Public Access for Teaching Genomics, Proteomics,and Bioinformatics

Introduction

Faculty and students increasingly depend on the internet for communication and accessing biological knowledge. Researchers often use specialized tools from the National Center for Biotechnology Information (NCBI), while instructors rely on it for educational resources and literature searches. Students typically turn to general search engines like Google, but due to the rapid expansion of biological data, they must learn to navigate DNA-focused databases to stay informed in modern biology.

The growing importance of molecular biology has unified previously separate fields—such as genetics, ecology, biochemistry, and behavior—through shared tools and overlapping data, making cross-disciplinary collaboration more common.

The growing emphasis on open access to genomic data and digital tools has created a unique opportunity in biology education. Although most educators lack formal training in genomics, student interest is high. In response, faculty are rapidly adapting—either by launching dedicated genomics courses or weaving genomic content into existing ones. Textbooks are evolving to reflect this shift, but genomics is more than static information; it's a dynamic, searchable field accessible online. By using these digital resources, teachers can offer students a more interactive and engaging experience. The author notes their own experience developing and teaching a genomics course twice.

TRADITIONS OF INNOVATION

BioQuest, founded by John Jungck at Beloit College, is a pioneering educational initiative that enhances undergraduate learning through real data and case-based methods. It emphasizes three core principles: Problem Posing, Problem Solving, and Peer Persuasion. Despite limitations like platform compatibility and cost, BioQuest's approach remains a model for innovative teaching. Since 1989, Project Kaleidoscope (PKAL) has championed innovation in STEM education by supporting faculty across institutions. Through workshops and white papers, PKAL outlines strategies for fostering change, sustaining reform, and cultivating future educational leaders. A key emphasis is on collaboration, which is vital for successful teaching improvements. The field of genomics presents new opportunities for STEM faculty to collaborate in both research and education.

TOOLS FOR A SYSTEMS APPROACH TO TEACHING

Online databases containing DNA sequences, gene annotations, protein structures, interactions, expression profiles, genomic variations, and biomedical literature are freely accessible and widely used in research and education. Students learn to query these dynamic resources, which enhances their learning but can lead to unexpected results due to frequent updates. This unpredictability, while sometimes challenging for instructors, adds excitement and realism to the classroom experience.

Interdisciplinary collaborations between biology and mathematics/computer science are thriving on college campuses. At Wheaton College, Betsey Dyer and Mark LeBlanc have built a successful teaching and research partnership. At Wofford College, George and Angela Shiflet have developed a strong computational science program that prepares students for careers and graduate studies. The rapid global growth of bioinformatics programs highlights the increasing importance of integrating biology with math and computer science.

Genomics Course Grading

A Positive Shift The author, a college instructor, shares their journey of improving student assessment in a genomics course. After years of dissatisfaction with traditional grading methods, they developed new evaluation techniques over two years that both they and their students appreciate. These methods are available online, and their success isn't just due to small class sizes, but to the effectiveness of the new approach.

Genomics Web Page Assignment

Students were tasked with comparing popular press and scientific publications about a human gene labeled in the media (e.g., “smart gene,” “fat gene,” “gay gene”). The goal was to:

- Develop skills in evaluation, application, and synthesis
- Understand the complexity of genomics vs. genetics

- Learn how to create and publish web pages
- To support them, the instructor provided:
- Guides on web page creation
- Resources for evaluating internet sources

This assignment blended scientific literacy with digital communication skills.

Describe the Expression Profiles for YFYG

The second YFYG assignment required students to use DNA microarray

databases such as Expression Connection. For their known genes, students typically found few surprises, though they occasionally encountered unexpected results that re-

quired them to evaluate apparently conflicting data.

Students investigated unknown genes by selecting ones adjacent to annotated genes, hypothesizing that proximity implied similar cellular roles. This idea was supported by research showing that neighboring genes are often transcribed together. One student confirmed this with coordinated gene expression, but most found no such link and had to revise their hypotheses. The exercise emphasized the importance of testing assumptions and adapting based on evidence.

Describe the Proteins Encoded by YFYG

Students investigated two yeast genes—one annotated (AFR1) and one unannotated (YDR089W)—to explore their protein functions using bioinformatics tools.

Tools Used

Databases included:

- DIP, PathCalling, Osprey (protein–protein interactions)
- Gene Ontology, MIPS, SwissProt, Function Junction (functional annotation)

➢ Goals

- Analyze known and unknown gene functions

- Document database findings or lack thereof

- Formulate hypotheses for unannotated genes

- Design experiments to test these hypotheses using genomic, proteomic, and molecular biology methods

➢ Outcome

Students practiced discovery-based science, learning to navigate incomplete data and propose meaningful, testable models for gene function.

➢ Tests

The genomics course emphasized higher-order thinking over memorization, as genomic data is vast and searchable. Since students already had a background in genetics, the instructor focused on testing comprehension, application, analysis, synthesis, and evaluation rather than basic terminology. While vocabulary was important, the goal was to assess deeper cognitive skills.

- Exam Format: Open-book, take-home exams using internet resources; students had several days to complete them.

- Materials Used: Full scientific papers (e.g., from Science or Nature), especially those with databases.

- Student Tasks:

  - Answer complex questions with multiple valid approaches.

- Print data from websites and include screenshots (especially for color images or protein structures).

- Purpose: To understand students’ reasoning and data interpretation.

- Outcome: Enabled you to distinguish between misunderstanding and poor choices due to ambiguous data (e.g., BLAST results).

ASSESSMENT OF STUDENT OUTCOMES

The author emphasizes the importance of assessing student outcomes with data, especially when evaluating educational innovations. Inspired by scientific standards, they argue that claims of improved learning should be backed by evidence. To evaluate their own teaching, they used both knowledge-based and attitude-based assessments alongside traditional tests and web activities, aiming to measure students’ understanding and personal growth.

Learning Gains

- Objective: Introduce students to key terms and concepts in genomics and proteomics.
- Entrance Exam Results: Average score was 0.77 ± 0.1 out of 4, showing limited prior knowledge.
- Challenges: Students struggled with basic vocabulary and concepts like genome sequence variations, DNA microarrays, and proteomics.
- Exam Design: Simple questions were used to highlight knowledge gaps.
- Exit Exam Results: Showed **substantial improvement**, indicating successful learning throughout the course.

Alumni Impact Highlights

- Career Advancement: Several students from Fall 2001 secured positions in genomics labs, driven by their growing interest in the field.

- Graduate Education: One student was accepted into an M.D./Ph.D. program, attributing her success to the course's emphasis on genomics and mathematics.

- Global Influence: A student participating in a fellowship in Bolivia impressed local physicians with her knowledge of cancer biology and genomics, leading to an invitation to lecture medical students in Spanish.

- Research Engagement:

1. 6 out of 25 students from both years conducted genomics research in the instructor's lab.

2. 3 additional students were interested but couldn't be accommodated due to resource constraints.

AREAS FOR IMPROVEMENT

You're enhancing your genomics lecture course by adding a laboratory component to provide hands-on experience, in line with Biology 2010 recommendations.

- In 2002, students lacked sufficient time to engage with 3D stereographic protein visualization, which limited their understanding of structure-function relationships.

- The new lab will require:

1. Training time for students to become proficient with visualization software.

2. Extended exposure to protein modeling to build intuitive understanding.

3. Stronger integration of math and computer science to support computational biology skills.

CONCLUSIONS:

Genomics offers free, data-rich resources that enhance both teaching and research in biology. Faculty can integrate these resources into coursework, benefiting students and reinforcing the connection between research and education. As more institutions adopt genomics, departments must decide whether to embed it in existing courses or create new ones. The author argues that genomics deserves its own dedicated courses, based on positive student outcomes and career impacts.