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Beyond the Tree: A Values-Based Approach to Teaching Phylogenetics

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Abstract: Bioinformatics is an interdisciplinary field that combines biology with computational and mathematical sciences. In this course, phylogenetics is an important section, which focuses on evolutionary relationships of organisms on earth using computational methods. Furthermore, "Curriculum Ideological and Political Education" (CIPE) is an educational strategy that aims to integrate ideological and political elements into all subjects. In this study, we present our pedagogical framework for integrating CIPE into the teaching of phylogenetics. The three core components of this course are Evolutionary Theory, Computational Methods, and Practical Applications. These components support the development of three CIPE principles: Scientific Integrity, Critical Thinking, and Social Responsibility. We apply this pedagogical framework in practice through a case study approach, with examples covering biodiversity conservation, public health, and food security.

1. Introduction

Bioinformatics is an interdisciplinary field that integrates biology with computational and mathematical sciences [1, 2]. Its education trains learners to apply computer-based methods for collecting, managing, and analyzing data to address biological questions [3, 4]. Since 2008, the College of Life Sciences at Anhui Normal University, China, has been a pioneer in this area within Anhui Province, offering a bioinformatics course to Biology and Biotechnology majors. Initially an elective, this course has become compulsory over the past five years for students in Biology, Biotechnology, and Biopharmaceutical programs, with approximately 400 students now enrolling each year. The curriculum covers a range of topics, including biological databases (NCBI, EMBL, etc.), sequence alignment methods, molecular phylogenetics, genome assembly and annotation, protein structure prediction, and the application of common bioinformatics tools for data analysis and visualization.

Within this curriculum, phylogenetics is a key module. It focuses on evolutionary relationships of organisms on earth using computational methods. In general, molecular data (DNA or RNA sequences, protein structures) are employed to infer these relationships. [5, 6]. This process is called phylogenetic inference. The results are visualized in a phylogenetic tree, which shows how organisms share common ancestors and how their evolutionary paths have changed over time. This analytical

method is useful for understanding biodiversity, tracing the origins of diseases, and securing our global food supply.

In China, "Curriculum Ideological and Political Education" (CIPE) is an educational strategy that aims to integrate ideological and political elements into all subjects [7]. CIPE integrates principles such as integrity, social responsibility, and a commitment to public service into the content and pedagogy of all academic disciplines [8, 9]. In this study, we apply this pedagogical framework in practice through a case study approach, with examples covering biodiversity conservation, public health, and food security.

2. A Pedagogical Framework for CIPE in Phylogenetics

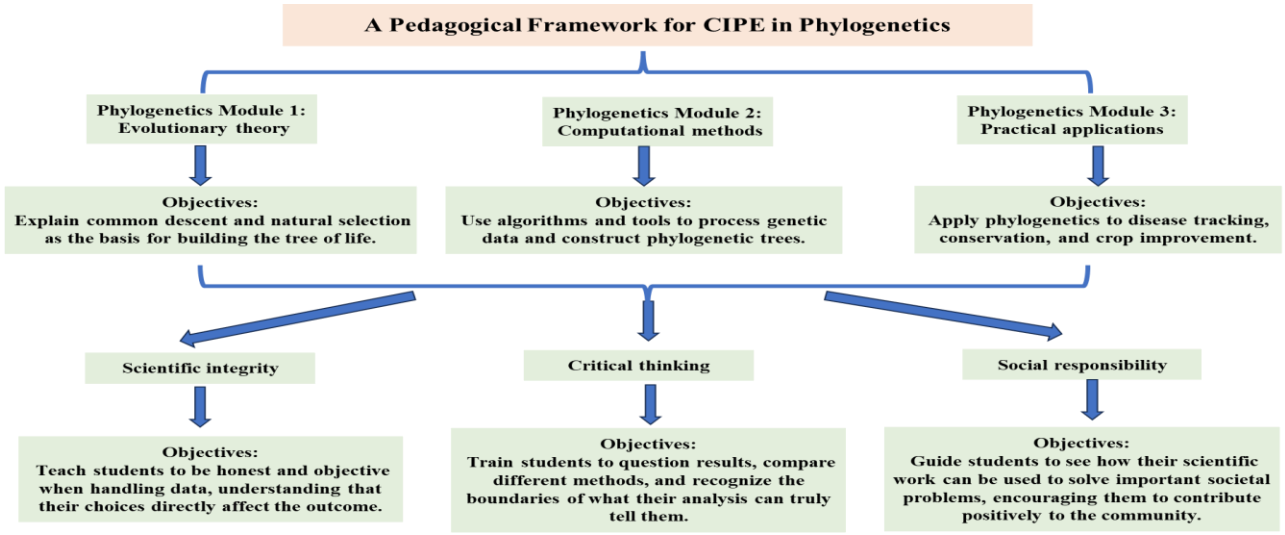

Figure 1 A diagram illustrating the pedagogical framework for integrating CIPE into phylogenetics.

Our pedagogical framework for integrating CIPE into the phylogenetics module is illustrated in Figure 1. It is designed to leverage the core components of the course (Evolutionary Theory, Computational Methods, and Practical Applications) as a foundation for cultivating key values. This foundation supports the development of three CIPE principles: Scientific Integrity, Critical Thinking, and Social Responsibility.

Firstly, Scientific Integrity is the foundation of all credible scientific endeavor. It refers to the adherence to professional values and practices of honesty, accuracy, and objectivity when conducting and reporting research [10]. Without scientific integrity, science will lose all credibility. Secondly, Critical Thinking is developed by evaluating evidence and methods, which involves analyzing data, identifying potential biases, and considering alternative interpretations rather than accepting conclusions at face value [11]. Thirdly, Social Responsibility is the principle that scientists have an ethical obligation to ensure their work benefits society and minimizes harm [12, 13]. This value is instilled by connecting research to societal needs (linking the lab to the real world) and ensuring that scientific pursuits contribute positively to the public good. This integrated structure creates a clear pathway from knowledge acquisition to character development, ensuring students become both technically skilled and ethically grounded professionals.

3. Implementation through Case Studies

We apply the pedagogical framework in practice by using a case study approach. These case studies aim not only to teach core phylogenetic approaches but also to promote the CIPE's focus on integrity, analytical thinking, and social duty. Through examples in biodiversity conservation, public

health, and food security, we demonstrate how classroom integration transforms theoretical principles into practical learning.

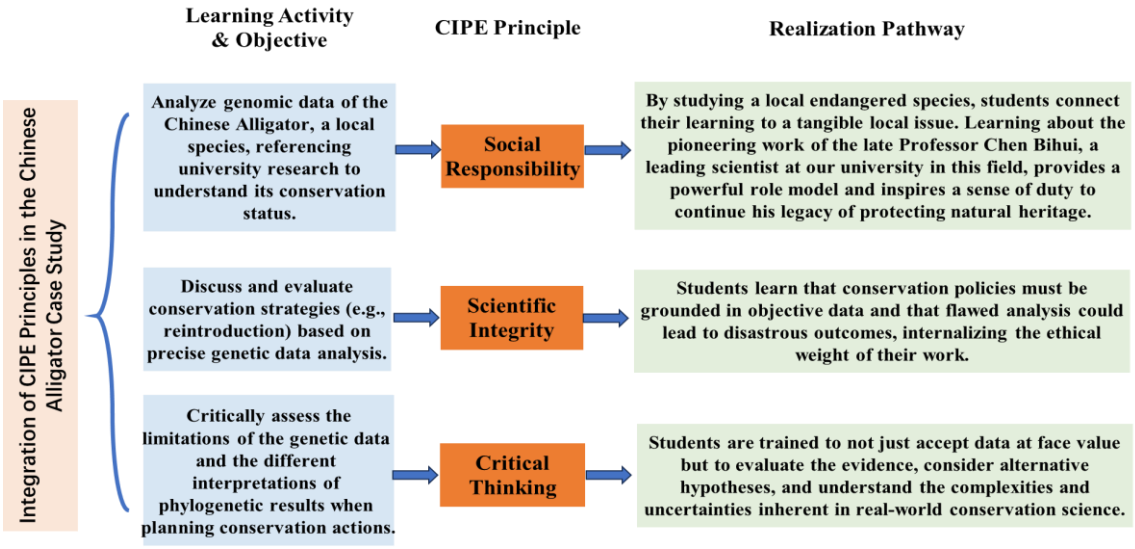

Figure 2 A flowchart illustrating the integration of CIPE principles in the Chinese Alligator case study.

3.1 Case Study 1: The Chinese Alligator

The first case study is about the critically endangered Chinese Alligator (*Alligator sinensis*), which now survives mainly in southeastern Anhui Province, with occasional historical or possible sightings in neighboring provinces. It is also a key subject of research at our university. As detailed in Figure 2, this case study links specific learning activities directly to the cultivation of CIPE principles. By examining genomic data, students explore the alligator's distinct evolutionary position and conservation issues, linking their work to the pioneering work of researchers at our own institution, like the late Professor Chen Bihui. Through active participation in conservation projects, students deeply understand the ethical responsibilities of scientific research.

3.2 Case Study 2: Chikungunya Virus

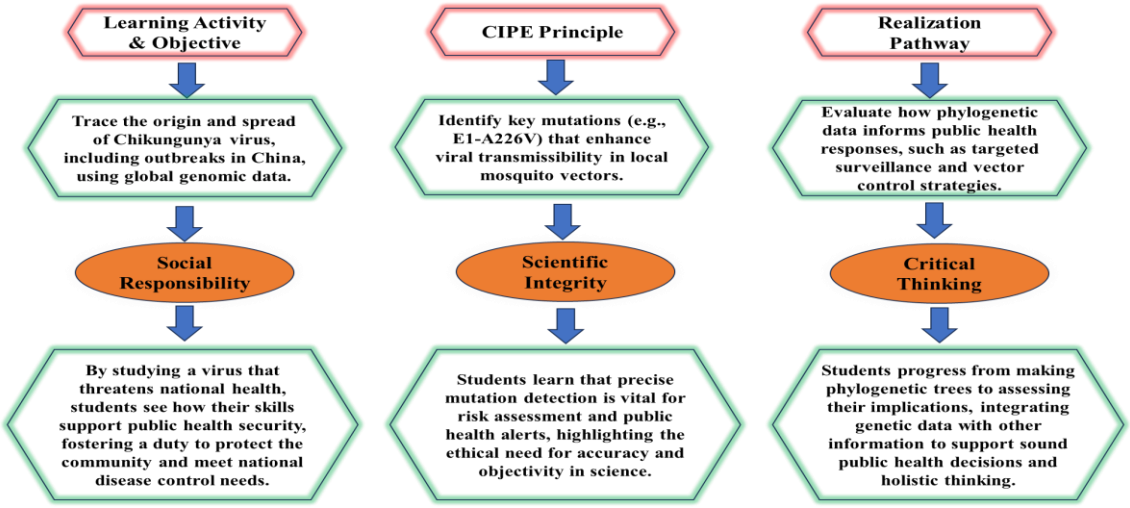

Figure 3 Integration of CIPE Principles in the Chikungunya Virus Case Study.

The second case study turns to public health, focusing on the Chikungunya virus [14, 15]. This mosquito-transmitted pathogen has been responsible for outbreaks around the globe, including imported cases and local transmissions in parts of China. In this case, phylogenetics is shown to play an important role in real-time epidemiological monitoring. Students study genomic sequences from various outbreaks to determine the virus's origin, spread patterns, and mutations associated with higher transmission. Here, bioinformatics is shown as central to defending national health. By tracing the virus's path and understanding its adaptation to local vectors, students see how their work can inform public health strategies and contribute to the "first line of defense" against infectious diseases. The integration of CIPE principles for this case is outlined in Figure 3.

3.3 Case Study 3: The Chinese Milk Vetch

Finally, to explore sustainable agriculture, we chose Chinese milk vetch (*Astragalus sinicus*) as the teaching subject. In our class, students obtained its genome sequence and analyzed candidate genes related to important traits like nitrogen fixation. This creates a direct link between teaching and agricultural innovation. The specific integration of CIPE principles is detailed in Figure 4.

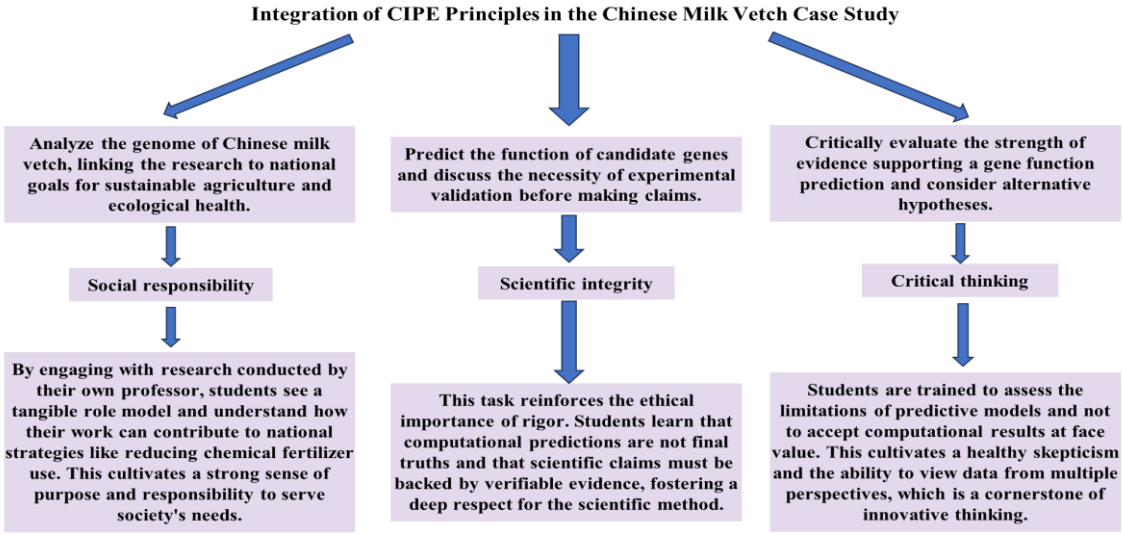

Figure 4 Integration of CIPE Principles in the Chinese Milk Vetch Case Study

4. Assessment and Student Feedback

To analyze the impact of this integrated pedagogical approach, we apply several assessment methods that differ from traditional examinations of technical knowledge. The aim is to assess not just students' knowledge, but also their thinking patterns and personal values.

Firstly, we adopt multiple-choice questions released via Rain Classroom for students to answer and submit. Rain Classroom is a smart teaching tool, developed by Tsinghua University and XuetangX, and it has been used for many years at Anhui Normal University. Here are some examples:

(1) A phylogenetic tree is a powerful tool for illustrating the evolutionary relationships between species. However, historically, some have misused the simplified concept of an "evolutionary ladder" to argue for the "superiority" of certain races. From the perspective of ideological and political education, what principle does this behavior primarily violate?

A) Prioritizing technology while ignoring the practical application of theory.

B) Scientific integrity and social responsibility, by misusing scientific theory to create social injustice.

C) The spirit of innovation, by failing to propose new evolutionary theories.

D) International cooperation, by not communicating sufficiently with scientists from other countries.

The correct answer is B.

(2) Through phylogenetic studies of endangered species (like the Chinese Alligator), scientists can determine their unique evolutionary status and level of genetic diversity. This information is crucial for developing conservation strategies. Which important quality that a scientist should possess does this reflect?

A) The pursuit of personal fame and academic status.

B) Combining scientific research with a sense of responsibility to serve the country and protect the ecological environment.

C) Focusing solely on theoretical research without considering its application value.

D) Strictly adhering to laboratory operating procedures.

The correct answer is B.

(3) Chinese scientists have made significant contributions to understanding the origin and domestication of rice and ensuring global food security through phylogenetic and genomic research. How should this achievement inspire us as young students?

A) To believe that only basic science is worth studying.

B) To be content with existing achievements and stop exploring.

C) To establish the lofty ambition of serving the country through science and technology, study professional knowledge diligently, and contribute Chinese wisdom and strength to solving major problems facing humanity.

D) To blindly worship foreign technology and neglect domestic innovation.

The correct answer is C.

Secondly, we ask students to write short essays after each case study. In these essays, they focus on deep ethical and social reflection, analyzing and discussing the potential consequences of their research for society.

Thirdly, we use class discussions as a main part of the grade. It's not about how many times you talk, but what you say. We give credit when students ask good questions, challenge ideas in a polite way, and connect case details to bigger social or ethical issues. The goal is to make the class a place where everyone thinks and learns together.

5. Conclusion

Bioinformatics is an interdisciplinary field that integrates biology with computational and mathematical sciences. Its education trains learners to apply computer-based methods for collecting, managing, and analyzing data to address biological questions. Within this curriculum, phylogenetics is a key module. It is the study of how living things have evolved and how they are related to each other. In China, "Curriculum Ideological and Political Education" (CIPE) is an educational philosophy that stresses that teaching should not only impart knowledge and skills but also foster character development. In this paper, we therefore present our redesigned phylogenetics module as a model for linking the history of life with real-world applications in biodiversity conservation and public health. Our pedagogical framework for integrating CIPE into the phylogenetics module is illustrated in Figure 1. It is designed to leverage the core components of the course (Evolutionary Theory, Computational Methods, and Practical Applications) as a foundation for cultivating key values. This foundation supports the development of three CIPE principles: Scientific Integrity, Critical Thinking, and Social Responsibility. We apply the pedagogical framework in practice by using a case study approach. These cases studies aim not only to teach core phylogenetic approaches but also to promote the CIPE's focus on integrity, analytical thinking, and social duty. Through

examples in biodiversity conservation, public health, and food security, we show how classroom integration turns theoretical values into real learning. To analyze the impact of this integrated pedagogical approach, we apply several assessment methods that differ from traditional examinations of technical knowledge. The aim is to assess not just students' knowledge, but also their thinking patterns and personal values.

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