Editorial

Advancing STEC Bioinformatics Training for the New Era

DOI:https://dx.doi.org/10.71373/AUEH9795
Submitted 9 December 2025
Accepted 25 December 2025
Published 31 December 2025

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Bioinformatics, positioned at the nexus of life, data, and computational sciences, is pivotal for cultivating innovators and enabling technology translation. Its growing importance, driven by the quantitative shift in life sciences, is met with universal challenges: outdated curricula, siloed pedagogy, and inadequate lifelong learning frameworks. To address these, the Guangdong-Guangxi-Hainan Bioinformatics Education Consortium convened in Nanning, China (14–16 November 2025). Guided by the STEC principle (Science, Technology, Engineering, Collaboration), educators and industry experts presented practical cases aligned with global educational trends. This framework offers a concrete strategy to tackle seven core challenges in contemporary bioinformatics education, providing a roadmap for its sustainable advancement.

Introduction

Driven by advances in omics technologies, synthetic biology, and precision medicine, bioinformatics now serves as a pivotal link between fundamental research and industrial applications[1], with a corresponding surge in demand for trained professionals. However, bioinformatics education currently faces multiple systemic challenges: a fragmented interdisciplinary curriculum that fails to integrate biology, mathematics, and computer science; slow adaptation to technological change, leaving tool instruction behind current practice; uneven regional distribution of teaching resources, practical platforms, and qualified instructors; inadequate lifelong-learning frameworks to support the continuing development of researchers and industry professionals[1,2]; and limited attention to ethical, legal, and social implications (ELSI), resulting in underdeveloped data ethics awareness among students. These issues closely mirror the seven core challenges recognized by the international bioinformatics education community[3] and together constrain the effectiveness of talent development.

To overcome these barriers, the Guangdong-Guangxi-Hainan (G-G-H) Bioinformatics Education Consortium initiated a coordinated reform under the mentorship of the national "101 Program" Virtual Teaching and Research Center for Bioinformatics. This initiative is structured around the STEC framework, including Science, Technology, Engineering, and Collaboration. By pooling regional strengths and high-quality resources, the consortium has innovated teaching models, strengthened practical training, and built a sustainable collaborative network. This systematic effort shifts the focus of bioinformatics education from knowledge transmission to competency development, aiming to cultivate professionals with integrated scientific literacy, technical proficiency, engineering thinking, and a collaborative mindset. The approach provides a localized and transferable model for addressing universal challenges in bioinformatics education.

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The core dimensions of teaching reform under the STEC concept

Science: strengthening the foundation of Interdisciplinary science

The scientific essence of bioinformatics lies in the deep integration of multidisciplinary theories. Consequently, our pedagogical reform prioritizes restructuring the core curriculum by dissolving the traditional boundaries separating biology, computing, and mathematics. We have implemented a dynamic competency framework designed to continuously incorporate emerging topics, such as genomics and protein structure prediction, ensuring the knowledge system remains synchronized with the pace of disciplinary advancement[5]. Instruction is built around a narrative-driven and problem-oriented model, where authentic research cases, including tracing Burkholderia pseudomallei outbreaks or screening for cancer biomarkers, are used to integrate fundamental concepts like sequence alignment, database utilization, and phylogenetic analysis. This methodology fosters scientific reasoning while bridging theoretical knowledge with practical application. For instance, by constructing phylogenetic trees for SARS-CoV-2, students learn to derive biological meaning from data, achieving a cognitive transition from abstract theory to applied understanding.

Technology: strengthen the innovative application of technical tools

Technological evolution represents the central engine of bioinformatics education. To mitigate challenges such as the accelerating pace of tool development and student apprehension toward hands-on computational work, our reform emphasizes tool accessibility and structured skill-building. We have established an AI-enhanced teaching toolkit that integrates platforms including AlphaFold2 (https://github.com/deepmind/alphafold)[5], Galaxy(http://www.g2.bx.psu.edu)[6], and Omics-Flow (https://www.henbio.com/en/tools)[7], spanning key workflows from gene circuit design and multi-omics analysis to protein structure prediction, thereby lowering technical barriers.

Instruction follows a scaffolded pedagogy, where learners begin by modifying parameters within standardized code templates and experimental protocols, progressively mastering programming in Python and R to build computational confidence. Furthermore, a modular digital repository consolidates MOOC videos, interactive courseware, and virtual simulations, supplemented by dedicated platforms such as TeachEnG. This integrated ecosystem supports blended and adaptive learning, effectively addressing diverse student needs across proficiency levels.

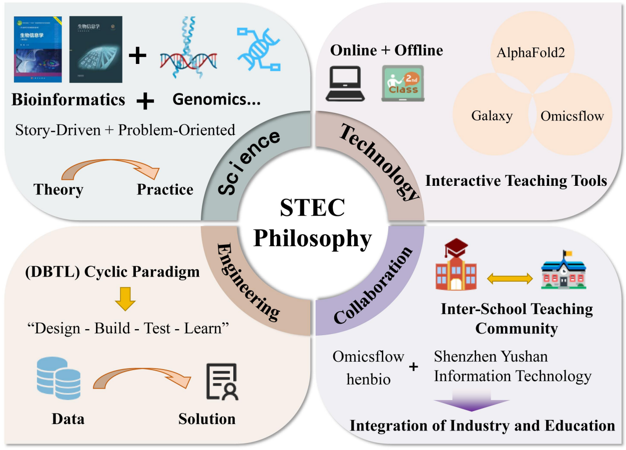
Engineering: developing engineering practice skills

Developing engineering thinking is essential for enabling students to tackle complex real-world problems. Our pedagogical reform incorporates structured engineering projects to cultivate system design and optimization skills. We have integrated the design, build, test, learn cycle into synthetic biology courses, where students design gene circuits with TinkerCell (http://www.tinkercell.com)[8], optimize primers using NCBI Primer-BLAST, and simulate fermentation processes in BioStudio[9], thereby experiencing a complete engineering workflow. Project-based learning is further implemented through competitions and research-driven tasks, such as designing plastic-degrading engineered bacteria or predicting drug-target interactions, that train students in project planning and execution. To bridge data analysis with biological insight, the curriculum emphasizes multi-omics integration, guiding students to apply convolutional neural networks for regulatory element mining and Bayesian models for metabolic network optimization, effectively translating data into actionable solutions.

Collaboration: establishing a cross-regional collaborative education system

Collaboration is essential for overcoming resource constraints and elevating teaching quality. By leveraging the complementary regional and disciplinary strengths of the Guangdong, Guangxi, and Hainan consortium, we established a multi-level collaborative education network. This includes forming cross-institutional teaching communities that integrate specialized expertise in synthetic biology from Guangxi University of Science and Technology, biological science from Hainan University, and precision medicine from Guangdong Medical University, enabling shared curriculum development, case libraries, and faculty exchanges. We also developed virtual teaching and remote collaboration platforms, utilizing integrated environments to support cross-regional joint experiments and project discussions (https://training.galaxyproject.org)[10], thereby transcending geographical limitations. Furthermore, deep academia-industry-research partnerships were fostered through the introduction of authentic industrial datasets and project requirements, along with the establishment of dedicated internship and training bases. This integrated approach ensures precise alignment between talent development and sectoral needs.

Our STEC framework can be summarized as follows:



Challenges and Prospects

The educational reform in bioinformatics across the G-G-H region has established an initial pedagogical framework guided by the STEC principle. However, several challenges persist, including the need to deepen and sustain cross-institutional collaboration, to achieve more equitable distribution of high-quality educational resources, and to develop robust ethical guidelines and quality assurance mechanisms for A-enhanced instruction. Moving forward, we will focus on three strategic priorities. First, we aim to institutionalize cross-regional coordination by establishing regular teaching workshops, systematic faculty exchanges, and joint student training programs. This will formalize the G-G-H Bioinformatics Education Consortium into a replicable model for multi-institutional collaboration. Second, we will advance the integration of AI into pedagogy by developing tailored large-language models for education and designing adaptive learning pathways, while concurrently implementing an ethical review framework to ensure the responsible use of educational technology. Third, we will deepen tripartite collaboration among academia, industry, and research by broadening enterprise engagement, co-establishing industry-linked academies and training bases, and fostering bidirectional exchange between curricular content and industrial needs, as well as between research outputs and teaching resources. Bioinformatics education is at a pivotal stage of rapid evolution. The coordinated reform undertaken in the G-G-H region offers a valuable case study for modernizing pedagogy in this field. We remain committed to the STEC framework and will continue to refine the educational ecosystem, innovate instructional methods, and strengthen collaborative networks. These efforts are directed toward cultivating a new generation of highly skilled bioinformatics professionals and supporting the continued growth of the life sciences sector.

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Acknowledgement

We gratefully acknowledge guidance from the Bioinfor- matics Virtual Teaching and Research Center under the Ministry of Education's "101 Program" of China. We also extend our thanks to Guangxi Medical University, Hainan University, and the Guangdong Bioinformatics Society for their support of the joint conference, and to all participating instructors, students, and scholars for their contributions to this pedagogical reform initiative. We also give thanks to the Project of the Degree and Graduate Education Reform from Guangxi Zhuang Autonomous Region (JGY2024305).

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