Editoria

Enhancing Undergraduate Academic Writing In the Context of Medical Research: A Comprehensive Training Framework

DOI:https://dx.doi.org10.71373/MKIN4148
Submitted 18November2025
Accepted 26 December 2025
Published 31 December 2025

Yong Cao[1,2#], Ying Wen[1#], Xuan Li[1#], Hongbin Huang[1,3], Liyi Zou[1], Yong Liu[1], Zunnan Huang[1*]

Objective: Scientific writing is essential for students to engage in research and contribute meaningfully to academic communities. Yet many undergraduates lack formal training in how to write clearly and rigorously. This often leads to work that falls short in logic, structure, and originality. This study asks how a structured, multi-component training framework can improve academic writing skills and research output among undergraduates. Methods: We present a long-term case study from Guangdong Medical University, where an undergraduate research group in computer-aided drug design implemented a comprehensive academic writing program. The framework combines four strategies: a student-led writing platform, peer mentorship and collaborative learning, regular outcome-focused seminars, and bilingual, practice-driven writing instruction. Results: Between 2015 and 2024, over 300 students participated. Many produced publishable manuscripts, with 34 Science Citation Index papers authored by undergraduates. These outcomes reflect both skill development and sustained research engagement. Conclusion: Our work offers a tested model for building academic writing capacity at scale. It may serve as a guide for institutions seeking to equip students especially non-native English speakers with the skills to write and publish scientific work.

Introduction

Medical schools are placing increasing focus on research training as part of preparing future clinicians and scientists. A key marker of student research competence is the ability to publish academic papers. These not only signal academic maturity but also promote critical thinking and exchange of ideas. For medical undergraduates in China, academic writing especially in English is a core skill. Yet, many students lack the structure and support needed to write with clarity and precision. Without formal guidance, their writing often lacks rigor and coherence. Addressing this gap requires training programs that are both systematic and practice-based. Review articles offer a practical entry point for undergraduates learning academic writing. Their structured format encourages comprehensive engagement with the literature[10] and strengthens skills in synthesis and analysis[3]. When done well, review writing enhances students' ability to critically evaluate research and communicate ideas with clarity[31]. This makes it not only an academic exercise but also a training ground for scientific reasoning and innovation.

However, despite broad recognition of its importance, academic writing remains a major weakness in undergraduate medical education. A clear gap persists between theoretical emphasis and the practical implementation of effective writing instruction. Undergraduate students face a range of challenges in this area[1]. One of the most pressing is the lack of systematic training and targeted guidance. This often results in writing that suffers from vague arguments, poor structural organization, superficial engagement with research findings, and weak logical flow[25] . In addition, students writing in English frequently struggle with limited vocabulary and recurring grammatical errors[27], which further compromise clarity and academic quality. Many treat review writing as an exercise in compilation extracting content from various sources and reusing figures with minimal adaptation rather than constructing a coherent argument or generating original visuals. This practice not only leads to work of low academic quality but also, in some cases, raises concerns about plagiarism.

The roots of these challenges are complex and reflect broader issues in how academic writing is taught. One major factor is the persistence of "spoon-feeding" methods in some specialized courses. These passive teaching styles discourage independent thinking and problem-solving, making it harder for students to write with academic rigor or originality. A second issue is the narrow scope of writing instruction. Many students receive only basic training in "foreign language composition," focused mainly on test preparation, with little exposure to structured writing methods or discipline-specific guidance[28] . As a result, they lack the tools needed to craft strong academic texts. Third, poor foundational knowledge of professional English hinders both the ability to read complex research and to express ideas clearly in writing[11]. This limits their capacity to interpret research and build original arguments. Finally, writing is often missing from course assessments. Few programs include structured writing exercises or view writing skill as a core learning outcome[7]. With limited practice and feedback, students rarely gain the confidence or competence to write independently at a high level. These persistent gaps point to the need for comprehensive, theory-informed frameworks that address writing development across multiple dimensions.

To respond to these persistent gaps, we designed our program around collaborative learning and situated learning principles. Both emphasize the role of peer interaction and hands-on practice in developing expertise. Since 2015, our team has worked to build a pathway for undergraduates to engage in meaningful research and develop scientific writing skills. We began with projects tied closely to student interests, focusing on evidence-based medicine and meta-analysis. Within three years, these efforts produced five Science Citation Index (SCI) papers

1.Guangdong Medical University Key Laboratory of Big Data Mining and Precision Drug Design, Dongguan Key Laboratory of Computer-Aided Drug Design, School of Pharmacy, Guangdong Medical University, Dongguan 523808, China.

2.School of Humanities and Management, Guangdong Medical University, Dongguan 523808, China.

3.The Second Clinical College of Guangdong Medical University, Dongguan 523808, China.

#Yong Cao, Ying Wen and Xuan Li contributed equally to this work and share first authorship.

** Correspondence:*

Zunnan Huang, Guangdong Medical University, Dongguan 523808, China. zn_huang@gdmu.edu.cn

and two additional English-language publication, with a combined impact factor of 14.4 and 194 citations to date. In 2021 and 2023, we published two teaching reform papers[5,6] that summarized our training experience based on these seven articles, highlighting our structured approach to developing undergraduate research skills. These early results demonstrated the potential of structured mentorship and topic alignment. We later expanded our focus to computer-aided drug design and formed a dedicated undergraduate research group. In 2017, our team was invited by Professor Daniela Schuster of Paracelsus Medical Private University to contribute to a special issue on virtual screening. This collaboration led to a student-led review on reverse screening targets an emerging area of drug discovery. The process not only deepened the group's technical expertise but also served as a practical training ground in high-level academic writing. This work laid the foundation for a scalable framework integrating research engagement with writing instruction. Unlike conventional academic writing programs that often separate writing from research or rely on passive instruction, our model integrates writing into active research projects, combines bilingual drafting, and emphasizes peer mentorship across academic levels.

Building on this foundation, and informed by principles of collaborative and situated learning, our study examines a central question: Can a structured, multi-component training framework measurably improve undergraduates' academic writing and research output? We explore four sub-questions:

(1) What are the essential elements of an effective writing program for undergraduate researchers?

(2) How do peer-based collaboration and mentorship shape writing development?

(3) What evidence supports the impact of hands-on, practice-driven training on publication outcomes?

(4) How can this model be adapted and applied across different institutional settings?

To support undergraduates in producing strong English-language review articles, we developed a training model centered on writing as a core academic skill. The approach targets specific barriers faced by students' unclear arguments, weak structure, and limited writing techniques. Our framework combines four elements: (1) a student-led research and writing platform; (2) a collaborative, peer-driven learning environment; (3) structured feedback through academic seminars; and (4) practice-based, bilingual writing instruction. Applied over several years, this model has led to measurable improvements in writing quality and publication outcomes. In this paper, we describe the design and implementation of the framework, offering practical guidance for other institutions. Our aim is to show how a theory-informed, hands-on training system can close the gap between writing instruction and research performance in undergraduate education.

Methods

Study Design

In China, undergraduate medical programs typically span five years and admit students directly after high school. Our study uses a longitudinal case study design to assess the implementation and outcomes of a structured writing training program over a ten-year period (2015 − 2024). The setting is the Computer-Aided Drug Design research group at Guangdong Medical University, which functions as both a research hub and a training platform for undergraduates. More than 300 students from clinical medicine, pharmacy, bioinformatics, and related disciplines participated in the program during winter and summer terms. Eligibility criteria included first- to second-year status, commitment to a 36−48 months training period, basic English proficiency (College English Test Band 4 level), and interest in research. Each cohort included 6−8 students, guided by 1−2 mentors. Each year, the program operated 3−4 parallel research groups. During winter and summer breaks, students attended weekly two-hour group meetings and bi-weekly 30-minute one-on-one consultations. In regular semesters, group meetings were held every two to four weeks, with timing adjusted to avoid conflicts with exams.

Comprehensive Training Strategy Framework

To tackle persistent gaps in undergraduate writing skills, we designed and implemented a structured four-part training strategy at Guangdong Medical University. Each component targets a distinct challenge in the writing process while contributing to an integrated framework for academic skill development.

Development of a Student-Centered Research and Writing Platform

The research group functions as the core unit for undergraduate research activity and plays a central role in developing students' academic writing skills. Beyond offering a platform for scientific training, it provides a structured environment where writing is treated as a key part of the research process. The group is designed to support student participation across multiple disciplines, combining mentorship with opportunities for collaboration. Its hierarchical structure includes assistant researchers, senior undergraduates (juniors and seniors), and junior undergraduates (freshmen and sophomores). This layered model creates a dynamic setting where students learn from peers and mentors while advancing their own writing and research capabilities. The group's structure is detailed in **Figure 1**.

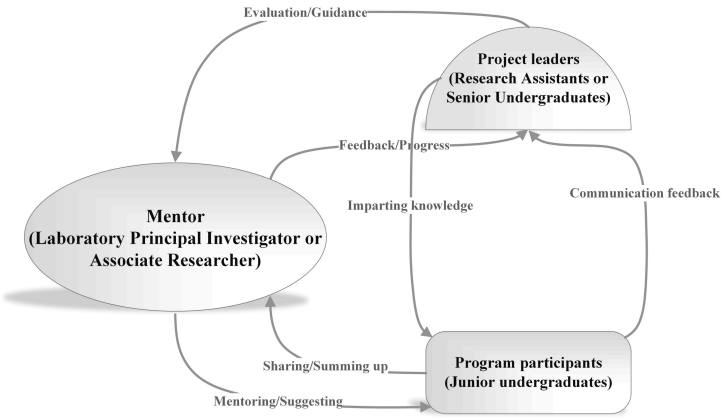

Figure 1. Organizational structure of the research group, showing the hierarchical roles of mentors, research assistants, senior undergraduates, and junior undergraduates. The diagram illustrates how each group contributes to collaborative research and academic writing, with defined responsibilities that support mentorship, skill development, and knowledge transfer.

Leadership and mentorship roles within the research group are held by assistant researchers and outstanding senior undergradu-

ates. These individuals are responsible for overseeing ongoing projects, monitoring student progress, and providing instruction in theoretical concepts, research methods, and academic writing techniques. They guide junior undergraduates in a range of tasks, including identifying appropriate journals, conducting literature reviews, and critically reading key articles. In addition, senior students organize academic activities such as literature exchange meetings, idea-sharing sessions, discussions on common writing difficulties, and updates on thesis progress. These activities are essential for evaluating whether students are developing the skills needed to address real-world research questions through writing.

The group emphasizes student-led learning, particularly in the review project on reverse screening targets, where students typically take the lead in research and manuscript preparation. This promotes autonomy and ownership of the writing process. Mutual learning is a core feature of the structure, with senior undergraduates guiding their junior peers through topic selection and thesis development. Regular discussions on both general writing approaches and specific structural elements play a key role in developing academic writing skills across the group. The diversity within the student cohort is actively leveraged by assigning responsibilities based on academic level[7]. For example, junior students focus on groundwork such as literature collection and background reading, while senior students handle more advanced elements like framing the manuscript and conducting data analysis. This tiered, collaborative structure encourages interaction, supports skill transfer, and creates a dynamic environment for academic growth.

The mentor plays a central role in shaping project direction, refining research ideas, and guiding the writing process[21]. Experienced mentors use challenges that emerge during group discussions as opportunities to lead students through the realities of research encouraging exploration, navigating uncertainty, and building resilience. They support students in independently formulating dissertation topics and structuring papers, helping them move toward academic autonomy. Mentors also incorporate feedback from both junior and senior students to improve writing strategies, strengthen research logic, and sharpen the clarity of argumentation. Through this ongoing guidance, students gain the skills to think critically, write with purpose, and engage more deeply with their scientific work.

Fostering a Collaborative and Motivational Research Environment Through Exemplary Leadership

Scientific research advances through stages of inquiry, moving from surface-level understanding to deeper, more nuanced insigh[8]. For undergraduates entering research for the first time, this progression often presents significant challenges. Many struggle with specialized terminology, constructing coherent research frameworks, and refining methodological approaches. These difficulties are often compounded by limited experience with academic English, unfamiliarity with technical literature, and underdeveloped writing skills. Such barriers can slow learning and reduce confidence. Research[16] suggests that close mentor-student interaction, along with a clear role and sense of purpose within the research group, is crucial for sustaining student motivation and engagement.

To support students through these early challenges, the research group has built a framework grounded in peer mentorship, academic tradition, and collaborative support. Central to this model are senior undergraduates who have published at least one SCI article as first authors and now mentor junior students. These student leaders organize academic sessions, lead discussions on literature and writing, and provide feedback on drafts. As shown in Figure 2, during the review project on drug target discovery via reverse screening, senior students guided junior participants through every stage of the writing process. By examining the published work and experiences of their senior peers, junior students gained insight into both the technical and logical demands of academic writing, gradually building the skills required to contribute independently.

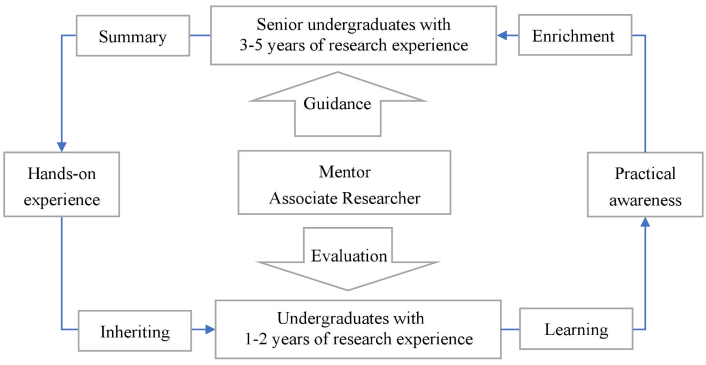

Figure 2. Teaching model within the research group, illustrating the interaction between mentors, senior undergraduates, and junior undergraduates. The schematic highlights key elements of the academic training process, including research supervision, writing guidance, and peer-led collaborative learning activities.

Collaborative learning structures enhance understanding by encouraging communication and shared problem-solving. Within the research group, open discussion helped clarify both the broader scientific process and the specific details of ongoing projects. This environment allowed junior students to develop the confidence and skills needed to write their own papers independently. By fostering effective research habits early on, the program also helped prepare these students to participate more productively in future academic work.

The mentor's role in guiding this process is critical. Beyond technical instruction, mentors play a key part in motivating students, encouraging open dialogue, and reinforcing ethical standards[12]. For example, in the review project on the computational method of reverse screening for target identification to predict potential biological targets of known compounds, the group encountered challenges that exceeded the capabilities of even the most experienced senior undergraduates, particularly in understanding complex terminology and specialized techniques. At such points, the mentor stepped in to bridge knowledge gaps and offer targeted advice on how to proceed. This type of mentoring is both iterative and adaptive, allowing students to learn continuously as their work evolves.

These interactions between mentors and students create a collaborative culture that improves both the research process and the resulting manuscripts[2]. Senior students also serve as an essential link in this system. By sharing their experiences and helping junior members build foundational skills in research and writing, they ensure continuity of learning. Over time, this model enables junior students to transition into leadership roles, completing the cycle of mentorship and sustaining the group's academic growth.

Implementation of Results-Oriented Feedback Mechanisms Through Academic Seminars

Academic seminars are a central feature of the research platform, serving as a tool to track research progress, support scientific writing, and provide outcome-focused feedback. Our approach is grounded in the principles of Outcomes-Based Education (OBE), which prioritizes student learning outcomes in the design and execution of educational activities[29]. Unlike traditional models that rely heavily on exams or fixed assessments, OBE emphasizes the importance of evaluating the entire learning process. In this setting, students are assessed not through formal tests but through regular internal seminars and evaluations of their research and writing. This results-driven model plays a vital role in supporting students' development as writers and researchers, equipping them with the skills needed for both academic and professional success.

The focus of this evaluation system is not on increasing publication counts, but on improving the quality of the learning process particularly the development of scientific reasoning and writing ability[13]. In our group, this process centers around academic seminars, which include both open discussion forums and structured mentor-led meetings. To ensure consistency and effective progression, each seminar follows a standardized format with clearly defined time allocations. Specifically, seminars include a 30-minute thematic presentation, followed by a 20-minute peer evaluation and questioning session, a 40-minute in-depth group discussion, and a 30-minute mentor feedback segment. This structured design supports focused exchange, sustained critical discussion, and timely expert guidance throughout the seminar process. These sessions offer students the chance to test their understanding of the subject matter, present their writing ideas, and receive peer input. Free discussions allow exploration of research topics, while mentor sessions guide students in organizing content and refining arguments. Students are encouraged to evaluate one another's work using defined criteria: the novelty and relevance of the topic, the clarity and quality of the presentation, the significance of the research progress made, and the handling of specific writing or research challenges. Building on these criteria, the peer evaluation component adopts a 100-point quantitative scoring system comprising four clearly defined sub-evaluation indicators. Novelty and relevance of the research topic (25 points) focuses on assessing the innovative value of the presented topic as well as its theoretical and practical significance within the disciplinary field. Clarity and quality of the presentation (25 points) covers the logic of the presentation slides, the fluency of oral expression, and the ability to respond to questions. Significance of research progress (25 points) concentrates on the value of phased research achievements, the rigor of research thinking, and the feasibility of project design. Ability to address writing and research challenges (25 points) evaluates students' competence and effectiveness in solving practical problems during the research and writing process. Regarding mentor feedback, a combined model of immediate guidance and phased guidance is adopted to balance timeliness and continuity. Centralized feedback is provided after each seminar to offer targeted guidance on the core issues of the current presentation, while monthly centralized phased guidance is conducted to systematically identify common problems and provide personalized improvement directions. With academic seminars serving as the primary implementation vehicle and outcome-based feedback as the core principle, these components together constitute the operational foundation of the feedback mechanism.

This outcome-based feedback model offers several clear advantages. It provides an objective view of each student's strengths and areas needing improvement, allowing timely interventions and clearer direction. It also supports course correction in project design and execution, helping students align their work with intended learning outcomes[15]. Through structured discussions and oral presentations, students learn to communicate their ideas effectively skills that directly translate into higher-quality writing. The process helps students move beyond passive knowledge absorption toward active, engaged scholarship, ensuring that their contributions both written and spoken advance scientific thinking and communication.

Practice-Oriented Academic Writing Training for Undergraduates

High-quality academic writing is shaped through repeated revision and focused refinement. Unlike writing for exams, scientific writing demands clarity, precision, and rigorous structure to effectively communicate research findings[4]. It reflects a researcher's foundational literacy in science combining logical reasoning, expressive language, and original thought. As Nancy Sommers[26] notes, academic writing is not acquired through passive instruction but through sustained, iterative practice.

For undergraduates, mastering academic writing requires both structured training and hands-on experience. Writing exercises serve not only to introduce scholarly conventions but also to help students revise and refine their work. In our training, the starting point is a clear understanding of the structure and purpose of an SCI-indexed review article. Unlike experimental papers, the review article is designed to synthesize, analyze, and critically assess existing research[10]. Students begin by closely reading and deconstructing high-quality review articles to understand their logical flow and argument structure. They then undertake targeted writing tasks focused on various formats Narrative, Systematic, and Mini-Reviews each designed to build specific academic writing competencies.

Our training model focuses on two core innovations: (1) the creation of original visual content to present central arguments and research logic, and (2) a two-phase bilingual writing approach ─ first drafting in Chinese to clarify structure and reasoning, followed by translation and refinement in English to enhance scientific expression and language precision.

In developing visual content, students begin by reviewing at least 50 high-impact review articles, analyzing their visual elements to identify effective strategies and common weaknesses. Next, students extract key findings, concepts, and research trends from their topic and represent them through charts such as flow diagrams, conceptual networks, or timelines. With support from mentors and senior peers, these visuals are revised to meet academic standards. These visual elements are not simply supplementary; they form the backbone of the article's logic and reflect the student's interpretation of the literature [19]. They also serve to communicate complex information clearly, a critical skill in review writing. For example, in the review article by Huang et al. (2018)[14], students developed a flow diagram illustrating the reverse screening process used for target identification, which visually clarified the stepwise logic of compound-to-target mapping. Similarly, in Wu et al. (2020)[32],

students designed a schematic that categorized different computational approaches for ADMET (Absorption, Distribution, Metabolism, Excretion, and Toxicity) prediction, highlighting the progression from basic *in silico* techniques to more advanced software capable of predicting multiple pharmacokinetic parameters.

The bilingual writing strategy is implemented in two distinct stages. The first, conducted in Chinese, focuses on establishing the overall structure and ensuring logical coherence between paragraphs. The second, written in English, concentrates on crafting effective transitions and maintaining sentence-level clarity. This approach addresses a fundamental difference between Chinese and English writing styles where Chinese tends to emphasize implicit logic and indirectness, English prioritizes explicit structure and direct expression. Recognizing the linguistic challenges undergraduates face in academic English, we adopt a "Chinese first, English later" model to build logical thinking and writing fluency. This phased approach not only lowers the entry barrier for students unfamiliar with academic English but also reinforces the structural rigor that beginners need to meet international publication standards.

For senior undergraduates who already have experience in both training and academic writing, such as those who have published at least a first-author SCI paper, they can write directly in English and skip the Chinese phase. However, the "Chinese first, English later" approach is important for beginners. Writing in Chinese helps both students and mentors quickly and clearly organize structure ideas through their mutual communications, forming a strong framework for the manuscript. This structured foundation then supports a more refined and accurate English rewrite.

Within the research training framework, mentors assign advanced students to lead topic selection for review articles, often based on emerging developments in reverse screening. Writing teams are formed by pairing senior and junior undergraduates. Initial drafts are written in Chinese, allowing junior students to build subject familiarity while contributing to a logically organized outline. This phase emphasizes conceptual clarity and coherent paragraph design in the native language. Senior undergraduates and research assistants review these drafts regularly to uphold academic standards and address logical gaps. Common issues are discussed in academic meetings, creating opportunities for shared learning and improvement. Once the Chinese framework is established, the group transitions to the English writing phase not as a direct translation, but as a full rewrite informed by the original logic and supplemented with current literature in both Chinese and English. The English phase sharpens paragraph transitions and hones precise technical language. Senior students and research assistants lead content drafting and refinement, while junior students practice expressing core ideas in English, gradually building fluency and familiarity with professional terminology. Weekly team meetings serve as checkpoints for reviewing progress and discussing revisions. Students are also encouraged to adopt interdisciplinary methods such as integrating data science into medical reviews or applying computational models to biomedical research expanding the analytical depth and relevance of their work.

Interdisciplinary collaboration is a core emphasis within the group, particularly when addressing complex research topics that benefit from diverse academic perspectives[23]. Students from varied disciplinary backgrounds bring complementary insights, expanding the range of solutions and enriching the research process. This collaborative model not only enhances students' overall academic competence but also cultivates an interdisciplinary mindset essential for addressing multifaceted problems. In review article writing, for instance, students are encouraged to move beyond traditional literature analysis by incorporating data analysis and visualization techniques. They integrate findings from multiple fields into coherent frameworks, which both improves the analytical quality of the review and builds fluency in applying technological tools for research. Each student participates in multiple cycles of literature review and group discussion. These discussions go beyond factual summaries, they require critical engagement, constructive commentary, and defense of viewpoints through structured debate. Through this process, students sharpen their perspectives and learn to construct arguments supported by evidence. The outcome is a noticeable improvement in both critical thinking and logical structure in their writing. Over time, the repeated integration of writing practice with discussion and analysis strengthens the clarity, coherence, and depth of students' academic expression.

Implementation Timeline and Process

The comprehensive training framework was implemented in stages from 2015 to 2024, with outcomes systematically documented and strategies refined throughout the process. Instruction was delivered during winter and summer breaks, allowing for concentrated, immersive training periods. Program quality was maintained through consistent mentor oversight, structured peer review, and alignment with established academic standards.

Results

Overall Training Outcomes and Publication Metrics

Following the introduction of the structured academic writing training framework, the Computer-Aided Drug Design research group recorded notable advancements in undergraduate research and publication. Over the ten-year period from 2015 to 2024, more than 300 undergraduate students received training, representing fields such as clinical medicine, pharmacy, bioinformatics, and related disciplines. The quantitative outcomes reflect the program's success. Students collectively published 34 SCI papers as first or co-first authors, with a cumulative impact factor (IF) of 175.0 (Figure 3). Among these, a recent publication appeared in *Molecular Cancer*, a leading international journal with an IF of 33.9[35], along with three additional articles in international peer-reviewed journals. In addition to these first-author contributions, more than 10 SCI papers included undergraduate students as co-authors, highlighting the depth and breadth of student engagement in the research process. Among the trainees, about 1% published more than five SCI papers as (co-)first authors, 10% published at least two, 15% published at least one, and around 40% had publications in SCI-indexed journals overall.

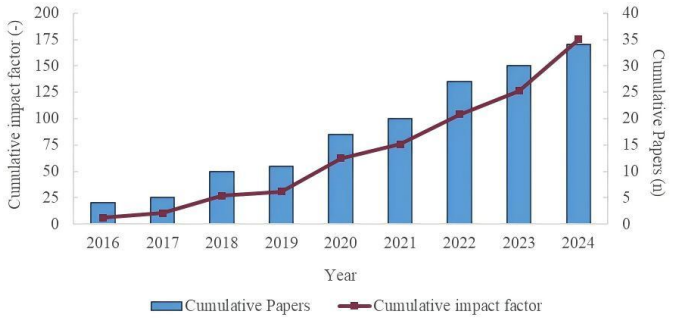

Figure 3. Temporal trends in undergraduate research output and cumulative impact factor. The bar plot (left y-axis) shows the cumulative number of SCI-indexed papers published by undergraduates as first or co-first authors from 2016 to 2024, while the line plot (right y-axis) indicates the cumulative impact factor (IF) of these publications. Data were compiled from the research group's publication records and include 34 SCI-indexed articles with a total cumulative IF exceeding 175; the highest single-journal IF was 33.9 (Molecular Cancer).

Strategy-Specific Effectiveness Analysis

Student-Centered Research Platform Outcomes

The hierarchical research platform led to measurable gains in student engagement and skill development. Within the Computer-Aided Drug Design specialization, 32 undergraduate students contributed to the publication of 12 SCI-indexed papers, with a combined impact factor of 73.6 and a total of 1030 citations. This output reflects a publication rate well above typical undergraduate research benchmarks. The cascading mentorship model proved especially effective. Senior undergraduates transitioned into leadership positions and took on responsibility for guiding incoming cohorts. This structure supported sustained training quality and consistent research outcomes across successive academic years.

Collaborative Learning Environment Results

The effectiveness of the exemplary leadership model was evident through longitudinal tracking of individual student progress. Many students who entered the program as junior participants later became active in scientific research. Over 50% of them continued to graduate studies and pursued research-intensive careers. The peer learning framework significantly accelerated skill acquisition; students typically reached publication-ready writing proficiency within 1–2 years of program involvement a marked improvement over the 3–4 years often required under conventional training models.

Results-Oriented Feedback Mechanism Effectiveness

The academic seminar-based feedback system played a critical role in upholding high publication standards. A notable example is the review article titled "*Reverse Screening Methods to Search for Protein Targets of Chemopreventive Compounds*"[14], which received strong endorsements from both peer reviewers and journal editors at the time of submission. The paper has achieved exceptional visibility and impact: (1) over 35,660 reads and downloads on the *Frontiers* platform; (2) 126 citations within *Frontiers* and 160 citations on Google Scholar; and (3) placement in the top 3%, 2%, and 3% of all articles across the 230 *Frontiers* journals based on reads, downloads, and citations, respectively. Additional high-impact review papers produced through the program span key phases of drug discovery, including drug target identification[33], active site identification and validation[18], target search via reverse screening[14], computational approaches in ADMET prediction [32], and marine small molecule drug design[30]. Among these, the ADMET review stands out, accumulating over 49,508 reads and downloads, 327 citations in Frontiers, and 386 citations on Google Scholar ranking in the top 2%, 1%, and 1% of Frontiers articles across these respective metrics.

Practice-Oriented Writing Training Effectiveness

The bilingual writing strategy effectively addressed a major barrier for undergraduate researchers: proficiency in academic English. Students who completed the training showed substantial improvement in the quality of their English writing, with acceptance rates for submissions to international journals notably exceeding institutional norms. The visual content development component also contributed significantly, yielding original, high-quality figures that improved both the clarity and impact of student-authored publications. The program's emphasis on interdisciplinary integration further strengthened research outputs. Students successfully applied methods from computer science, data analysis, and artificial intelligence to their medical research reviews, enhancing both the analytical depth and originality of their work. This cross-disciplinary approach broadened the scope of inquiry and fostered more innovative perspectives in review writing.

Longitudinal Impact and Quality Progression

Analysis of publication quality over time indicates a steady upward trajectory in both journal impact factors and citation rates for student-authored papers. This trend reflects the program's ongoing refinement and growing effectiveness. More recent publications show higher average impact factors compared to earlier cohorts, pointing to sustained improvements in both training quality and student research capability. Long-term career tracking further supports the program's impact. Many alumni have gone on to pursue advanced research degrees, with several securing positions at leading international institutions. These outcomes suggest that the skills developed through the training framework extend beyond immediate publication success, contributing meaningfully to students' long-term academic and professional development.

Comparative Performance Analysis of Undergraduate Publication Rates

Compared to standard undergraduate research participation in medical education, which typically yields publication rates of 5–10%, our structured training framework has resulted in substantially higher engagement and productivity. Among active participants, the publication rate around 40%, demonstrating the effectiveness of a systematic, mentorship-driven model. Moreover, the quality of student-authored publications consistently meets or surpasses benchmarks expected of establi-

shed researchers. Several student-led articles have been recognized as highly cited within their respective fields. These outcomes indicate that the training framework not only enhances participation but also effectively elevates student output to professional research standards.

Discussion

Theoretical Implications and Mechanism Analysis

The success of our comprehensive training framework can be explained through several theoretical perspectives that clarify why this integrated approach yields stronger outcomes than conventional academic writing instruction. From a social constructivist standpoint, the framework fosters authentic learning communities where knowledge is co-constructed through structured peer interaction. The hierarchical mentorship model operationalizes the concept of the zone of proximal development: junior students engage in tasks just beyond their independent capability, supported by senior peers and mentors. This dynamic accelerates learning, explaining why students typically reach publication-ready writing proficiency within 1–2 years, in contrast to the 3–4 years often observed under traditional training schemes.

Collaborative learning theory further elucidates the framework's effectiveness. By promoting positive interdependence, where each student's success contributes to group achievement, the structure enhances both individual development and collective progress. Our longitudinal outcomes show that this model fosters sustainable academic communities. Former junior participants transition into senior mentoring roles, perpetuating a peer-learning cascade that reinforces knowledge transfer and community continuity across cohorts.

Insights from situated learning theory clarify why embedding writing instruction within real research activities produces stronger results than classroom-based approaches. Students develop writing skills alongside domain expertise by engaging directly in ongoing research. This dual exposure not only enhances technical writing abilities but also deepens disciplinary understanding reflected in the professional quality of student publications, which consistently meet or exceed field standards.

Finally, the framework's foundation in deliberate practice theory ensures skill acquisition through focused, repetitive exercises coupled with continuous, targeted feedback. Unlike traditional academic writing courses, which often emphasize passive knowledge of writing mechanics, our model prioritizes direct engagement and real-time application. The seminar-based feedback system exemplifies this: it offers structured, iterative assessment that guides students through progressive refinement. This design enables not only rapid development of writing competence but also long-term retention and adaptability of skills. In combination, these theoretical foundations explain the distinctive outcomes achieved through our training program. They validate the value of an integrated, practice-based, and socially supported approach to undergraduate academic writing development.

Comparative Effectiveness and Best Practices

When evaluated against conventional academic writing instruction, our integrated framework addresses several persistent limitations of traditional approaches. Most conventional programs treat writing as a generic skill, often detached from disciplinary content. This separation results in limited transferability of writing proficiency to specific research contexts, and typically produces outputs that fall short of publication standards in scientific disciplines. In contrast, our framework embeds writing within the research process itself, enabling students to acquire field-specific writing competencies aligned with the conventions and expectations of their academic domain. This integration directly contributes to the high acceptance rates and quality of student-authored publications.

A central innovation of our approach is the bilingual writing strategy, which effectively mitigates the challenges faced by non-native English speakers in producing scholarly work. By allowing students to first conceptualize and structure their ideas in their native language before transitioning to English, we ease the dual cognitive burden of content generation and language articulation. This phased model supports logical development while building fluency in scientific English. The result is greater clarity in expression, stronger logical flow, and a higher rate of success in international journal submissions compared to approaches that rely solely on direct English instruction.

The practice-oriented nature of the framework, grounded in the principles of deliberate practice, further distinguishes it from traditional academic writing courses. Rather than focusing on abstract principles or isolated writing exercises, students engage in sustained, task-relevant writing projects with real publication goals. This hands-on model ensures repetitive exposure to writing challenges, guided by continuous feedback from mentors and peers. Such structured practice accelerates learning, fosters long-term retention, and builds confidence in navigating the demands of scholarly communication. Together, these components constitute a best-practice model for undergraduate academic writing training one that simultaneously develops linguistic proficiency, disciplinary fluency, and scholarly independence.

Scalability and Institutional Implementation

The core elements of our training framework hierarchical mentorship, collaborative learning environments, systematic feedback mechanisms, and practice-oriented instruction demonstrate strong potential for adaptation across a range of institutional settings and academic disciplines. Although initially developed within the context of medical and pharmaceutical education, these components are structurally versatile and can be tailored to different fields with minimal modification. Successful replication, however, requires institutional commitment to long-term program development. The benefits of this approach are cumulative and typically emerge over multi-year cycles, rather than within a single academic term. Institutional leaders must recognize the value of sustained engagement, not only from students but also from faculty members who serve as mentors. Faculty buy-in is essential, as effective implementation depends on their understanding of collaborative learning theory, domain-specific writing conventions, and the mentoring responsibilities inherent to this model.

Resource planning is another critical factor. Intensive training periods, especially those conducted during winter and summer breaks, demand dedicated time, space, and instructional support.

Institutions seeking to adopt a similar framework must allocate sufficient resources to ensure consistency and quality in mentorship, feedback, and evaluation activities. International collaboration, a distinguishing feature of our program, offers further scalability advantages. Engaging with global partners introduces students to broader academic standards and diverse scientific perspectives, while also providing external validation for their work. Institutions implementing comparable models should consider integrating opportunities for cross-border academic exchange, which can enrich the training experience and elevate the visibility of student research. Taken together, these structural, institutional, and international dimensions offer a practical roadmap for extending the framework beyond its original context, while preserving its core focus on discipline-integrated, outcome-driven academic writing development.

Addressing Limitations and Future Directions

Several limitations of the present study should be acknowledged. The absence of a control group restricts our ability to attribute observed improvements exclusively to the training framework. Without comparative data from students trained under conventional methods, it remains difficult to fully isolate the framework's effects from other institutional or temporal influences. Future research should incorporate randomized controlled trials to directly compare our model with traditional academic writing instruction, thereby strengthening causal inferences. The current study also focuses exclusively on medical and pharmaceutical sciences. While the outcomes demonstrate clear effectiveness within these domains, writing conventions and research practices vary across disciplines. Broader applicability of the framework must be tested through replication studies in diverse academic contexts, including the humanities, engineering, and social sciences. Such investigations would clarify which elements of the framework are discipline-specific and which are universally transferable.

In addition, current evaluation methods rely heavily on publication metrics and qualitative assessment of writing quality. Although these indicators are useful, they do not capture the full range of skill development. The lack of standardized, quantitative tools for assessing academic writing proficiency in medical science contexts limits the precision of outcome measurement. Future work should focus on developing and validating discipline-specific writing assessment instruments. These tools would not only enhance the rigor of internal evaluation but also enable meaningful cross-institutional comparisons. Despite these limitations, the sustained success of our training framework provides a strong foundation for continued research and development. By addressing these methodological gaps, future studies can further refine the model and contribute to the broader field of undergraduate research education.

Future Plans

Building on the demonstrated success of our comprehensive training framework, we aim to further strengthen and expand its scope through targeted innovations. These include the integration of artificial intelligence (AI) in academic writing, deepening interdisciplinary collaboration, developing a dedicated undergraduate thesis database, and establishing international academic exchange initiatives.

AI-assisted Writing Training

To further support the development of high-quality academic writing, we plan to systematically incorporate AI tools into the existing training framework, while maintaining the core principles of collaborative learning. One of the persistent challenges faced by undergraduates is the accurate use of academic English and adherence to scientific writing conventions. To address this, we will introduce AI-driven tools such as ChatGPT[34], Grammarly[9], and DeepL Write[24] to assist students with grammar refinement, standardization of academic language, and paragraph-level restructuring. These tools will support students in streamlining sentence structure, improving clarity and coherence, and reducing language-related errors, thereby aligning manuscripts more closely with the expectations of SCI-indexed journals[17]. In addition, we will explore the use of AI-based reference management platforms such as Zotero[22] and Mendeley[20] to help students organize citations, manage source material, and enhance the efficiency of literature review writing. The integration of these AI tools will be carefully structured within our feedback-driven model, ensuring that technological assistance complements rather than replaces critical thinking and manual drafting. This approach aims to equip students with advanced, practical tools while preserving the pedagogical value of hands-on writing development.

Interdisciplinary Collaboration

As modern scientific inquiry increasingly relies on interdisciplinary integration, traditional single-discipline training models are no longer sufficient to prepare students for the complexity of contemporary research writing. To address this gap, we plan to expand interdisciplinary collaboration within our training framework, particularly in fields intersecting with computer science, data analytics, artificial intelligence, and bioinformatics. Undergraduates will be encouraged to acquire foundational knowledge and technical skills in areas such as data mining, visualization, and statistical modeling, and to incorporate these approaches into their review articles. For instance, in the context of computer-aided drug design, students may apply machine learning algorithms for drug target prediction or use data-driven methods to identify emerging trends in therapeutic development. These integrations will enrich the analytical depth and innovation of their work. To support this effort, we aim to strengthen cross-departmental cooperation among units such as the School of Pharmacy, Department of Biomedical Engineering, and School of Information Science. Joint training sessions, collaborative research projects, and interdisciplinary seminars will be introduced to foster a broader, more integrative academic environment. This strategy not only enhances the quality of review writing but also cultivates a research mindset equipped for navigating the increasingly interconnected landscape of scientific disciplines.

Establishing an Open Undergraduate Thesis Database

A common barrier to undergraduate academic writing is the absence of accessible, high-quality reference models. This often leads to uncertainty in topic selection, methodological design, and manuscript structure. To address this gap, we plan to establish a structured, open-access database of undergraduate theses and review articles produced within our program. The database will serve several functions. First, it will house exem-

plary SCI-indexed papers authored by undergraduates, allowing future students to study their structure, argumentation, and stylistic conventions. Second, it will feature annotated examples of high-performing manuscripts, accompanied by supervisor feedback and narrative commentaries outlining the paper's conceptual development. These resources will help students understand how to frame research questions, build coherent arguments, and follow discipline-specific conventions. Third, the repository will include reviewed drafts, highlighting common writing errors and revisions made during the training process. This will provide a realistic view of how academic writing evolves through feedback and iteration. Finally, the database will offer supplemental resources such as submission guidelines for SCI journals, journal selection strategies, and best practices for manuscript revision. By providing students with detailed, practical references throughout the writing process, the database will help demystify scientific writing and foster independent research skills. This initiative is intended to support a transparent, reproducible learning model that accelerates the development of academic literacy at the undergraduate level.

International Academic Writing Exchange

To broaden the global perspective of undergraduate researchers and enhance the international relevance of their academic writing, we plan to establish a structured platform for international academic exchange. This initiative will create opportunities for students to collaborate with mentors and researchers from leading global institutions, gaining exposure to diverse scientific standards and feedback practices. Students will be encouraged to participate in joint writing projects, co-author manuscripts with international peers, and engage in collaborative review writing under the guidance of overseas experts. Regular participation in international academic conferences and virtual seminars will be promoted, allowing students to present their work, refine their communication skills, and receive critical input from a global scholarly audience. In parallel, we will offer online writing workshops led by experienced researchers with proven publication records in high-impact journals. These sessions will provide targeted guidance on manuscript preparation, submission strategies, and reviewer engagement, with one-on-one mentoring to support the revision process. By integrating these global elements into our existing training model, the exchange program will not only raise the standard of undergraduate research writing but also cultivate international academic literacy, preparing students for future careers in an increasingly interconnected research environment.

Conclusion

Medical professionals today must be equipped not only with clinical competence but also with the ability to engage in scientific research and produce high-quality academic writing. However, formal training in dissertation writing is often overlooked at the undergraduate level. As a result, many students advance to graduate programs or enter the workforce without adequate exposure to research methodologies or academic writing standards. This gap not only limits their individual academic and professional development but also poses broader challenges for cultivating future talent in the medical field. Our experience in undergraduate research training reveals that students possess considerable, often untapped, potential in scientific writing and inquiry. The challenge lies in identifying and guiding this potential through well-structured, sustained support. This study demonstrates that systematic training grounded in mentorship, interdisciplinary engagement, practical writing exercises, and the strategic use of AI tools can significantly enhance students' writing abilities and research competencies. By building a comprehensive framework that fosters critical thinking, academic literacy, and cross-disciplinary integration, institutions can take an active role in preparing students to meet the expectations of scientific publishing and contribute meaningfully to research communities. Such a proactive and long-term approach is essential to closing the current training gap and ensuring that undergraduates are not only capable of completing high-quality dissertations but are also positioned to participate in scientific advancement. The strategies outlined here offer a practical model for institutions seeking to strengthen academic writing programs and support the development of research-capable graduates.

Reference

1. Alexander, P. A., Fusenig, J., Schoute, E. C., et al. (2023). Confronting the Challenges of Undergraduates' Argumentation Writing in a "Learning How to Learn" Course. *Written Communication*, 40(2), 482 – 517. doi:10.1177/07410883221148468

2. Alghasab, M., Hardman, J., and Handley, Z. (2019). Teacher - student interaction on wikis: Fostering collaborative learning and writing. *Learning, Culture and Social Interaction*, 21, 10 - 20. doi:10.1016/j.lcsi.2018.12.002

3. Badenhorst, C. (2018). Citation practices of postgraduate students writing literature reviews. *London Review of Education*, 16(1), 121 - 135. doi:10.18546/LRE.16.1.11

4. Bertin, M., Atanassova, I., Larivière, V., et al. (2015). Mapping the linguistic context of citations. *Bulletin of the Association for Information Science and Technology*, 41(2), 26 - 29. doi:10.1002/bult.2015.1720410208

5. Cao, Y., Wen, Y., Li, J., et al. (2021). Reform and Practice of Undergraduate Medical Research Training Based on Innovative Talent Cultivation: An Example of the Undergraduate Evidence - based Medicine Research Team of Guangdong Medical University. *Medical Education Research and Practice*, 29(6), 811 - 814. doi:10.13555/j.cnki.c.m.e.2021.06.002 (in Chinese)

6. Cao, Y., Wen, Y., Lin, S., et al. (2023). Strategies and Practice of Undergraduate Innovative Research Talent Cultivation: An Example of the Undergraduate Evidence - based Medicine Research Team of Guangdong Medical University. *Chinese Journal of Medical Education Research*, 22(10), 1505 - 1509. doi:10.3760/cma.j.cn116021-20211114-01449 (in Chinese)

7. Castelló, M., Mateos, M., Castells, N., et al. (2012). Academic Writing Practices in Spanish Universities. *Electronic Journal of Research in Education Psychology*, 10(27), 569 - 590. doi:10.25115/ejrep.v10i27.1517

8. Dai, J. (2024). Pursue the nature of science: Advocate for a better research environment. *The Innovation*, 5(5), 100686. doi:10.1016/j.xinn.2024.100686

9. Dong, Y., and Shi, L. (2021). Using Grammarly to support students' source - based writing practices. *Assessing Writing*, 50, 100564. doi:10.1016/j.asw.2021.100564

10. Faryadi, Q. (2018). PhD Thesis Writing Process: A Systematic Approach—How to Write Your Literature Review. *Creative Education*, 9(16), 2912 - 2919. doi:10.4236/ce.2018.916219

11. Fauzan, U., Hasanah, N., and Hadijah, S. (2022). The Undergraduate Students' Difficulties in Writing Thesis Proposal. *Indonesian Journal of EFL and Linguistics*, 7(1), 175 - 192. doi:10.21462/ijefl.v7i1.515

12. Grusec, J. E., Saas-Kortsak, P., and Simutis, Z. M. (1978). The Role of Example and Moral Exhortation in the Training of Altruism. *Child Development*, 49(3), 920 - 923. doi:10.2307/1128273

13. Gruppen, L. D., and Gruppen, L. D. (2012). Outcome - Based Medical Education: Implications, Opportunities, and Challenges. *Korean Journal of Medical Education*, 24(4), 281 - 285. doi:10.3946/kjme.2012.24.4.281

14. Huang, H., Zhang, G., Zhou, Y., et al. (2018). Reverse Screening Methods to Search for the Protein Targets of Chemopreventive Compounds. *Frontiers in Chemistry*, 6, 138. doi:10.3389/fchem.2018.00138

15. Iqbal, S., Willis, I., Almigbal, T. H., et al. (2020). Outcome - based education: evaluation, implementation and faculty development. *MedEdPublish*, 9, 121. doi:10.15694/mep.2020.000121.1

16. Joshi, M., Aikens, M. L., and Dolan, E. L. (2019). Direct Ties to a Faculty Mentor Related to Positive Outcomes for Undergraduate Researchers. *BioScience*, 69(5), 389 - 397. doi:10.1093/biosci/biz039

17. Kacena, M. A., Plotkin, L. I., and Fehrenbacher, J. C. (2024). The Use of Artificial Intelligence in Writing Scientific Review Articles. *Current Osteoporosis Reports*, 22, 115 - 121. doi:10.1007/s11914-023-00852-0

18. Liao, J., Wang, Q., Wu, F., and Huang, Z. (2022). In Silico Methods for Identification of Potential Active Sites of the Therapeutic Targets. *Molecules*, 27(20), 7103. doi:10.3390/molecules27207103

19. Maamuujav, U., Krishnan, J., and Collins, P. (2020). The utility of infographics in L2 writing classes: A practical strategy to scaffold writing development. *TESOL Journal*, 11(2), e484. doi:10.1002/tesj.484

20. MacMillan, D. (2012). Mendeley: teaching scholarly communication and collaboration through social networking. *Library Management*, 33(7/8), 561 - 569. doi:10.1108/01435121211279902

21. Miao, X., Chen, X., Li, J., et al. (2024). Enhancing undergraduate research talents: the role of tutors in dental basic research education. *Frontiers in Medicine*, 10, 1323183. doi:10.3389/fmed.2023.1323183

22. Murimboh, J. D., and Hollingdale, C. R. (2012). Zotero: A Reference Manager for Everyone. *Journal of Chemical Education*, 89(2), 173 - 174. doi:10.1021/ed1010618

23. Pennington, D. (2008). Cross - Disciplinary Collaboration and Learning. *Ecology and Society*, 13(2), 8. doi:10.5751/ES-02520-130208

24. Polakova, P., and Klimova, B. (2023). Using DeepL translator in learning English as an applied foreign language – An empirical pilot study. *Heliyon*, 9(1), e18595. doi:10.1016/j.heliyon.2023.e18595

25. Sandra, R. P, Hwang, W. Y., Zafirah, A., et al. (2024). Crafting Compelling Argumentative Writing for Undergraduates: Exploring the Nexus of Digital Annotations, Conversational Agents, and Collaborative Concept Maps. *Journal of Educational Computing Research*, 62(5), 1327 - 1357. doi:10.1177/07356331241242437

26. Sommers, N., He, M., and Yu, H. (2022). How Expository Writing Has Become the Only Required Course at Harvard University: A Conversation between Nancy Sommers and He Mingzhu, Yu Haiqin. *Journal of East China Normal University (Educational Sciences)*, 40, 116. doi:10.16382/j.cnki.1000-5560.2022.01.009 (in Chinese)

27. Sulaiman, N., Ganapathy, N. N. D. F., Ghazali, I. M., et al. (2023). Undergraduate Students' Self - Perceived Difficulties in Academic Writing. *International Journal of Academic Research in Business and Social Sciences*, 13(10), 407 - 416. doi: 10.6007/ijarbss/v13-i10/18786

28. Taye, T., and Mengesha, M. (2024). Identifying and analyzing common English writing challenges among regular undergraduate students. *Heliyon*, 10(17), e36876. doi:10.1016/j.heliyon.2024.e36876

29. Thirumoorthy, G. (2021). Outcome Based Education (OBE) is Need of the Hour. *International Journal of Research – Granthaalayah*, 9(4), 571 - 582. doi:10.29121/granthaalayah.v9.i4.2021.3882

30. Wei, J., Liu, R., Hu, X., Liang, T., Zhou, Z., and Huang, Z. (2021). Targeting the MAPK Signaling Pathway via Marine Compounds in Cancer Therapy. *Journal of Cancer Research and Clinical Oncology*, 147(1), 3 - 22. doi:10.1007/s00432-020-03459-w

31. Williams, J. (2018). A Comprehensive Review of Seven Steps to a Comprehensive Literature Review. *The Qualitative Report*, 23(2), 345 - 349. doi:10.46743/2160-3715/2018.3374

32. Wu, F., Zhou, Y., Li, L., et al. (2020). Computational Approaches in Preclinical Studies on Drug Discovery and Development. *Frontiers in Chemistry*, 8, 726. doi:10.3389/fchem.2020.00726

33. Zhang, X., Wu, F., Yang, N., et al. (2022). In silico methods for identification of potential therapeutic targets. *Interdisciplinary Sciences - Computational Life Sciences*, 14(2), 285 - 310. doi:10.1007/s12539-021-00491-y

34. Zhang, R., Zou, D., and Cheng, G. (2025). ChatGPT affordance for logic learning strategies and its usefulness for developing knowledge and quality of logic in English argumentative writing. *System*, 128, 103561. doi:10.1016/j.system.2024.103561

35. Zhuang, K., Wang, L., Lu, C., et al. (2024). Assessment of SWI/SNF chromatin remodeling complex related genes as potential biomarkers and therapeutic targets in pan - cancer. *Molecular Cancer*, 23(1), 176. doi:10.1186/s12943-024-

02015-w

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Conceptualization: Yong Cao, Zunnan Huang; Writing- Original draft preparation: Yong Cao, Ying Wen, Xuan Li, Hongbin Huang; Writing-Reviewing and Editing: Zunnan Huang, Ying Wen, Xuan Li, Liyi Zou, Yong Liu; Supervision: Zunnan Huang; Funding acquisition: Zunnan Huang

Funding

This work was supported by Guangdong Province Higher Education Teaching Reform Project “Research and Practice on Special Training for Cultivating High-level Innovative Research Undergraduate Talents” (2019268).

Acknowledgments

We gratefully acknowledge Dr. Muhammad Waqas and Dr. Aamir Fahira for his help in revising the English grammar and columnist Lixin Wan from Shanghai Daily for his help in addressing some of the stylistical issues.