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Research Progress of Bioinformatics in Medical Laboratories and Its Significance and Application in Graduate Student Teaching

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Abstract:

Objective: To explore the advancements in bioinformatics within medical laboratories and assess its importance and application in graduate-level education. *Methods:* This study analyzes bioinformatics analysis papers in the medical laboratory field included in the CNKI database. Considering bioinformatics' specificities and the educational requirements for graduate students in medical laboratories, the study examines bioinformatics' significance and potential implementation strategies in graduate medical laboratory education. *Results:* The annual number of bioinformatics analysis papers in the medical laboratory field included in CNKI is consistently rising, covering a wide range of medical disciplines and research depths. Interdisciplinary integration represents the current trend in scientific and technological advancement. Ideal graduate students in medical laboratories are expected to possess solid foundational and clinical expertise, formulate pertinent scientific inquiries, and proficiently utilize bioinformatics techniques for analytical thinking, problem design, and resolution. *Conclusion:* Bioinformatics plays a pivotal role in medical laboratory research and scientific innovation. The integration of bioinformatics courses and problem-oriented teaching methodologies can enhance graduate student's ability to apply bioinformatics in addressing medical challenges, aligning with the demands of the big data era and the cultivation of innovative talents.

Keywords:

Bioinformatics
Graduate student teaching
Medical laboratory

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1. Introduction

With the integrated application of new achievements in disciplines such as molecular biology, basic medicine, materials science, and bioinformatics, laboratory medicine has made rapid progress in automation, information management, molecular diagnosis, and point-of-care testing technologies. These advancements enable better service for early screening and diagnosis of patient diseases, monitoring of disease conditions, and assessment of treatment efficacy during therapy, as well as prognostic evaluation. Simultaneously, with the deepening of research on disease biomarkers, the development of detection materials and technologies, and the clinical translation of related products, medical laboratory graduates are not limited to clinical or sanitary inspection work. Instead, independent laboratories, new material and technology industries, and translational medicine-related industries have become new career options. To adapt to this new landscape and cultivate high-quality medical laboratory talents, the teaching content of postgraduate education in medical laboratory science also needs to undergo corresponding transformations. Therefore, the training of medical laboratory postgraduates should shift from being professionally focused to being interdisciplinary, evolving from pure clinical laboratory skills to developing comprehensive abilities. Among these, research capability is a crucial indicator that measures the quality of medical postgraduate education and reflects the innovativeness of talents. It is also the core competency of medical postgraduates.

2. Research progress of bioinformatics in medical laboratory science

With the initiation of the Human Genome Project, a new discipline of bioinformatics has emerged, becoming a powerful tool for researchers to store, process, and analyze data. For instance, in the field of oncology, the Cancer Genome Atlas (TCGA), jointly promoted by the National Cancer Institute and the National Human Genome Research Institute in the US, has collected over 20,000 tumor samples across 33 different tumor types since its launch in 2006. This initiative has generated more than 2.5 petabytes of data, making significant contributions to the screening and identification of tumor markers, the discovery of novel targeted therapeutic targets, and precise molecular typing of tumors in medical laboratory science. The analysis of biomedical big data through bioinformatics reveals profound life mysteries, represents a trend in the development of life sciences, and has pushed medical progress to a new stage. It is also changing the paradigm of medical research.

By searching the three keywords “bioinformatics,” “medicine,” and “laboratory” simultaneously on CNKI, the trend of bioinformatics research papers in medical laboratories was analyzed. The results showed that the number of bioinformatics research papers in the field of medical laboratory included in CNKI has been increasing year by year, from 6 papers in 2002 to 45 papers in 2021, and it is expected to reach 54 papers in 2022 (**Figure 1**). These papers cover a wide range of medical disciplines, with oncology accounting for the largest proportion (25.40%), followed by biology (19.96%), and then traditional Chinese medicine (6.05%), basic medicine (5.04%), obstetrics and gynecology (4.23%), traditional Chinese pharmacology (4.23%), and 19 other specialized fields. At the same time, these papers also conduct research at multiple research levels, including applied basic research, technical research (clinical), technology development, technical research (clinical trial), basic research, applied research, etc. (**Figure 2**) The publication of these papers indicates that bioinformatics is changing the research model at different levels in the field of medical laboratory and involves almost all medical specialties.

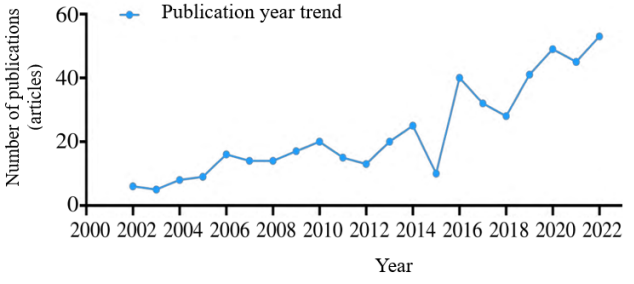

Figure 1. Number of bioinformatics research papers in the field of medical laboratory included in CNKI each year.

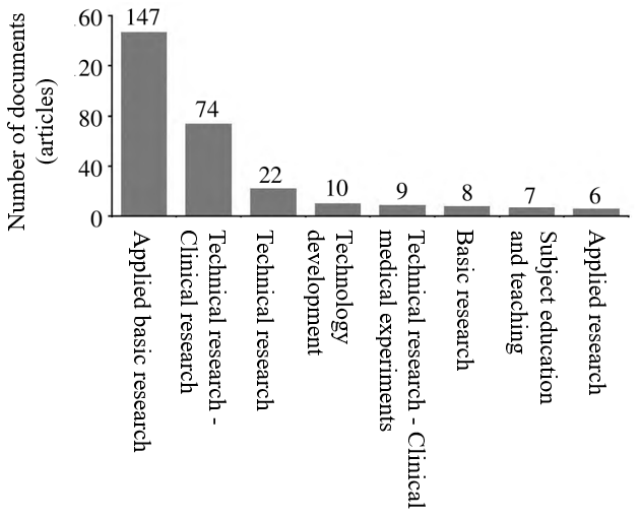

Figure 2. Research levels involved in bioinformatics research papers in the field of medical laboratory included in CNKI.

3. The importance of bioinformatics in scientific research activities for medical laboratory graduate students

The traditional medical research model primarily involves searching through a vast amount of literature, organizing, summarizing, and discovering unknown genes or unknown functions, pathways, and molecular mechanisms of genes within their research field. Research is then conducted targeting one or more of these unknowns. Specifically, this involves the classic "three axes" of cell biology, molecular biology, and animal models, to linearly investigate and address these unknowns from gene expression to function and mechanism of action. However, the information and results obtained through this model are often limited and one-dimensional.

In recent years, the integration of high-throughput multi-omics research and bioinformatics is transforming this scientific research paradigm. Scientific questions can now be raised from clinical practice, and by learning and mastering bioinformatics knowledge, researchers can utilize the currently abundant bioinformatics database resources with high-throughput and big-data advantages. Data mining and statistical analysis can be conducted based on clinical questions, followed by experimental validation of the analysis results from different perspectives. This approach enhances originality and innovation and allows for quick and effective achievements. Compared to the traditional research model, this model also enables the identification of networked connections [5], and the conclusions obtained can guide clinical practice, creating a mutually beneficial and complementary relationship between clinical issues and scientific research development. This promotes the pragmatic nature and translational potential of scientific research work [6]. Therefore, the transformation of teaching content that integrates bioinformatics has important theoretical and practical significance for cultivating high-level innovative talents capable of addressing cutting-edge issues in the field of medical laboratory science.

4. Application of bioinformatics in medical laboratory graduate education

Bioinformatics will play a crucial role in future scientific research activities for medical laboratory graduate students. However, for students with a medical background, computer skills and application abilities are often inadequate. Many students also fall into two extreme misconceptions when learning bioinformatics, either they pursue hot topics blindly without a clear understanding of basic concepts and sufficient application abilities, hoping for quick success and instant benefits or they become intimidated and discouraged when faced with complex coding. How can medical laboratory graduate students rapidly improve bioinformatics skills and apply them appropriately to research areas and scientific activities? Given the current educational model, staged teaching is a reasonable approach to overcome these misconceptions, achieved through the following methods.

4.1. Understanding and mastering basic concepts and methods through bioinformatics courses

Databases and analytical methods are tools, but the core lies in understanding the basic concepts underlying the data and interpreting the medical significance of analysis results. Graduate students in medical laboratory science must grasp the basic concepts involved in medical testing by understanding the analytical needs of biological data when studying bioinformatics. Courses should initially introduce ways to understand and analyze

data information related to medical testing from a bioinformatics perspective.

However, further mastery and practice of these contents can be tedious. Here, problem-based learning (PBL) can be introduced. PBL starts with a problem, incorporates independent and group learning, and leverages team collaboration to solve issues [7]. Assigning individual learning tasks, such as how to perform pairwise sequence alignment, only allows students to passively acquire isolated knowledge. Conversely, PBL involves proposing problems, collecting and analyzing relevant information, establishing reasonable hypotheses, progressively testing these hypotheses, and finally comparing, summarizing, and drawing conclusions. This approach fully engages students' initiative and creativity, enabling them to quickly grasp basic theories. PBL has been successfully implemented in clinical laboratory diagnostics education and can be similarly adopted in bioinformatics courses for medical laboratory graduate students. The true allure of PBL lies in the process of facing and solving various problems step by step. Through PBL, students learn to address a category of problems from a single case, thereby building a systematic knowledge system [8].

4.2. Mastering coding and command usage through bioinformatics training and seminars

Bioinformatics integrates computer science, life sciences, basic medicine, and clinical medicine, requiring the processing of complex and vast background information. This necessitates powerful, highly intelligent professional software and programming skills. Currently, common languages and software involved in bioinformatics include R, Python, Perl, and platforms developed using these languages, such as Bioperl, Biopython, and Bioconductor [5]. Learning to utilize these software tools is fundamental in bioinformatics. However, mastering and applying these tools requires a considerable amount of time, effort, and practice.

While classroom learning provides an introduction to basic concepts and methods, targeted training is essential for further advancement. Professional data analysis software introductions and hands-on training sessions, such as those for single-cell sequencing software or R language applications, not only delve into various bioinformatics software but also offer practical opportunities accompanied by expert explanations. This rapidly enhances graduate students' ability to interpret, analyze, and deeply mine database data or their high-throughput omics data.

The ultimate goal of bioinformatics teaching is to have students learn one or two websites or analysis tools and cultivate their information acquisition and analysis skills. Some lectures organized by schools or affiliated hospitals introduce examples of using big data resources to obtain medical information in this field and apply it to their scientific research activities. These lectures are highly targeted and purposeful, often focusing on a specific theme each time, such as transcriptomics and proteomics. The lectures often combine everyone's scientific research practice, and outline conventional ideas and methods for conducting medical scientific research activities using these databases, such as searching for differentially expressed genes in a certain disease state in the Geo database or screening target genes from the transcription group data of their research group in early stages, verifying expression differences through patient samples, and then validating them at the animal or cellular level, followed by mechanism research. These lectures provide medical graduate students with convenient big data utilization models that they can quickly and effectively integrate into their scientific research fields.

4.3. Continuous learning and innovation through online resources

Bioinformatics is one of the fastest-growing disciplines in the past two decades. With innovations in high-throughput detection technologies such as next-generation sequencing and single-cell sequencing, as well as further exploration of big data through analytical methods like multi-omics studies and spatial transcriptomics for various diseases, there is still vast room for the development of bioinformatics in the future. Therefore, it requires continuous learning, reading the latest high-quality literature, staying abreast of disciplinary advancements, and having the courage to try and innovatively apply the latest data analysis tools or algorithms to solve problems in medical laboratory science. Currently, many online resources such as professional bioinformatics websites,

video teaching platforms, and WeChat official accounts constantly update and provide the latest and most timely learning resources and models. To further master and use professional bioinformatics databases and software as well as to conduct deep data mining proficiently, it is necessary to keep up with the era and fully utilize online resources on the internet.

In summary, under the backdrop of the big data era, the utilization and integration of bioinformatics have brought tremendous challenges and opportunities to medical laboratory science. Offering bioinformatics courses to graduate students in the field of medical laboratory science can provide the necessary support for their clinical and scientific research skills accumulation, comprehensively improve teaching quality, and have important practical significance for promoting students' comprehensive development and cultivating innovative and entrepreneurial talents. By utilizing bioinformatics to solve practical problems in this field, medical laboratory science graduate students can become high-end talents with innovative thinking who are adapted to the background of the big data era and keep pace with the era, thereby promoting continuous progress in medical laboratory science and serving the ultimate goals of clinical care and people's health.

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