

PRACTICE

Interdisciplinary integration in undergraduate education: The practice of biomedical engineering program in a Chinese STEM university

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ABSTRACT

In recent decades, biomedical engineering (BME) has rapidly evolved into cutting-edge research and industrial applications, leading to increased demand for undergraduate education. The BME undergraduate program has faced challenges as an interdisciplinary field. Here, we introduce the BME undergraduate program at Southern University of Science and Technology (SUSTech), characterized by its integration of broad general education with interdisciplinary specialization, tiered practical ecosystems, and multifaceted extracurricular involvement. This program provides students with comprehensive knowledge, rigorous scientific research training, and diverse internship opportunities. After eight years of implementation, the program demonstrates significant outcomes: students exhibit strong research engagement with excellent outputs, including 51 publications, 22 patents, and 112 competition awards. This perspective serves as a reference for cultivating next-generation medical engineers and inspiring innovation in engineering education.

Key words: biomedical engineering, undergraduate program, interdisciplinary education

INTRODUCTION

Biomedical Engineering (BME) is a comprehensive discipline that applies the principles and methods of engineering to solve biomedical problems and improve human health. BME emerged in the 1950s as a bridge between engineering and medicine. Since then, BME has grown into a discipline that integrates knowledge from various fields, such as mathematics, physics, chemistry, materials, and computer science, into biology and medicine. It applies engineering principles and methods to acquire and generate new knowledge to solve problems in medical practice (Linsenmeier & Saterbak, 2020; Nebeker, 2002). Interdisciplinary integration is a crucial characteristic of BME (Karagözoglu, 2013; Miller *et al.*, 2023; White *et al.*, 2020). However, it causes

problems in the design of the curriculum system for student education, particularly at the undergraduate level. Selecting the most crucial parts of the interdisciplinary knowledge and successfully integrating them into limited class hours has been challenging for BME student training (Miller *et al.*, 2023; Prestigiacomo *et al.*, 2024; White *et al.*, 2020).

In China, the national standard for undergraduate education in BME emphasizes the importance of interdisciplinary integration as a critical feature of the field and an essential measure for assessing the quality of education. It recommends that universities address the challenges related to interdisciplinary integration in their education programs based on their unique characteristics. The Department of BME at Southern University

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of Science and Technology (SUSTech) was established in 2016. The department focuses on research areas of mechanomedicine, multimodal biomedical imaging, wearable devices and wireless monitoring, biomedical micro-electromechanical systems (MEMS), biomaterials and tissue engineering, and computational medicine. The BME undergraduate program at SUSTech aims to provide students with a broad range of knowledge, comprehensive scientific research training, and diverse practical opportunities. The main objective is to develop students' ability to solve advanced BME problems, equipping them with the skills needed to excel in interdisciplinary fields.

Over the past eight years, the BME program at SUSTech has evolved to address the challenges of integrating engineering and medical sciences in an educational setting. The program integrates broad general education with interdisciplinary specialization, builds tiered practical ecosystems that provide diverse, student-centered experiential layers and mentor-guided professionalization led by research-active faculty enabling tailored professional development, and enables multifaceted extracurricular involvement. Its evolution involves sustained curriculum refinement, implementation of innovative teaching methods, and establishment of strong collaborations with leading institutions to ensure global competitiveness. This perspective seeks to share our experiences and practices of the BME program, including the strategies adopted to overcome the challenges of interdisciplinary integration, and the outcomes achieved in terms of student development and research productivity. By detailing these aspects, we aim to contribute to the broader discussion on advancing BME education and inspiring further innovation in the field.

BME UNDERGRADUATE PROGRAM DESIGN

Curriculum

The curriculum for the BME undergraduate program at SUSTech is thoughtfully designed to provide students with a comprehensive education that integrates engineering principles with biomedical applications. As illustrated in Figure 1, the curriculum is divided into four main categories of required courses—General Education Courses, Major Foundational Courses, Major Core Courses, and Lab and Practice Courses. These categories are structured to build upon one another, culminating in a course framework that prepares students for real-world challenges in BME.

In SUSTech, a university dedicated to STEM (science, technology, engineering, and mathematics) innovation students start their undergraduate study from general

education with courses across the spectrum of sciences and liberal arts that provide opportunities for students to explore their interests through courses and help students prepare themselves for the major declaration and their development of critical thinking, communication, and understanding of culture, values and science for the future (Li & Li, 2023; Wu & Zhang, 2024). The General Education courses are administered by the college and delivered by designated departments. These courses are typically recommended for completion during the freshman year.

The Major Foundational Courses serve as the critical scaffolds between broad general education and advanced disciplinary specialization, which are generally taken during the freshman and sophomore years. These courses—delivered collaboratively by the Department of BME and related engineering departments—establish essential competencies in mathematics, physics, materials science, and computational methods, creating a unified conceptual framework that bridges disparate disciplines. By mastering instrumentation principles, quantitative analysis techniques, and engineering problem-solving paradigms during freshman and sophomore years, students develop the technical literacies necessary to decode complex biomedical challenges. This foundational layer operates as both an intellectual catalyst and methodological toolkit, enabling the transition from theoretical knowledge to applied biomedical contexts.

The Major Core Courses are coordinated by the Department of BME. The Major Core Courses include six theory-based courses and two laboratory courses. The theory courses cover fundamental principles and cutting-edge advancements in five key areas of BME: biomechanics, medical imaging, biomedical optics, biomaterials and tissue engineering, and quantitative physiology. These subjects are not only foundational but also represent active and highly relevant fields within BME. Beyond traditional textbook-based instruction, considerable emphasis is placed on integrating the latest research developments, particularly those aligned with the department's primary research focuses. These courses extensively employ pedagogical approaches such as case studies, problem-based learning (PBL), project-based learning (PjBL) (Falade, 2023), inquiry-based learning (IBL), modular-based design and scaffolded instruction. Through solving real-world challenges, students acquire advanced knowledge and practice integrating interdisciplinary concepts to develop solutions. This approach equips students with a deeper understanding and prepares them for practical application in the subsequent laboratory and practice courses.

Take the core laboratory course *Biomedical Engineering Laboratory I* as an example. The laboratory course is

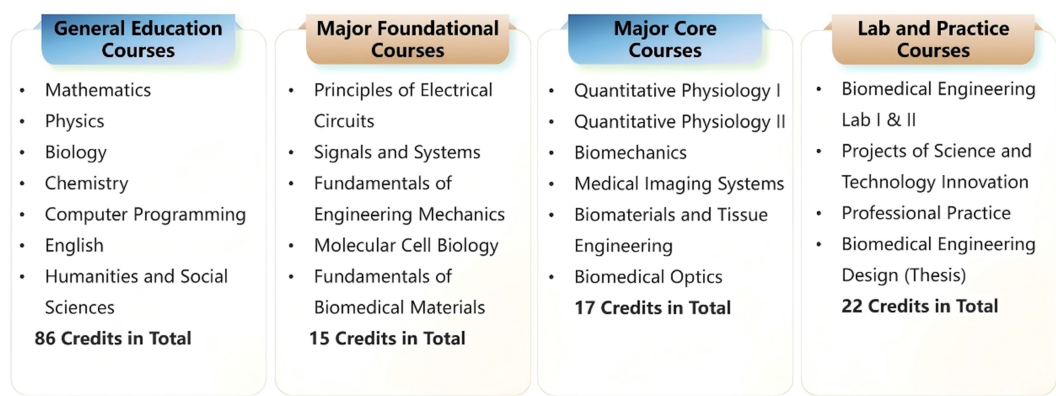


Figure 1. Course framework for the BME program in SUSTech. BME: biomedical engineering; SUSTech: Southern University of Science and Technology.

structured around thematic laboratory modules, such as microvasculature modeling using microfluidics, cell behavior analysis under pathological conditions, and hand gesture recognition, *etc.* These modules are designed to replicate research scenarios aimed at addressing real-world BME challenges, requiring students to perform a series of experimental steps and apply techniques from multiple disciplines. This structure reflects the complexity and interconnected nature of problems in the field of BME. Critically, these modules implement scaffolded instruction—a progressive instructional framework where support is systematically faded as competency develops. Initially, students receive structured protocols with explicit guidance; at intermediate stages, they tackle problem-defined challenges requiring autonomous technique selection; finally, they engage in open-ended research inquiries mirroring professional practice. This tiered scaffolding offers dual advantages: cognitively, it manages intrinsic load by segmenting complex tasks into achievable phases (Hmelo-Silver *et al.*, 2007); pedagogically, it cultivates adaptive expertise through graduated responsibility transfer. By completing these modules, students gain proficiency not only in laboratory techniques but also in critical areas such as experimental design, statistical analysis, problem identification, scientific writing, ethics, and teamwork. Furthermore, the problem-based themes are carefully curated to stimulate students' interest in science and technology, fostering a deeper engagement with the discipline.

In addition to the required courses, students can choose from a pool of up to 44 Major Elective Courses offered across all academic units in the university to customize their academic experience and pursue specific areas of interest within the field. A minimum of 22 elective credits is required, enabling students to explore advanced topics and gain deeper insights into specialized domains. The combination of required and elective courses ensures that students receive a balanced

education, blending theoretical knowledge, practical skills, and research experiences. This holistic approach equips students with the competencies needed to excel in both academic and industry contexts.

Research and extracurricular opportunities

The BME program at SUSTech emphasizes not only academic learning but also student-centered, tiered hands-on research and extracurricular involvement, providing students with a well-rounded educational experience.

From their second semester, students have the opportunity to join cutting-edge research laboratories led by faculty members in the department. These opportunities allow them to actively engage in scientific research projects, often addressing real-world biomedical challenges. Through initiatives such as the *Project of Science and Technology Innovation*, students are guided in research practices, including experimental design, data analysis, and scientific writing, under the mentorship of professors and senior researchers. These projects culminate in assessments that evaluate their contributions and learning outcomes.

Students at SUSTech are required to declare their majors by the end of the spring semester of their freshman or sophomore years. Following the declaration, they must select an academic mentor from the department faculties. These academic mentors play a pivotal role in guiding students throughout their academic journey, helping them identify their interests, chart personalized academic paths, and explore a variety of academic opportunities. The mentoring system fosters close student-faculty interaction, enabling mentors to provide tailored advice on course selection, research involvement, and career planning. By fostering a supportive and collaborative environment, this system helps students develop a clearer sense of direction, refine their academic goals, and unlock their full potential,

ensuring they are well-prepared for both academic and professional success upon graduation.

Beyond research, students are required to complete *Professional Practice* internships, typically during the summer semester of their junior year. These internships, lasting at least four weeks, place students in BME-related industries, enabling them to apply their knowledge in professional settings and gain invaluable exposure to industry practices. Additionally, the capstone *Biomedical Engineering Design I & II* courses provide a platform for students to undertake comprehensive research projects. These projects integrate theoretical knowledge and experimental skills, guiding students through the entire research process, from topic selection to data analysis and final presentation.

The BME department actively organizes a variety of activities to encourage student engagement in research and academic communication. One of these initiatives is the weekly student-led “Happy Hour”, which provides an informal setting for open discussions. With or without a set topic, this event fosters a relaxed and collaborative environment, promoting interdisciplinary exchange and idea sharing among students. This peer-driven design forum accelerates practical knowledge exchange through cross-disciplinary problem-solving cycles. On a monthly basis, the department hosts the academic salon “BME Talk”, where undergraduate and graduate students present their research projects. This platform not only allows students to showcase their work but also helps them hone essential skills such as public speaking, critical thinking, and constructive feedback. The discussions following each presentation encourage active engagement and foster a deeper understanding of diverse research topics. A highlight of the academic calendar is the annual “Research Day”, a full-day event dedicated to celebrating student research achievements. During this event, students present their findings through oral presentations and poster sessions, competing for excellence awards in recognition of their work. The event attracts over 200 attendees, including faculty, peers, and external guests, creating a vibrant atmosphere for intellectual exchange and networking. Through these activities, the department cultivates a dynamic and supportive research culture, empowering students to thrive academically and professionally. Within these tiered activities, peer-mediated learning synergizes with deliberate practice frameworks and authentic assessment to holistically enhance student development.

Extracurricular activities further enhance students’ learning experiences. The department encourages participation in national and international competitions, such as innovation challenges and design contests, which foster creativity, teamwork, and problem-solving skills.

Through these diverse opportunities, students not only refine their technical expertise but also develop leadership, communication, and collaboration skills, preparing them for success in their future careers.

OUTCOMES

After 8 years of implementation, the BME program at SUSTech has shown positive outcomes. In 2020, the BME major was selected as a national first-class undergraduate program. In 2024, the BME graduate program was approved to award doctoral degrees by the Ministry of Education (MOE), China. SUSTech offers undergraduate students the opportunity to freely choose their majors. All students select their majors of interest in their sophomore years. During this process, each department needs to showcase its appealing characteristics and learning experiences to the students. During these years, BME became increasingly attractive and popular among students of SUSTech. Since the class of 2016, the total number of students enrolled in the BME department has increased from 18 to around 115. This group also represents a significantly increasing proportion of the total student body over 41 majors in the university each year (Figure 2). The BME department, with its interdisciplinary nature and cutting-edge research focus, has attracted a large group of students deeply interested in the fields of BME and healthcare. It has become the third-largest department in terms of student numbers, following the popular majors in Computer Science and Microelectronics.

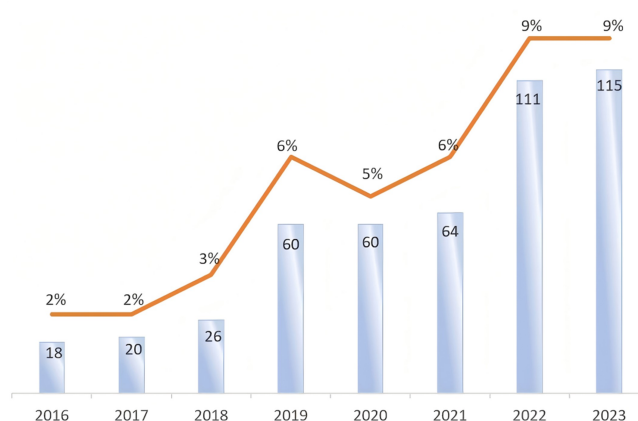


Figure 2. The number of students enrolled in the BME department and the corresponding percentage in SUSTech in past 8 years. BME: biomedical engineering; SUSTech: Southern University of Science and Technology.

Within this program, students’ academic interests are effectively stimulated, their capabilities progressively developed, and comprehensive competencies systematically cultivated. Over the past eight years, 474 BME undergraduates have collectively published 51 research articles in international journals or conferences, among

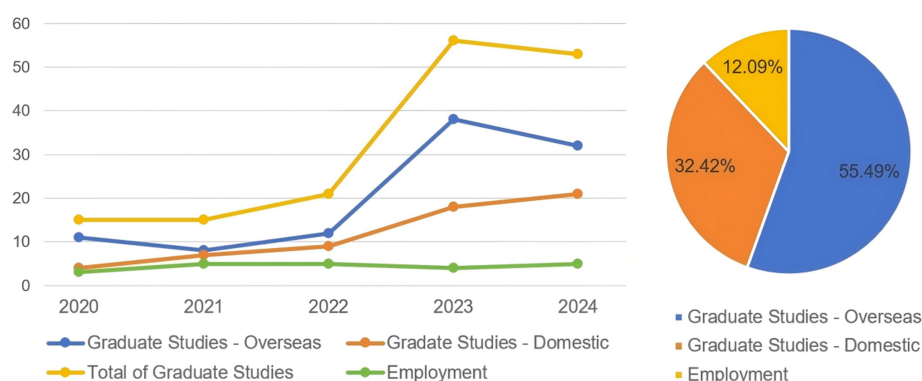


Figure 3. The career development of BME undergraduate students after graduation. BME: biomedical engineering.

which 22 were first authored or co-first authored publications; several impactful research outcomes have appeared in high-impact journals (Deng *et al.*, 2019; Liu *et al.*, 2023; Xie *et al.*, 2023; Yang *et al.*, 2024; Zhang *et al.*, 2022; Zhao *et al.*, 2021), earning recognition from peers. Furthermore, BME undergraduates have contributed as key participants in filing 24 patents and secured 112 awards across international, national, and provincial competitions such as the International Genetically Engineered Machine Competition (iGEM), the Mathematical Contest in Modeling (MCM), and the National Mathematical Modeling Contest.

Meanwhile, evidence demonstrates that this multifaceted development equips our students with significant competitiveness when pursuing graduate admissions and employment opportunities. All BME students successfully secure either graduate program offers or industry positions. The majority choose to pursue graduate studies after completing their undergraduate education, demonstrating that their research-oriented interests have been effectively cultivated during the program. As of 2024, 182 students have graduated from SUSTech's BME department, with 88% pursuing advanced degrees and 12% entering industry careers. Figure 3 shows the number of students choosing for graduate studies as well as those for industry. Taking the 2024 cohort of students as an example, 53 out of 58 graduate students chose to pursue further studies. Among those, 21 pursued studies domestically, while 32 opted for institutions abroad. Domestic institutions included prestigious universities such as Peking University and Tsinghua University, while international institutions were highly ranked and globally distributed, including Johns Hopkins University, the University of Cambridge, Cornell University, University of California, Los Angeles (UCLA), Boston University, the University of Toronto, and the National University of Singapore. Additionally, 22 of 61 graduates in 2025 have successfully secured conditional offers from renowned institutions such as Tsinghua University and Peking

University through recommended admission applications.

In 2021, SUSTech and King's College London (KCL) jointly established the SUSTech-KCL School of Medicine, an educational partnership integrating resources from both institutions. This collaboration demonstrates international recognition of our educational philosophy. By combining Shenzhen's innovative academic environment with London's established expertise, the initiative pioneers a global engagement model for developing future biomedical professionals. This framework creates fertile ground for cultivating advanced training programs through bilateral wisdom exchange, while simultaneously enhancing our core BME curriculum. The joint institute offers two undergraduate programs: BME and Biomedical Science (BMS). Co-developed by faculty teams from both universities, these programs award dual degrees recognized in China and the UK. In 2024, the inaugural cohort was successfully admitted (28 BME and 25 BMS students), with Gaokao scores equivalent to domestic program entrants. This competitive admission profile confirms the program's strong appeal and demonstrates exceptional potential for cultivating talent through world-class biomedical education.

CONCLUSION

Since its establishment, SUSTech has prioritized the cultivation of top talent. In line with this mission, the BME program at SUSTech trains students in engineering and applied sciences to tackle advanced challenges in life sciences and clinical medicine. The program aims to provide students with a solid knowledge base, comprehensive research training, and diverse practice opportunities, preparing them for a deeper understanding and greater achievement in the field of BME in the future.

The program has been well-received by students,

faculties, and industry professionals, garnering positive feedback across the board. The steady rise in student enrollment numbers underscores its appeal. With tailored academic training and career planning, all students can secure graduate admission offers from highly ranked institutions or job offers from established companies after graduation, enabling them to pursue advanced career paths. Furthermore, the increasing international collaboration expands students' global perspectives and enhances their international competitiveness.

The accelerating pace of scientific and technological innovation—particularly recent breakthroughs in Artificial Intelligence (AI), unmanned systems, robotics, and brain-computer interfaces—continuously reshapes educational imperatives. These disruptive innovations are fundamentally transforming the conceptual foundations, instructional modalities, and pedagogical methodologies of engineering education, simultaneously presenting educators with unprecedented challenges and opportunities. In proactively embracing this evolving landscape, we have extensively integrated AI into instructional design and practice while guiding students to adopt responsible approaches toward AI in their learning. Simultaneously, we have begun introducing cutting-edge content—including highly promising medical robotics and brain-computer interface technologies—into our laboratory teaching modules. In the future, we will remain committed to continuously refining our program to keep pace with the advancements.

While refining this article, we discovered our design and practices resonate with approaches used by some peers (Xu, 2025). Knowing so many outstanding colleagues share common goals, perspectives, and dedicated efforts is both profoundly encouraging and inspiring. We look forward to exchanging experiences and practices with all BME educators, and to collaborating on future program design initiatives.

DECLARATIONS

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Author contributions

Cheng P, Conceptualization, writing- original and revised draft preparation, writing- reviewing and editing. Xiaofeng F, Data collection and analysis, visualization, writing- reviewing and editing. Dan W, Data collection and analysis, visualization, writing- reviewing and editing. Yanqi S, Data collection and analysis, visualization, writing- reviewing and editing. Changfeng W, Conceptualization, research questions formulation,

writing- original draft preparation, writing- reviewing and editing, supervision. All authors have read and approved the final version of the manuscript.

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Ethical approval

Not applicable.

Informed consent

Not applicable.

Conflict of interest

The authors declare no competing interest.

Use of large language models, AI and machine learning tools

None.

Data availability statement

Not applicable.

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