-proposed topics to ensure technical feasibility while supporting creative exploration, creating a balance between guidance and autonomy that enhances engagement and ownership of the learning process.

Industry-academia-research collaboration

Our curriculum has established a comprehensive industry-academia-research collaboration framework. Through partnerships between the college and leading companies such as Google, IBM, Samsung, and Tencent, the teaching team has established three on-campus and thirty-five off-campus internship bases, facilitating student participation in industry-academia-research internships at prestigious domestic and international companies.

This integrated approach has demonstrated significant positive impacts on students' participation in technological competitions, academic publications, employment prospects, and advanced education opportunities. Through engagement in industrial projects, students can apply theoretical knowledge in practical contexts while gaining insights into industry developments and requirements.

The course regularly invites industry experts to participate in teaching activities through guest lectures and seminars, providing students with current perspectives on computer graphics applications in industry. The integration of industry, teaching and research not only expands students' professional horizons but also provides valuable guidance for their career development.

The teaching team has proposed an educational framework integrating "three creations" (innovation, creation, and entrepreneurship), establishing an innovative talent development system that combines "professional knowledge + innovation capability + entrepreneurial quality". The connection between curricular and extracurricular learning is facilitated through student research programs and national innovation projects, while the progression from innovation to entrepreneurship is achieved through participation in competitions such as Association for Computing Machinery (ACM) contests, Challenge Cup, and Internet+ competitions.

Comprehensive assessment methods

Our curriculum has implemented a reformed assessment approach, establishing a comprehensive, multidimensional evaluation system. Faculty members continuously monitor student learning progress, adjusting teaching strategies and pacing to optimize educational outcomes. This flexible and diverse instructional model ensures teaching quality while promoting student engagement.

The course assessment framework has evolved from traditional examination-based evaluation to a more comprehensive approach incorporating: (1) Classroom discussion participation, (2) Group project performance, (3) Practical programming implementation, (4) Theoretical knowledge assessment.

The assessment design reflects the dual emphasis on theoretical foundations and practical capabilities characteristic of computer graphics education. Programming assignments are structured to reinforce theoretical concepts while developing implementation skills. Students are encouraged to undertake course projects through collaborative research approaches, exploring cutting-edge technologies in computer graphics while developing independent innovation capabilities.

Course evaluation is crucial for quality enhancement. Moving beyond traditional end-of-term surveys, the teaching team has implemented a comprehensive evaluation approach involving: extended evaluation timeframes, diverse stakeholder feedback (students, faculty, alumni, academic advisors, and employers), long-term tracking of student career trajectories, and systematic integration of feedback into course iterations.

Recent course evaluation results (Figure 4) demonstrate strong positive outcomes, with 92.68% of students rating overall course quality as good or outstanding, 78.57% acknowledging the emphasis on creative thinking and practical skills, and 85.71% indicating the course's positive impact on their career development or advanced studies.

Through these innovative teaching practices, the course maintains the integrity of core computer graphics knowledge while emphasizing international characteristics, effectively supporting the development of internationally competitive innovative talents.

TEACHING EFFECTIVENESS AND OUTCOMES

The implementation of the "five-in-one" international teaching framework has yielded substantial outcomes across multiple dimensions, demonstrating effectiveness in enhancing international recognition, advancing teaching methodology, and improving student achievement. Through the integration of research-based education, international frontier developments, and coordinated industry-academia partnerships, the course quality has gained widespread recognition from domestic and international institutions while significantly enhancing student capabilities and career prospects. These achievements are manifested in the following aspects.

Enhancement of international recognition

The graduate course "Fundamentals of Computer Graphics" delivered by our team members has been incorporated into the Master in Advanced Computing program offered by the Department of Computer Science and Technology at Tsinghua University. This program has gained significant global recognition, being selected as one of "The 10 Best AI And Data Science Master's Courses for 2021" in an article published on the influential American Forbes magazine website in 2022,

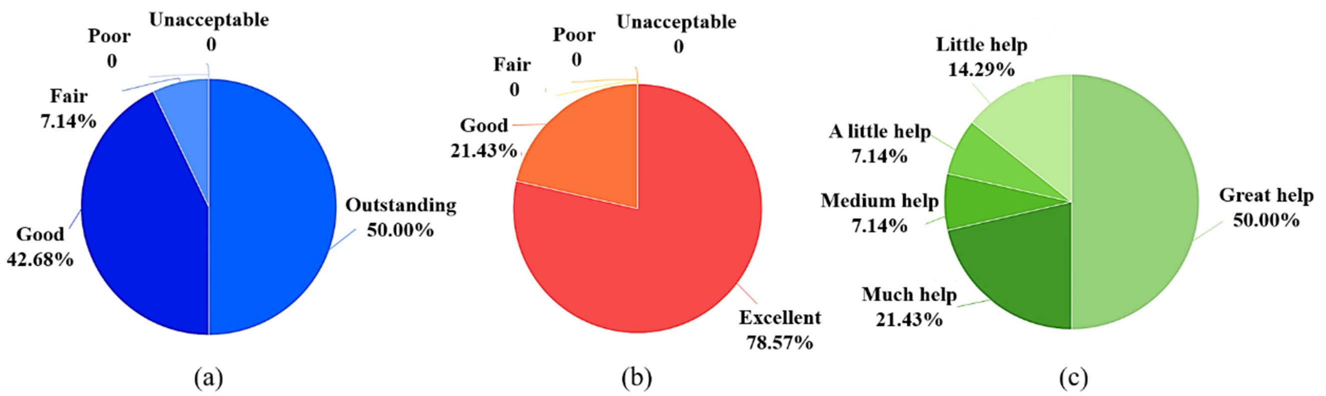

Figure 4. Results from the latest graduate course survey. (a) Overall course quality assessment. (b) Creative thinking and practical skills training (c) Course benefits for further studies or career development.

and is the only program from mainland China to receive this recognition (Figure 5). The computer graphics course at South China University of Technology, led by our team members, was designated as a university-level inquiry-based undergraduate teaching demonstration classroom in 2018. The teaching effectiveness has received positive student feedback, ranking among the top ten in overall evaluation among university-wide inquiry demonstration courses. During the 2020-2021 academic year, our team members were responsible for teaching two courses to American Rutgers University transfer students at the South China University of Technology. Under American assessment standards, these students achieved performance levels exceeding those of their counterparts at both the U. S. home campus and other branch campuses in Beijing and Shanghai. As a highlight of the university's international teaching, this achievement was prominently featured by Chairman Zhang Xichun of the University Affairs Committee in recruitment presentations.

Advancement in teaching methodology

Our team has continuously optimized teaching approaches and innovated teaching methods through long-term course teaching reform exploration, with its educational concepts receiving recognition from peer experts: the 3D virtual simulation-based teaching design won the First Prize in the 2019 National University Teacher Teaching Innovation Competition Finals. Based on this teaching philosophy, team members were approved for the Ministry of Education's first batch of national-level first-class offline courses. The team's teaching capabilities have been continuously refined, earning numerous awards including the First Prize in the Guangdong Provincial Division of the First National University Micro-course Teaching Competition and National Excellence Award, First Prize in Tsinghua University Excellence in Teaching, Tsinghua University "Challenge Cup" Outstanding Instructor Award, First Prize in South China University of Technology Young Teacher Undergraduate Classroom Teaching Competition, South China University of Technology Undergraduate Teaching Excellence "Nanguang Award", and South China University of Technology Outstanding Undergraduate Thesis Supervisor Award. The course reform effectiveness has already received four teaching achievement awards, including the 2017 Guangdong Province Education and Teaching Achievement Award (Higher Education) Second Prize (Computer Engineering Research and Development Talent Training Based on Industry-Academia-Research Integration), 2021 University-level Teaching Achievement Award Second Prize (Construction and Practice of "Knowledge-Ability-Quality" Trinity Innovation and Entrepreneurship Education System), 2019 University-level Teaching Achievement Award Second Prize (Exploration and Practice of Multi-integrated Deep Internationalization All-English Innovative Research Talent Training Model), and 2017 University-level Teaching Achievement Award Second Prize (Reform and Practice of All-English Teaching Methods for Computer Science Professional Courses). In recent years, nine high-quality educational research papers related to the course's reform experience have been published (Lin *et al.*, 2020; Liu & Luo, 2010; Mao & Luo, 2019; Mao & Zhang, 2014; Mao & Zhang, 2015; Mao & Zhang, 2018; Mao *et al.*, 2019; Mao *et al.*, 2022; Mao *et al.*, 2024), with three papers indexed by EI. These publications contribute to the broader discourse on international computer graphics education and provide valuable insights for other institutions.

Enhancement of student achievement

The integration of research-based education has significantly enhanced student innovation capabilities and academic achievements. In recent years, the students of South China University of Technology who were supervised by our team member have been approved for


Forbes

The 10 Best AI And Data Science Master's Courses For 2021

Bernard Marr Contributor
Enterprise Tech

This article is a follow-up to my list of best data science undergraduate courses. While AI and data science make up part of most computer science undergrad degrees, it's at a post-grad level where students can really start to develop expertise.

MIT	Master of Business Analytics
Stanford University	MSc in Statistics: Data Science
Carnegie Mellon University	Master of Computational Data Science
Imperial College London	MSc in Business Analytics
University of Bath	MSc Data Science
University of Toronto	Master of Science in Applied Computing: Data Science
University of Helsinki	Masters Degree in Data Science
École Polytechnique	MSc in Data Science for Business
Tsinghua University	Master in Advanced Computing
University of Hong Kong	Master of Data Science

Figure 5. The "Fundamentals of Computer Graphics" course taught by team members was incorporated into the Advanced Computing Master's program, which was selected as one of "The 10 Best AI And Data Science Master's Courses for 2021" in a Forbes magazine website article in 2022 as the only selected program from mainland China.

more than 50 National (Provincial) College Student Innovation Program projects. From 2013 to 2017, they continuously represented China at the ACM/ICPC World Finals for five consecutive years, being one of only seven Chinese universities to achieve this distinction. The teaching team guided undergraduate students to win gold medals in the International Track of China International "Internet+" College Students' Innovation and Entrepreneurship Competition for two consecutive years in 2020 and 2021, and as the sole representative of the International Track, received recognition and encouragement from Vice Premier Sun Chunlan who attended the event. The team also guided undergraduate students to win silver awards in the Higher Education Main Track of the 2020 and 2022 Guangdong Provincial Division of the China International "Internet+" College Students' Innovation and Entrepreneurship Competition.

The curriculum's academic impact is reflected in the publication of students (Table 1). Our team members have supervised undergraduate students of South China University of Technology in publishing 13 academic papers in journals including *IEEE Transactions on Visualization and Computer Graphics (TVCG)*, *The Visual Computer (TVC)*, and *Computers & Graphics (C & G)*. Moreover, we guided Brazilian student Zhang Haozhe in publishing a paper at *IEEE International Conference on Robotics and Automation (ICRA)*, a top conference in robotics; Pakistani international student Qin Li in publishing a paper in the geometry journal *Computer Graphics and Applications (CGA)*; and guided further international students in publishing five Science Citation Index Journal Citation Reports Quartile 1 (SCI JCR Q1) papers. The teaching team members jointly supervised students in publishing six papers in *TVCG*, European Conference on Computer Vision (ECCV), and Special Interest Group on Computer Graphics and Interactive Techniques Asia (SIGGRAPH ASIA) Poster. Multiple papers received honors including China Science: Information Science Annual Hot Paper, Bronze Medal in ACM Multimedia 2022 Virtual Human Dialogue Video Generation Challenge, Beijing Youth Outstanding Science and Technology Paper, and First Prize Paper Award at the 16th Conference on Image and Graphics Technology and Application.

Graduate career development

The curriculum has demonstrated consistent improvement in both international student recruitment and outcomes, generating positive effects in promoting Chinese culture. Students have achieved excellent results in further education and employment. Some international students have remained in China to continue working or pursuing advanced studies, attracting more international talents for China's technological development. French student Hugo Garcia-Cotte founded Cyphen Technology (Shenzhen) Co., Ltd. after graduation, which was reported by Le Figaro newspaper. Malaysian student Wu Yiying established AllSome in Shenzhen, a cross-border e-commerce warehouse service provider for Southeast Asia, adopting the concept of "sharing" to utilize excess space in residential and commercial premises for warehouse services, reducing costs and providing one-stop cross-border logistics transfer and end-delivery services for sellers. Yemeni student Ahmed Mohammed successfully founded two companies in China related to big data and content distribution platforms, becoming the first Arab entrepreneur to receive a Chinese "green card". Pakistani student Qin Li returned to his home country and continued research work in Pakistan government departments.

Some domestic course graduates have achieved significant success in academic pursuits, gaining admission to

Table 1: Publications of International Students under Course Guidance.

	Authors	Title	Journal/Conference	Classification
1	Yiheng Han, Irvin Haozhe Zhan, Long Zeng, Yu-Ping Wang, Minjing Yu, Matthieu Gaetan Lin, Jenny Sheng, Yong-Jin Liu	Point cloud completion and key point refinement with fusion data for 6D pose estimation (Han *et al.*, 2024)	IEEE Transactions on Visualization and Computer Graphics	SCI JCR Q1
2	Sheng Ye, Yubin Hu, Matthieu Lin, Yu-Hui Wen,. Wang Zhao, Wenping Wang, Yong-Jin Liu	Indoor scene reconstruction with fine grained details using hybrid representation and normal prior enhancement (Ye *et al.*, 2024)	IEEE Transactions on Visualization and Computer Graphics	SCI JCR Q1
3	Jenny Sheng, Matthieu Lin, Andrew Zhao, Kevin Pnost, Yu-hui WVen, Yangguang Li, GaoHuang, Yong-Jin Liu.	Exploring text-to-motion generation with human preference (Sheng *et al.*, 2024)	Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops	CCF-A Level
4	Kashif Shaheed, Aihua Mao, Imran Qureshi, Munish Kumar, Oaisar Abbas, Inam Ullah, Xingming Zhang	A systematic review on physiological-based biometric recognition systems: Current and future trends (Shaheed *et al.*, 2021)	Archives of Computational Methods in Engineering	SCI JCR Q1
5	Yiheng Han; Irvin Haozhe Zhan, Wang Zhao, Yong-Jin Liu	A double branch next-best-view network and novel robot system for active object reconstruction (Han *et al.*, 2022)	IEEE International Conference on Robotics and Automation (CRA)	TH-CPL A Level
6	Aamir Khan Jadoon, Chenming Wu, Yong-Jin Liu, Ying He, Charlie C. L. Wang	Interactive partitioning of 3D models into printable parts (Jadoon A *et al.*, 2018)	IEEE Computer Graphics and Applications	SCI (Impact Factor 2.088)
7	Kashif Shaheed, Imran Qureshi	A hybrid proposed image quality assessment and enhancement framework for finger vein recognition (Shaheed& Qureshi, 2024)	Multimedia Tools and Applications	SCI JCR Q1

prestigious institutions including Oxford University, Carnegie Mellon University, MIT, University of Southern California, National University of Singapore, Chinese University of Hong Kong, and Hong Kong University of Science and Technology. Among them, Liu Yebin, who took the Tsinghua University graduate course "Fundamentals of Computer Graphics" in 2008, is now a tenured professor in the Department of Automation at Tsinghua University. Due to his academic contributions in computer graphics, he received funding from the 2021 National Science Fund for Distinguished Young Scholars and the 2015 National Science Fund for Excellent Young Scholars. Jiao Yang, who took the course in 2013, is now an assistant researcher at the Academy of Arts and Design and class advisor at Xin Ya College of Tsinghua University, receiving the 2017 Tsinghua University Outstanding Doctoral Dissertation award for his contributions in human-computer interaction design. Hu Xiaowei, a 2018 graduate from the all-English computer class, received a Hong Kong government scholarship to pursue doctoral studies at the Chinese University of Hong Kong. Chen Xingyu, a 2019 graduate from the all-English computer class, went to Carnegie Mellon University for further studies and won the gold award and third prize in the Higher Education Main Track Finals of the 2020 China International "Internet+" College Students' Innovation and Entrepreneurship Competition.

Among those who have started their careers, some international students have returned to government positions in their home countries or started their own businesses, while the vast majority have chosen to work for famous IT companies such as Microsoft, Google, Baidu, Tencent, Alibaba, and Huawei. Huang Guan, a 2013 undergraduate graduate, is the founder of Lizhi Weke, and was selected for the Forbes 30 Under 30 list, received nearly 100 million yuan in two rounds of financing, and has become an elite figure in the "consumer technology" field.

DISCUSSION

Theoretical foundations

The proposed 'five-in-one' framework demonstrates strong alignment with established engineering education theories. The framework embodies the core principles of social constructivist learning theory, creating rich social construction environments through cross-cultural collaborative learning that promotes diversified knowledge construction (Vygotsky & Cole, 1978). Meanwhile, the framework aligns closely with the Conceive-Design-Implement-Operate (CDIO) engineering education model in emphasizing industry-academia-research integration, practical capabilities, and innovative thinking development (Crawley *et al.*, 2014), providing solid theoretical foundations for internationalized computer graphics education.

Comparative analysis with traditional approaches

Compared to traditional computer graphics education that primarily relies on single-cultural theoretical instruction and individual assignments, the 'five-in-one' framework significantly enhances students' innovative thinking and international communication capabilities through cross-cultural group collaboration. However, the framework also faces challenges such as communication barriers caused by cultural differences and increased coordination costs during implementation. Nevertheless, the learning improvements brought by diversified teaching environments substantially exceed the implementation difficulties, providing an effective pathway for cultivating internationally competent talent.

Broader applicability to engineering disciplines

The "five-in-one" framework demonstrates strong disciplinary adaptability, with its core elements being extendable to internationalized teaching practices in other engineering disciplines. For example, in software engineering education, cross-cultural team collaboration can be applied to large-scale system development projects, while in mechanical engineering design courses, international faculty teams can introduce diverse design philosophies and manufacturing standards from different countries. This teaching model based on multicultural integration provides a replicable reference framework for engineering education internationalization.

Scalability and adaptability considerations

The implementation of this framework in diverse institutional settings may encounter challenges such as insufficient faculty resources, high costs for establishing international cooperation platforms, and differences in educational systems. To address these obstacles, a phased implementation strategy is recommended, initially utilizing online international collaboration platforms to reduce costs and partnering with existing international education consortiums to share faculty resources. Furthermore, the modular design of the framework allows institutions to flexibly select and adapt implementation elements according to their specific conditions, ensuring sustainable development across different environments.

CONCLUSION AND FUTURE WORKS

This research presents a systematic exploration of international computer graphics education through the development and implementation of a "five-in-one" teaching framework, which integrates international faculty team setup, diverse student recruitment, collaboration platforms, cross-cultural competency training, and integration of industry, teaching and research. The framework successfully combines research-based education with cross-cultural collaborative learning, contributing valuable insights to the internationalization of computer science education. The implementation has yielded three significant contributions to the field of computer graphics education. First, it has constructed a "five-in-one" international teaching framework, forming a complete talent cultivation cycle and achieving optimized allocation and efficient utilization of teaching resources. Second, it has explored an innovative teaching model that integrates science and education, organically incorporating research training into daily teaching through cross-cultural group learning to enhance students' international communication capabilities while emphasizing the cultivation of innovative thinking and practical abilities. Third, it has achieved international dissemination of course resources, gaining recognition from world-class universities, establishing stable international teaching cooperation platforms, and producing students who have demonstrated outstanding competitiveness on the international stage. Future work will focus on advancing the cultivation of innovative talents with international competitiveness. We will continue to adapt to emerging technological developments and evolving requirements for talent development, while maintaining its established educational principles. Through sustained innovation and improvement, this framework demonstrates how computer graphics can be effectively taught through this international framework. The experience will provide valuable reference and demonstration for the internationalization of not only computer graphics teaching but also other computer science and engineering disciplines that require similar cross-cultural technical collaboration.

DECLARATIONS

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Author contributions

Yu MJ developed the conceptual framework, conducted the investigation, and wrote the original draft. Liu YJ provided supervision, secured funding, and contributed to manuscript revision. Yi R performed data analysis and participated in manuscript editing. Mao AH provided supervision, conducted investigation, and contributed to manuscript revision. Paul L. Rosin supervised the international collaboration aspects and contributed to manuscript revision. All authors have read and approved the final manuscript.

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The authors declare no competing interest.

Use of large language models, AI and machine learning tools
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No additional data.

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