Developing Quantitative Skills in Your Courses Using HHMI BioInteractive Resources

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Welcome!

Label your sticker with the course(s) you teach:
BIO, MICRO, A&P, other (specify)

Discuss with your table:
1. What is your biggest strength as a professor?
2. What is your biggest challenge in your courses?
Workshop Agenda

- Introductions
- Importance of teaching quantitative skills
- Overview and exploration of HHMI resources
- Examples from our classrooms
- Assessment activity
- Implementation: What will you take home to your classrooms?
Workshop Goals

• To understand quantitative literacy as part of the Call to Action
• To become familiar with the HHMI website and available resources
• To learn about modifying, scaffolding, and supplementing of HHMI and partner resources for your classroom
• To participate in an active assessment strategy of quantitative skills
• To explore development and modification of HHMI resources in your own classroom
Summarize this figure

Effect size of active learning by discipline

Horizontal lines show 95% confidence interval

Numbers indicate the number of independent studies included in meta analysis

Scott Freeman et al. PNAS 2014;111:8410-8415
Benefits of active learning

Which of the following are important to you?

“Relate concepts to real-world examples”
“Develop lifelong science-learning competencies”
“Introduce fewer concepts in greater depth”
“Stimulate the curiosity of students”
“Demonstrate the passion scientists have for their discipline”
“Engage students as active participants”
“Use multiple modes of instruction”
“…active, outcome oriented, inquiry-driven and relevant.”
Vision and Change

NSF “Vision and Change” identifies quantitative reasoning as a core competency
Students need quantitative skills...

Now: inability to transfer and apply skills between math and science courses (Brent 2004, Gross 2004, Hoy 2004)

In the near future: standardized tests (GRE, MCAT) now assess quantitative reasoning because of its importance in graduate school (Barraquand et al 2014) and medical school (AAMC/HHMI 2009)

In their careers: “omics” era is quantitative and interdisciplinary; lack of quantitative skills is impeding advances in research (Chitnis and Smith 2012, Fawcett and Higginson 2012, Fernandes 2012)
Brainstorm Activity:
Which quantitative skills are important in your classroom?

- Quantitative reasoning applied to biological teaching practice:
  - Evaluate and interpret data
  - Developing and interpreting graphs
  - Applying statistical methods to diverse data
    - Calculate descriptive statistics
    - Conduct inferential statistical tests
    - Interpret statistical significance
- Mathematical modeling
- Managing and analyzing large data sets
How Should We Approach Design of Biology Curricula?

1. How Disciplinary Practice Informs What We Teach
2. How Disciplinary Themes Organize What We Teach
3. How We Teach and How We Assess Student Learning in Biology

Vision and Change 2011 Report
Why we like HHMI BioInteractive

- Free and accessible
- Clear, polished, entertaining
- Focused on active learning and engagement
- Use of real data and real scientists
- Diversity of resources

Short Courses

Data Points

Scientists at Work

Virtual Labs
Working with Data

CLICK & LEARN

Sampling and Normal Distribution
Graphically explore how sample distribution and standard error of the mean depends on the sample size.

TEACHER GUIDE

Teacher Guide: Math and Statistics
Topics include measures of average (mean, median, and mode), variability (range and standard deviation), uncertainty (standard...
Working with Data

**Activity**

**Evolution in Action: Data Analysis**
These two activities support the film *The Origin of Species: The Beak of the Finch*. They provide students with the opportunity to...

**Virtual Lab**

**Lizard Evolution Virtual Lab**
The Lizard Evolution Virtual Lab was developed by a team of scientists, educators, graphic artists, and film makers to explore the...

**Activity**

**Mapping Genes to Traits in Dogs Using SNPs**
In this hands-on genetic mapping activity, students identify single nucleotide polymorphisms (SNPs) correlated with...

**Activity**

**Diet and the Evolution of Salivary Amylase**
Students explore the effects of different diets on the evolution of an enzyme that breaks down starch.

**Activity**

**Allele and Phenotype Frequencies in the Pocket Mouse**
A lesson that uses real rock pocket mouse data collected by Dr. Michael Nechman and his colleagues to illustrate the Hardy-Weinberg...

**Activity**

**Genetics, Probability, Pedigree, and Chi Square Statistics**
A lesson that requires students to work through a series of questions pertaining to the genetics of sickle cell disease and its relationship to....
Links with Annotated Science Papers

Science in the Classroom

• http://www.scienceintheclassroom.org/

• Papers published in the journal Science with a rich library of supporting information

• How many of you are familiar this resource?
Does bad luck cause cancer?

EDITOR'S INTRODUCTION

Variation in cancer risk among tissues can be explained by the number of stem cell divisions

Annotated by Alyssa Chamberlain

Scientists traditionally believed that cancer risk was due to a person's genetics and lifestyle risk factors, such as smoking, alcohol use, and exposure to radiation. However, this theory, called the somatic mutation theory, does not explain why some parts of the body are much more likely to develop cancer than others. For example, even though the small intestine is exposed to more environmental risk factors than the brain, it is three times more likely that a tumor will develop in the brain. Is there something else that affects our risk of getting cancer? Studies of the correlation between a given cell line's number of stem cell divisions and the lifetime risk of cancer suggest that we have been underestimating what may be the biggest factor in cancer risk: chance.
If hereditary and environmental factors cannot fully explain the differences in organ-specific cancer risk, how else can these differences be explained? Here, we consider a third factor: the stochastic effects associated with the lifetime number of stem cell divisions within each tissue. In cancer epidemiology, the term "environmental" is generally used to denote anything not hereditary, and the stochastic processes involved in the development and homeostasis of tissues are grouped with external environmental influences in an uninformative way. We show here that the stochastic effects of DNA replication can be numerically estimated and distinguished from external environmental factors. Moreover, we show that these stochastic influences are in fact the major contributors to cancer overall, often more important than either hereditary or external environmental factors.

That cancer is largely the result of acquired genetic and epigenetic changes is based on the somatic mutation theory of cancer (9-13) and has been solidified by genome-wide analyses (14-16). The idea that the number of cells in a tissue and their cumulative number of divisions may be related to cancer risk, making them more vulnerable to carcinogenic factors, has been proposed but is controversial (17-19). Other insightful ideas relating to the nature of the factors underlying neoplasia are reviewed in (20-22).

The concept underlying the current work is that many genomic changes occur simply by chance during DNA replication rather than as a result of carcinogenic factors. Since the endogenous mutation rate of all human cell types appears to be nearly identical (23, 24), this concept predicts that there should be a strong, quantitative correlation between the lifetime number of divisions among a particular class of cells within each organ (stem cells) and the lifetime risk of cancer arising in that organ.

To test this prediction, we attempted to identify tissues in which the number and dynamics of stem cells have been described. Most cells in tissues are partially or fully differentiated cells that are typically short-lived and unlikely to be able to initiate a tumor. Only the stem cells—those that can self-renew and are responsible for the development and maintenance of the tissue's architecture—have this capacity. Stem cells often make up a small proportion of the total number of cells in a tissue and, until recently, their nature, number, and hierarchical division patterns were not known (25-26). Tissues were not included in our analysis if the requisite parameters were not found in the literature or if their estimation was difficult to derive.
A Science-Based Approach to Restoring Gorongosa's Wildlife
(07 min 45 sec) Scientists from Gorongosa National Park relocate zebras from a nearby reserve as part of the effort to restore...

Steve Palumbi & Megan Morikawa Study Coral Reef...
(07 min 01 sec) Field research on coral bleaching suggests possibilities for saving threatened reefs.

Surveying Ant Diversity in Gorongosa National Park
(07 min 46 sec) Conservation biologist Leanne Alonso is surveying ant species Gorongosa National Park to monitor the...
Embrace the power of the story to motivate students to dive into the data
Scavenger Hunt Activity

• Select a resource type you’d like to explore further:
  1. Data Points
  2. Short Courses
  3. Activities
  4. Click and Learns
  5. Virtual Labs
  6. Science in the Classroom
• Use the worksheet to guide you through your chosen resource (15 min)
• Discuss your findings with your table (15 min)
How Can I Modify HHMI Resources?

- Deconstruct and scaffold to your learning outcomes and technology
- HHMI resources are best when modified for your learning environment
  - Addresses posted answer key concerns
- Use the references to locate original sources
- Bring in more data
  - Recognize data types
  - Recreate figures
  - Perform summary calculations
- Bring in more graphs
  - Identify components of figures
  - Connect research questions with data presentation and conclusions
Available Modified Activities

**QUBES Hub**

- Platform for collaboration and open sharing of quantitative teaching resources

https://qubeshub.org/groups/hhmibiointeractive/

- The original HHMI resource link plus modified educator resources are provided on this site
Examples of Modifying and Scaffolding Quantitative Skills in HHMI Resources

- Analyzing Data from a Viral Outbreak
- Interpreting and Troubleshooting ELISAs
- Amylase Copy Number and Diet using Spreadsheet Tutorials
- Calculating Lifetime Cancer Risk Resulting from DNA Replication
Analyzing Data from a Viral Outbreak: Scientists at Work
Analyzing Data from a Viral Outbreak

Interpret a data table
Calculate:
  Incidence
  Prevalence
  Morbidity
  Mortality
  Case Fatality Ratio
  $R_0$

1998-1999 Outbreak in Malaysia

2004 Outbreak in Bangladesh
Analyzing Data from a Viral Outbreak: Extension Activities

Creating Phylogenetic Trees from DNA Sequences

THIS IS A PART OF Bones, Stones, and Genes: The Origin of Modern Humans

Summary

This Click and Learn explains how DNA sequences can be used to generate such trees, and how to interpret them. English version is ADA accessible.

Start Click and Learn

English | Spanish

https://qubeshub.org/groups/hhmibiointeractive/collections/all
Analyzing Data from a Viral Outbreak: Learning Outcomes Addressed

**Students will be able to…**

- Synthesize knowledge of antigens and antibodies with knowledge of enzymes to understand enzyme immunoassay technology.
- Distill complex, real-world data using basic calculations.
- Describe an outbreak of a disease using appropriate scientific terms, including “reservoir” and “spill over”.
- Discuss limitations in experimental design.
Interpreting and Troubleshooting ELISAs: Virtual Labs

Click the small-volume pipettor to draw 0.1ml of the positive control.
Interpreting and Troubleshooting ELISAs: Extension Activity

1. Explain how Dr. Epstein can use ELISAs to detect the presence of an active Nipah virus infection in bats.

   1. Draw a picture of the interactions that would occur molecularly in this ELISA, labeling the antigen and the antibody.

2. How might ELISAs be used to determine if a bat has ever been infected with Nipah virus?

   1. Draw a picture of the interactions that would occur molecularly in this ELISA, labeling the antigen and the antibody.
Interpreting and Troubleshooting ELISAs: Learning Outcomes Addressed

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- Discuss limitations in experimental design.
Lunch

• Think about a learning outcome in your course that could integrate more quantitative reasoning or a quantitative skill that needs development.

• Identify potential collaborators for this afternoon’s activity
Figure of the Day

What’s Going on in this Graph?
Peak Break-Up Times
According to Facebook status updates

Spring Break “spring clean”
Valentine’s Day
April Fool’s Day
Mondays
summer holiday
Christmas “too cruel”
2 weeks before winter holidays

David McCandless & Lee Byron
InformationIsBeautiful.net / LeeBryon.com

source: searches for “we broke up because” taken from the infographic ultrabook The Visual Miscellaneous

TED Talk: “The beauty of data visualization,” David McCandless
Assessing Quantitative Skills

- Modeling assessment using Immediate Feedback Assessment Technique, ("IF-AT") cards
  - http://www.epsteineducation.com/home/
Spreadsheet Tutorials to Analyze Amylase Copy Number and Diet
Rebecca Orr, Collin College, Ruth Buskirk and Kristin Harvey, U.T. Austin

https://qubeshub.org/qubesresources/publications/308/1
Exploring Descriptive Statistics

- Compare the mean and median for each population. Which value best describes the center of the data distribution (the central tendency) for each population?
- The standard deviation is the most widely used measure of variability. Which population has more variation around the mean?
Using a Histogram to Evaluate Data Distribution

• A histogram is a graph of frequency distribution. It graphs how many data points fall between a range of values, and is a very useful graph for illustrating data distribution.

• How do the centers of each population compare with each other?

• How does the distribution of gene frequencies compare in each population?
Where Does Your Dog Fall in Distribution?

Number of individuals

Diploid copy number

0 2 5 10 15 20 25 30

Digest starch worse

Digest starch better
Calculating Lifetime Cancer Risk Resulting from DNA Replication

- Rebecca Orr, Collin College, Ruth Buskirk and Kristin Harvey, U.T. Austin

- Took existing Data Point resource, Mismatch Repair Animation, and Science in the Classroom, created a story to add relevance.

- Added specific content instruction on stem cells, DNA replication, & proof reading/mismatch repair.
Evaluating Scatterplots

• Created questions to build skills in
  • Process of science
  • Evaluating Pearson correlation coefficient \((r)\) to identify relationships between variables

• Activity was designed to fit into a team-based learning environment.
Explore implementing these resources...

• With the collaborators you identified at lunch, in groups of 2-3, plan how you might implement one or more of these resources in your classroom (45 min)

• Report out within your table
You don’t have to do it alone!

1. Join an FMN
2. Modify existing materials

https://qubeshub.org/community/fmn
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Don’t forget to fill out your evaluations!