

Webinar: Quantitative Education in Life Science Graduate programs

Presented by:

*National Institute for Mathematical and Biological
Synthesis, University of Tennessee, Knoxville*

*Southeast Center for Mathematics and Biology
Georgia Tech*

*With support from the National Science Foundation
(DBI-1300426) and Burroughs Wellcome Fund*



MEET YOUR MODERATOR

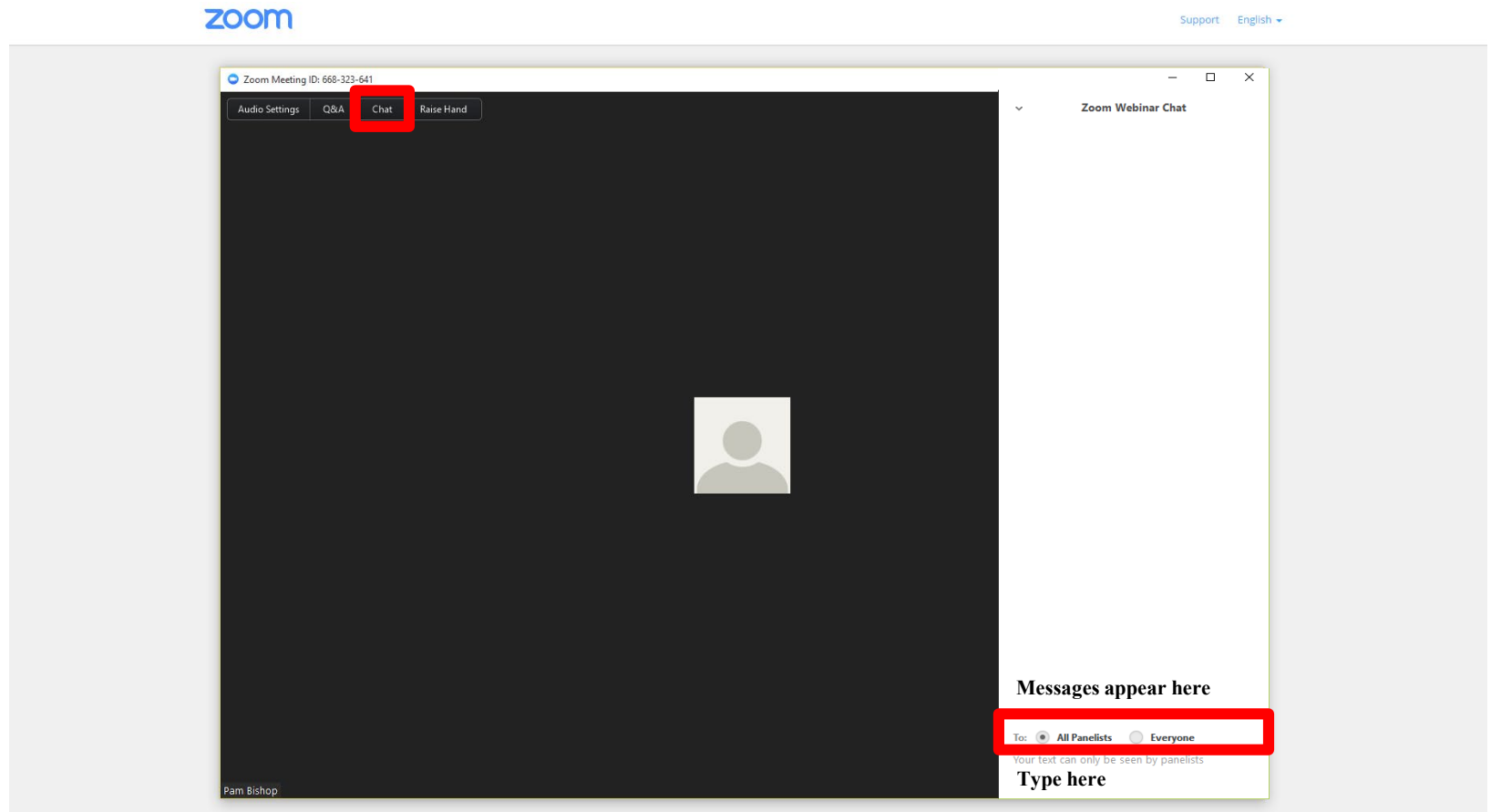


Greg Wiggins, PhD

Education and Outreach Coordinator,
NIMBioS

University of Tennessee, Knoxville

HOW TO INTERACT TODAY



MEET YOUR PRESENTER



Louis J. Gross, PhD

Director, National Institute for Mathematical and Biological Synthesis (NIMBioS)

Director, The Institute for Environmental Modeling, University of Tennessee

Chancellor's Professor of Ecology and Evolutionary Biology and Mathematics, University of Tennessee



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Description

Participants

Agenda (draft)

NIMBioS/SCMB Investigative Workshop

Quantitative Education in Life Science Graduate Programs

Topic: Quantitative Education in Life Science Graduate Programs

Meeting dates: March 16-18, 2020

Location: NIMBioS at the University of Tennessee, Knoxville

Organizers:

Stefano Allesina, Ecology & Evolution and Computation Institute, Univ. of Chicago

Louis Gross, Ecology & Evolutionary Biology and Mathematics, Univ. of Tennessee, Knoxville

Christine Heitsch, Mathematics, Biological Sciences and Computational Science and Engineering, Georgia Tech

Mariel Vazquez, Mathematics and Microbiology & Molecular Genetics, Univ. of California, Davis

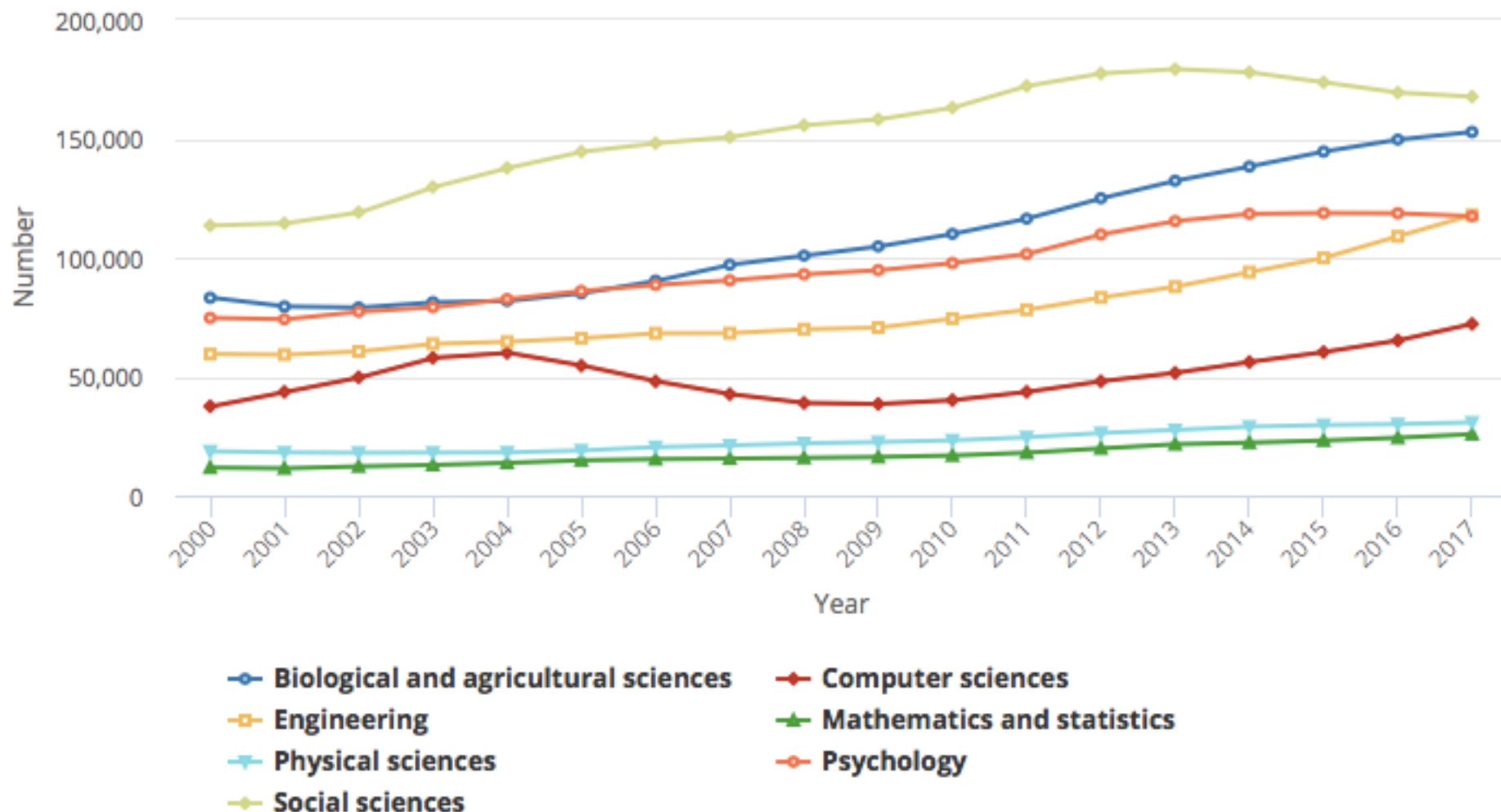


Webinar Objectives

- Summarize the variety of efforts to enhance quantitative education for undergraduates in the life sciences to indicate what might be usefully transferred to enhance life science graduate education.
- Discuss the quantitative backgrounds of those entering life science graduate programs.
- Discuss suggestions of possible topics for breakout sessions during the Workshop.

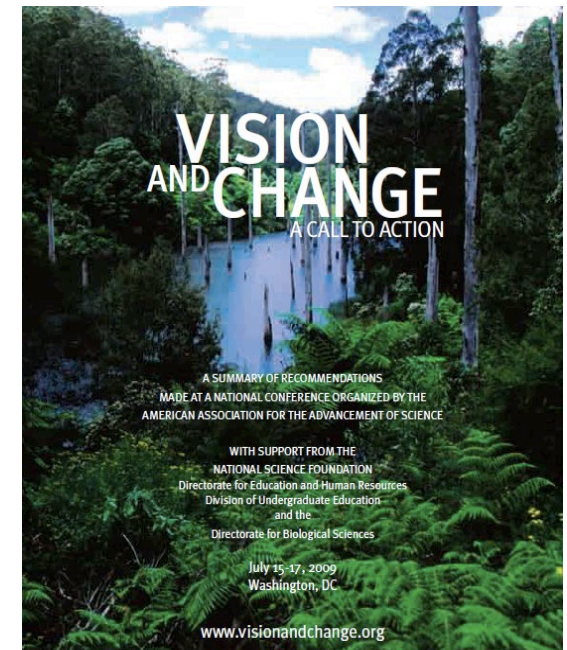
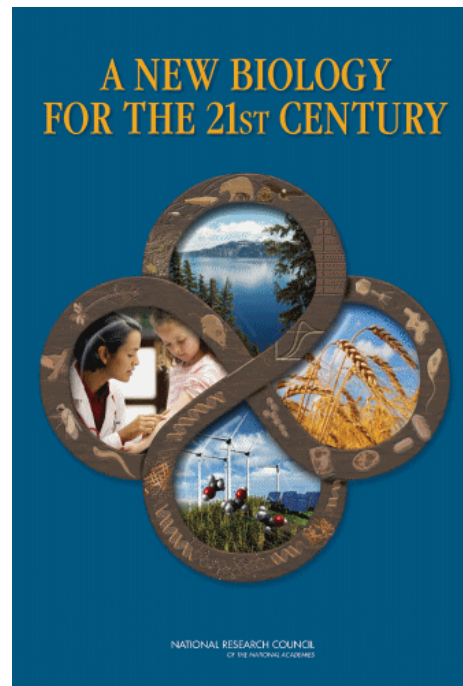
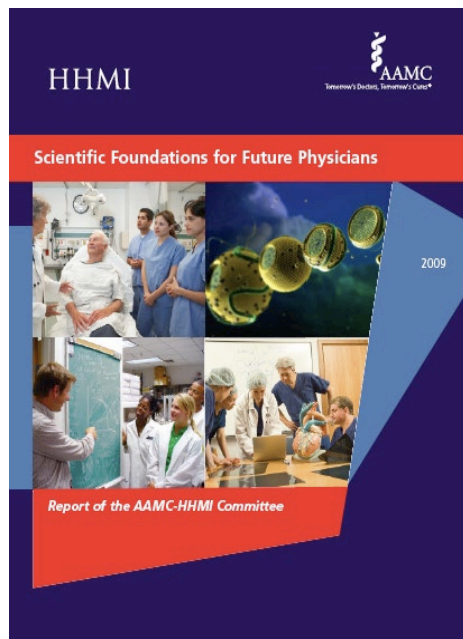
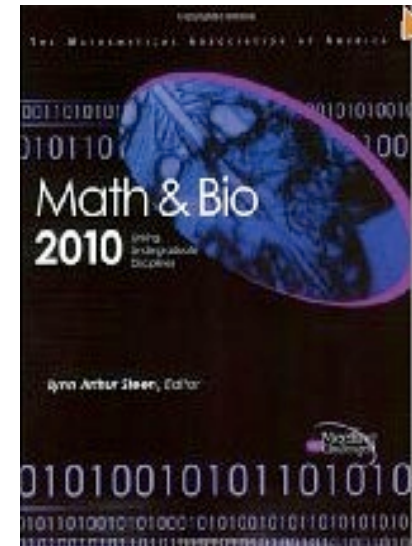
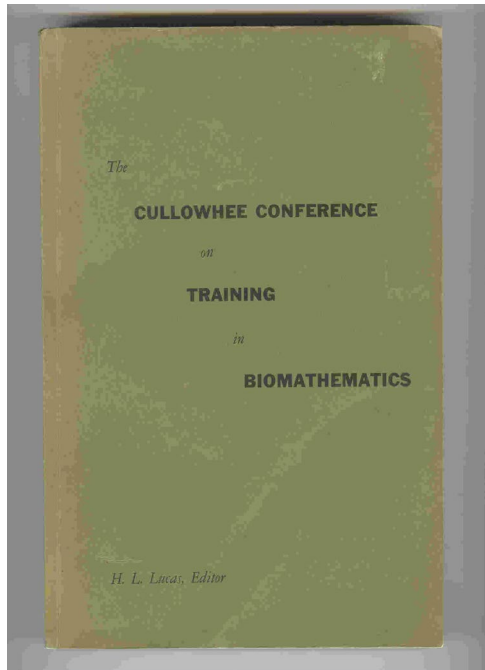
The Undergrad S&E Landscape

S&E bachelor's degrees awarded, by field: 2000–17



National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Completions Survey; National Center for Science and Engineering Statistics, National Science Foundation, Integrated Data System (IDS), **Science and Engineering Indicators 2019**

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2020 Summer Workshop



CULTIVATING SCIENTIFIC CURIOSITY
SUMMER WORKSHOP 2020

June 22-27th

University of Pittsburgh

BioQUEST.org

QUANTITATIVE UNDERGRADUATE BIOLOGY EDUCATION AND SYNTHESIS

*The Power of Biology × Math ×
Community*

[Learn more about QUBES...](#)



QUBES Consortium



**Alliance of societies, institutions,
programs with a common goal**

FEATURED IN COMMUNITY



Leading Students and Faculty to
Quantitative Biology Through
Active Learning

FEATURED IN RESOURCES



Teaching Exponential and Logistic
Growth in a Variety of Classroom
and Laboratory Settings

NEWS AND EVENTS

JAN 17, 2015

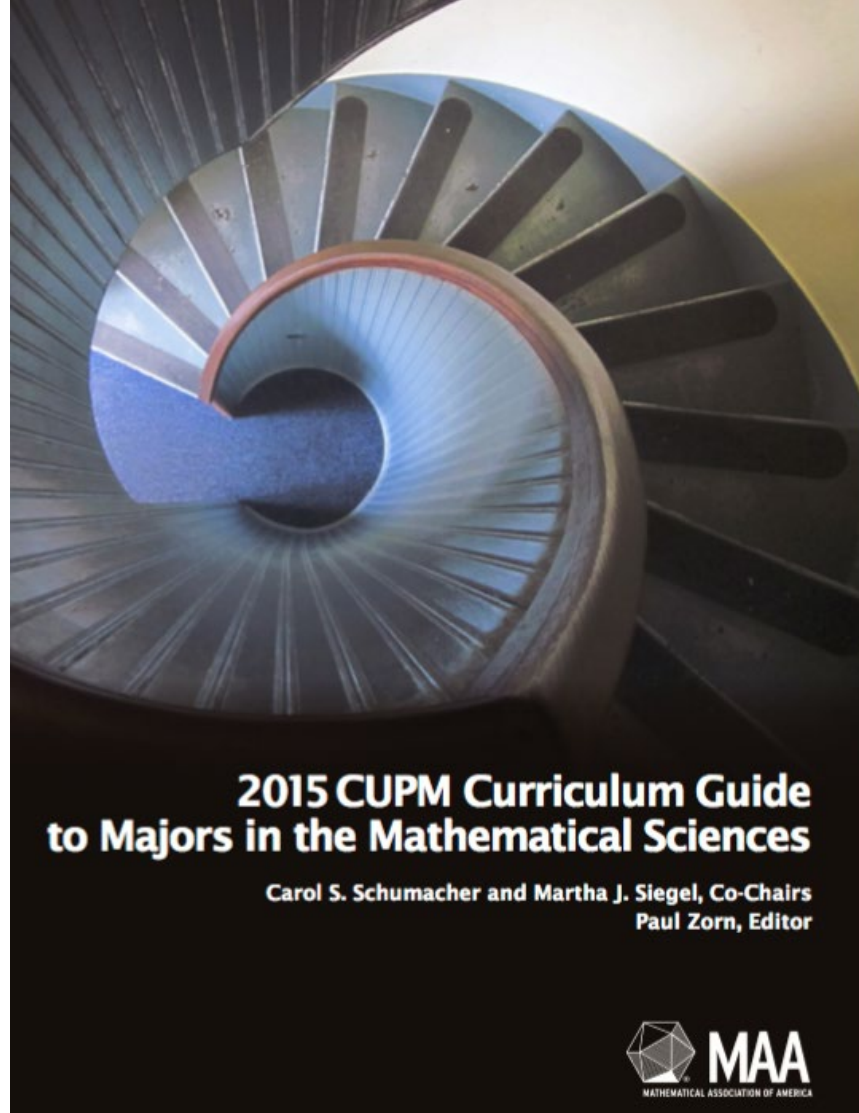
[American Fisheries Society Internship
Opportunity for HS Students](#)

FEB 27, 2015

[An In-Depth Introduction to Using R for HPC](#)

JUN 03, 2015

[iDigBio ADI Hackathon - RSVP 2/28 to be held](#)



**2015 CUPM Curriculum Guide
to Majors in the Mathematical Sciences**

Carol S. Schumacher and Martha J. Siegel, Co-Chairs
Paul Zorn, Editor



MAA.org

Report from the Program Area Study Group on Mathematical Biology

Fred Adler, University of Utah
Lou Gross, University of Tennessee and NIMBioS
Andrew Kerkhoff, Kenyon College
Joe Mahaffy, San Diego State University
Jennifer Galovich, St. John's University (Chair)

The

CULLOWHEE CONFERENCE

on

TRAINING

in

BIOMATHEMATICS

H. L. Lucas, Editor

THE CULLOWHEE CONFERENCE
ON
TRAINING IN BIOMATHEMATICS

An International Conference
held at Western Carolina College
Cullowhee, North Carolina
August 14-18, 1961

Sponsored by
The Institute of Statistics of
North Carolina State College
Raleigh, North Carolina

with the aid of funds provided by

The Division of General Medical Sciences of the
National Institutes of Health, U.S. Public
Health Service, Grant Number 2G-804

and also by

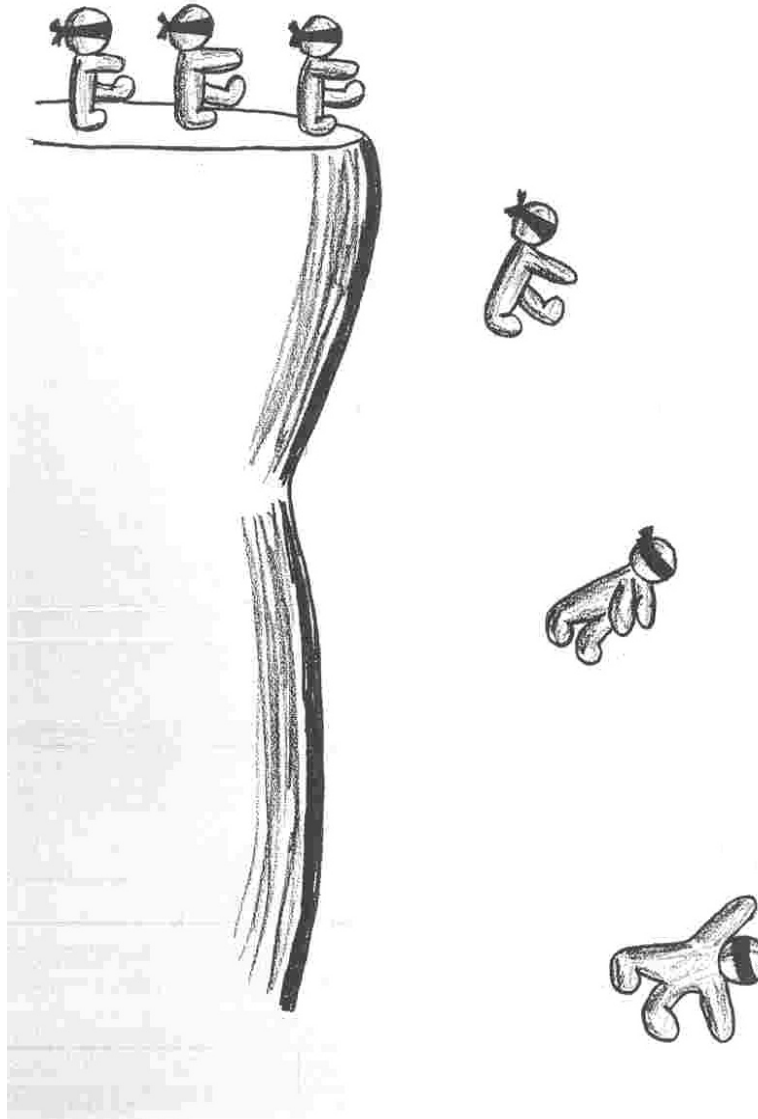
The Air Force Office of Scientific Research of
the Office of Aerospace Research, U.S. Air
Force, Grant Number AF-AFOSR 62-25

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“ There does not exist now, and it is unlikely that there ever will exist, a unique answer to the question of the kind and the extent of training that a mathematical biologist should receive.”

**J. Z. Hearon, Chief,
Office of Mathematical
Research, NIH (1961)**

"In biomathematics let us follow the course charted so well by theoretical physics,"



In biomathematics let us follow the course charted so well by theoretical physics

**Cartoons by
J. R. Troyer
Botany and
Bacteriology
NC State U.
Raleigh, NC**

SESSION 5

DIFFERENTIAL EQUATIONS AND OTHER ITEMS OF
CLASSICAL ANALYSIS IN BIOLOGY



" Now here is a model which
has proved useful... "

**So have we learned
anything in the past 59
years?**

Yes!

Many model programs across the biology/quantitative science interface have been successful;

Many new textbooks have been written focused on entry-level biology students as well as many applying quantitative methods in every area of biology;

Lots of curricular material has been developed for students at all levels;

New software allows investigation of research problems by undergraduates;

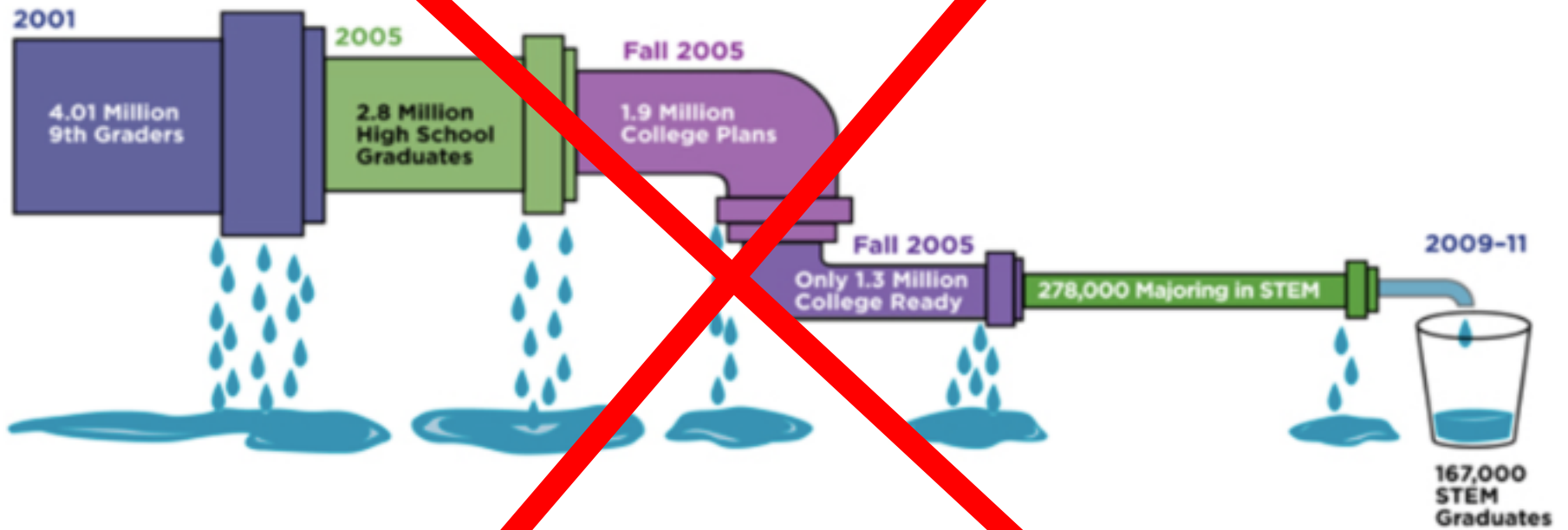
Biologists are much more attuned to the utility of quantitative approaches;

Novel data collection and analysis methods across biology have been linked to education programs;

Education research provides guidance on what really works - learning not rote training, peer collaboration.

Changing the metaphor

The STEM Pipeline



An illustration of the "leaking" STEM pipeline showing how more and more students do not end up pursuing STEM careers despite initial interest. Reprinted from Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics, Table C-6, The STEM pipeline [Online image], (2012). Retrieved from <http://www.achieve.org>. Copyright [2012] Washington, DC: President's Council of Advisors on Science and Technology. Reprinted with permission.

Changing the metaphor

BOX 4.1

A Watershed Instead of a Pipeline

A “pipeline” metaphor has been a standard means to consider the flow of students through a STEM curriculum, with “leakage” used to indicate that some students step out of this path and potentially move to others. It has been argued that this metaphor should be replaced by a “watershed” in which there are multiple flow pathways by which students may enter a degree program dependent upon their own backgrounds. For inherently interdisciplinary degree programs with multiple potential routes for student success, such a metaphor structures a more open, collaborative approach toward building programs that attract diverse students than a fixed pipeline metaphor.



SOURCE: Library of Virginia (2014) via David Asai, Howard Hughes Medical Institute.

Envisioning the Data Science Discipline: The Undergraduate Perspective: Interim Report. National Academies. 2018.

Changing the metaphor

We can't determine *a priori* who will be the researchers of the future – educational initiatives need to be inclusive and not focused just on the elite. Assume all life science students can enhance their quantitative training and proceed to motivate them to realize its importance in real biology. Similarly, assume all math/CS students can be enticed into research by including realistic applications in biology in their math/CS courses.

MCAT (Medical College Admissions Test)

Questions on data-based and statistical reasoning:

- Using, analyzing, and interpreting data in figures, graphs, and tables
- Evaluating whether representations make sense for particular scientific observations and data
- Using measures of central tendency (mean, median, and mode) and measures of dispersion (range, inter-quartile range, and standard deviation) to describe data
- Reasoning about random and systematic error
- Reasoning about statistical significance and uncertainty (i.e., interpreting statistical significance levels, interpreting a confidence interval)
- Using data to explain relationships between variables or make predictions
- Using data to answer research questions and draw conclusions

MCAT

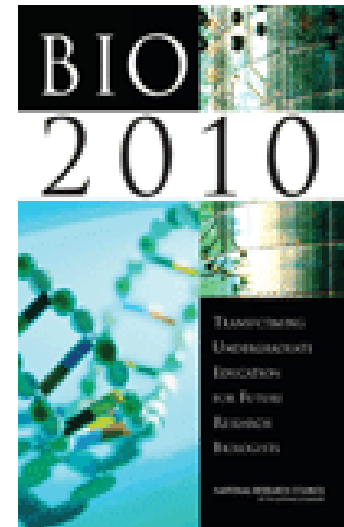
General math concepts competency expected:

- Recognize and interpret linear, semilog, and log-log scales and calculate slopes from data found in figures, graphs, and tables
- Demonstrate a general understanding of significant digits and the use of reasonable numerical estimates in measurements and calculations
- Use metric units; dimensional analysis
- Perform arithmetic calculations involving the following: probability, proportion, ratio, percentage, square-root estimations
- Demonstrate understanding (Algebra II-level) of exponentials and logarithms (natural and base ten), scientific notation, solving simultaneous equations
- Demonstrate understanding of trigonometry: definitions of basic (sine, cosine, tangent) and inverse functions; sin and cos values of 0° , 90° , and 180° ; relationships between the lengths of sides or right triangles containing angles of 30° , 45° , and 60°
- Demonstrate understanding of vector addition and subtraction

Understanding of Calculus is NOT required

Training Fearless Biologists: Quantitative Concepts for all our Students

1. Rate of change
2. Modeling
3. Equilibria and stability
4. Structure
5. Interactions
6. Data and measurement
7. Stochasticity
8. Visualizing
9. Algorithms



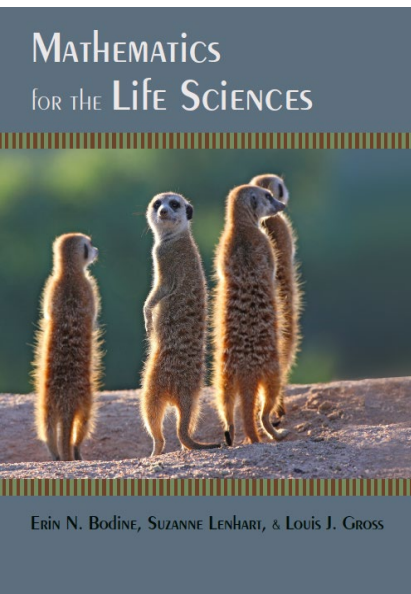
BIO2010: Transforming Undergraduate Education for Future Research Biologists

Slide presented at Bio2010 public release - Sept. 10, 2002. Listing arose from Workshops at UTK in 1992 and 1994

Mathematics for the Life Sciences – Princeton U. Press

Rule of Five- different learning styles to meet needs of diverse students: **Symbolically, Graphically, Numerically, Verbally, Data-driven**

We use this approach throughout the text which includes descriptive statistics (regression, semi-log, log-log), matrix algebra (eigenvalues, eigenvectors), discrete probability, discrete dynamical systems, basic calculus, differential equations, emphasizing data and hypothesis formulation (math and biological), using R/Matlab.



Erin Bodine

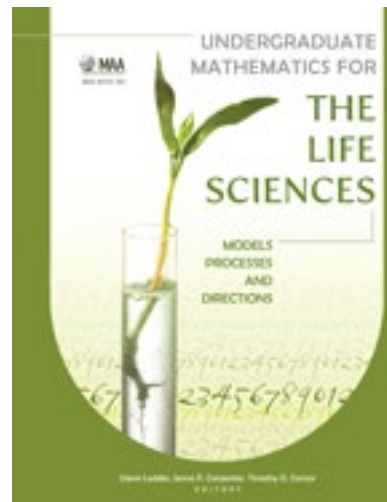


Suzanne Lenhart

Undergraduate Mathematics for the Life Sciences: Models, Processes, and Directions



Glenn Ledder, Jenna P. Carpenter and Timothy D. Comar (editors)
Mathematical Association of America Notes (2014)



What is holding back reform in quantitative bio education?

Lethargy

Inertia

Infrastructure



Data Science



Geography

Mathematics

Computer Science

Statistics

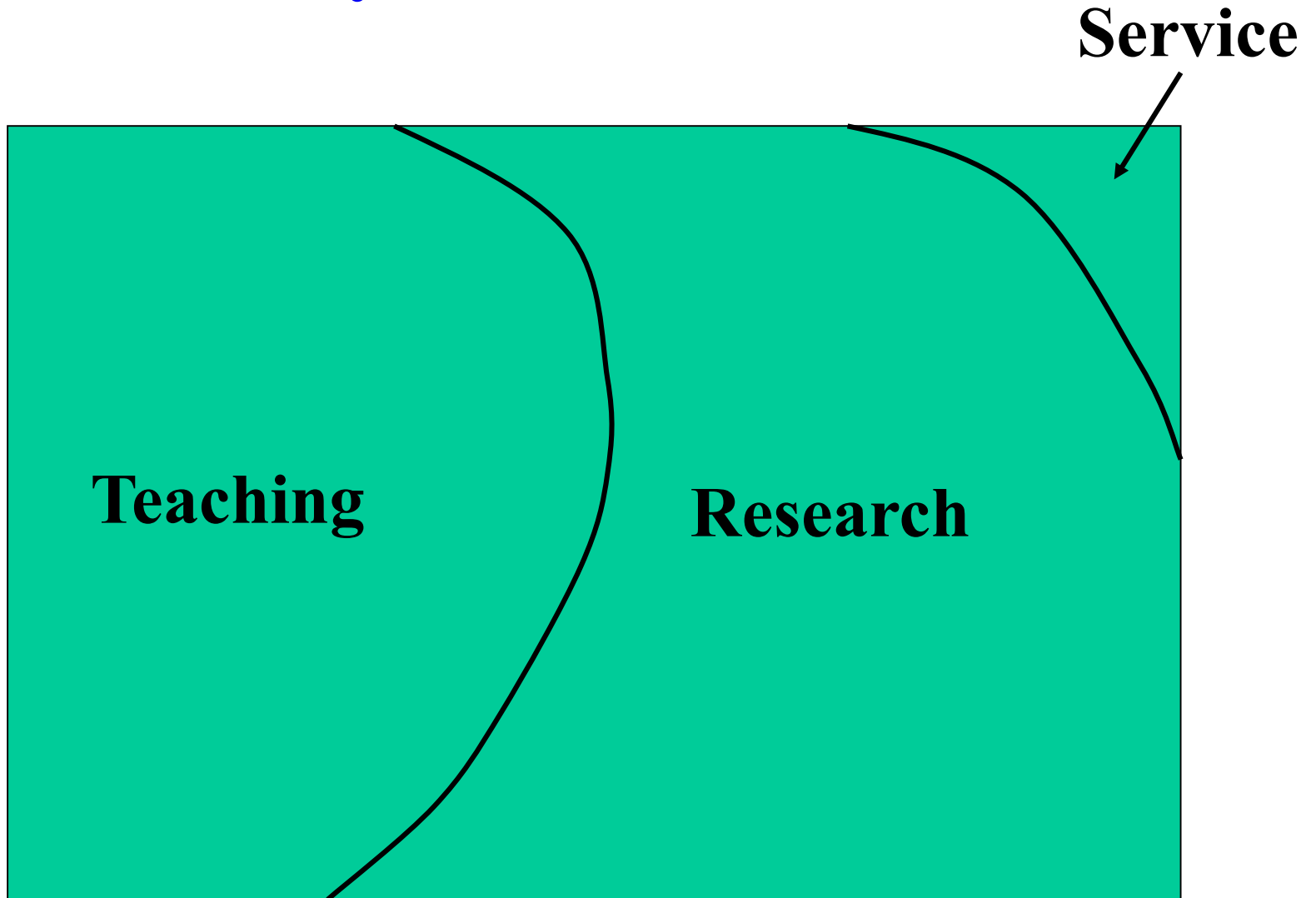
Information Science

2005 10 27

A cacophony of specialization



Faculty Time Allocation



What's left over in the above is for curriculum development!

The CPAR Approach to Quantitative Curriculum Development across Disciplines

Constraints

Prioritize

Aid

Repeat

Assessing Success

An ongoing activity in undergraduate education research is the generation of “concept inventories” for various fields, as a means to provide some uniformity in assessment of learning outcomes




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Development of the Statistical Reasoning in Biology Concept Inventory (SRBCI)




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 Free Access

Development of the BioCalculus Assessment (BCA)

Robin T. Taylor, Pamela R. Bishop, Suzanne Lenhart , Louis J. Gross, and Kelly Sturner

Ross Nehm, Monitoring Editor

Published Online: 14 Feb 2020 | <https://doi.org/10.1187/cbe.18-10-0216>

Needs Assessment for UTK Life Science Grad Students

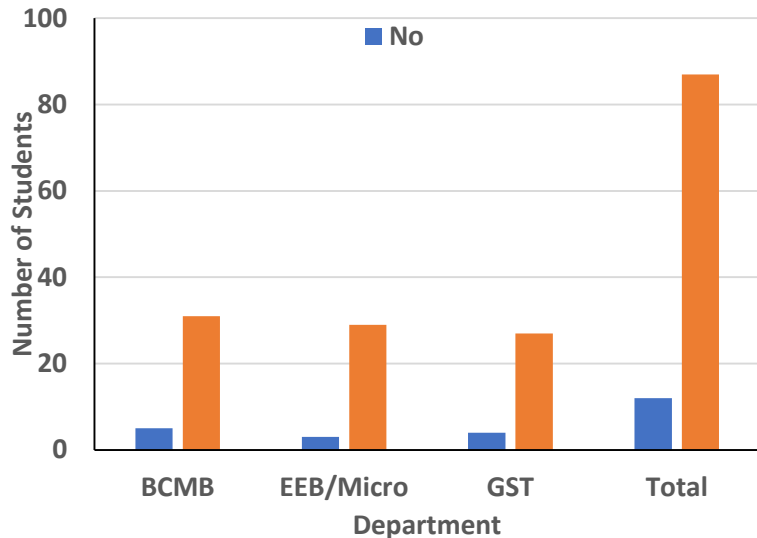
- Current grad students (essentially all seeking PhD degrees) in life science programs self-assessed their quantitative background prior to entering any graduate program
- Included students in Genome Science and Technology (GST), Biochemistry, Cellular and Molecular Biology (BMB), Ecology and Evolutionary Biology (EEB) and Microbiology (Micro) – Note: EEB and Micro were combined in the analysis and the analysis did not include students in other life science graduate programs (biomedical engineering, biosystems or environmental engineering, agriculture programs)

Needs Assessment for UTK Life Science Grad Students

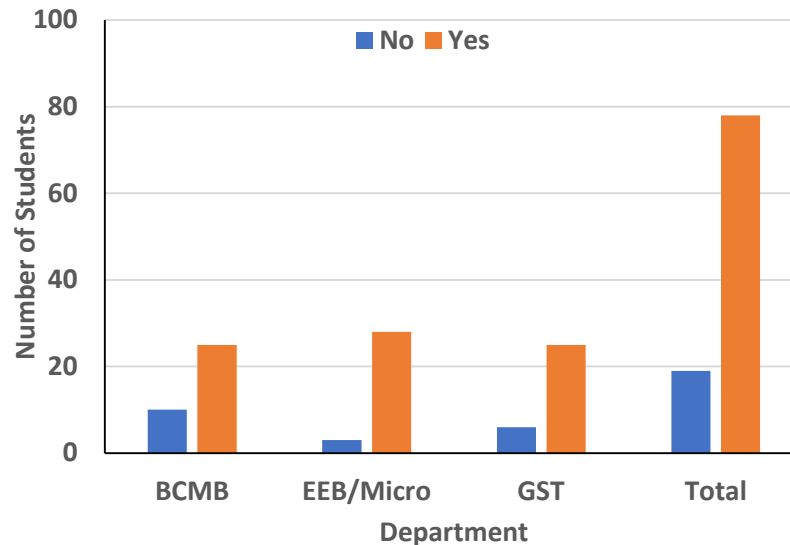
- Students were asked if they had taken, prior to graduate school, each of a formal one-term (i) calculus, (ii) statistics and (iii) computer science (including computing, data science or informatics) course.
- Students were asked how many courses in each of these areas, beyond one-term, they had taken.
- Students were asked to assess their experience using any statistical/data analysis/graphing software package, and their experience in computer programming using any language or package.

Data from Needs Assessment for UTK Life Science Grad Students

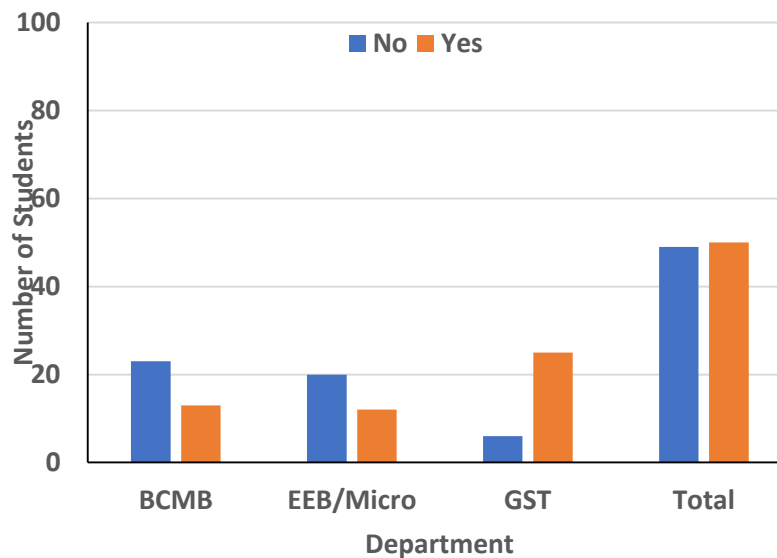
Q1. Formal Calculus Course?



Q3. Formal Statistics Course?

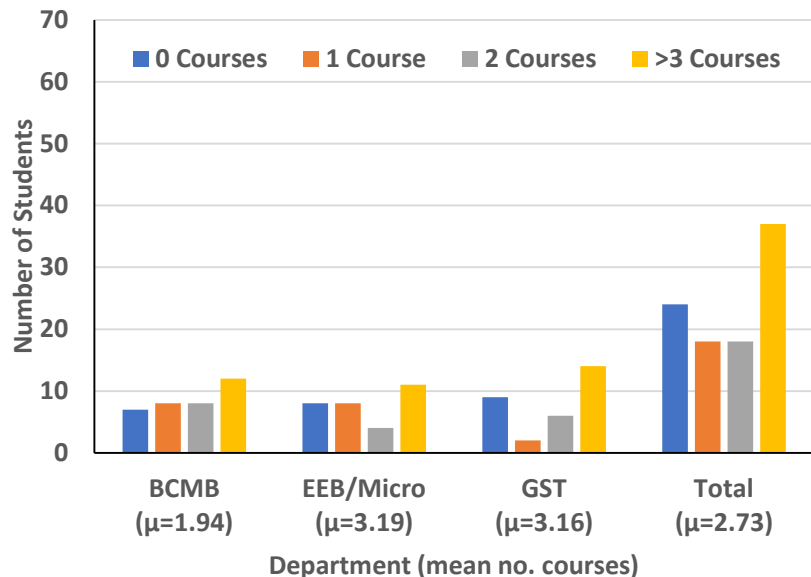


Q5. Formal Computer Science Course?

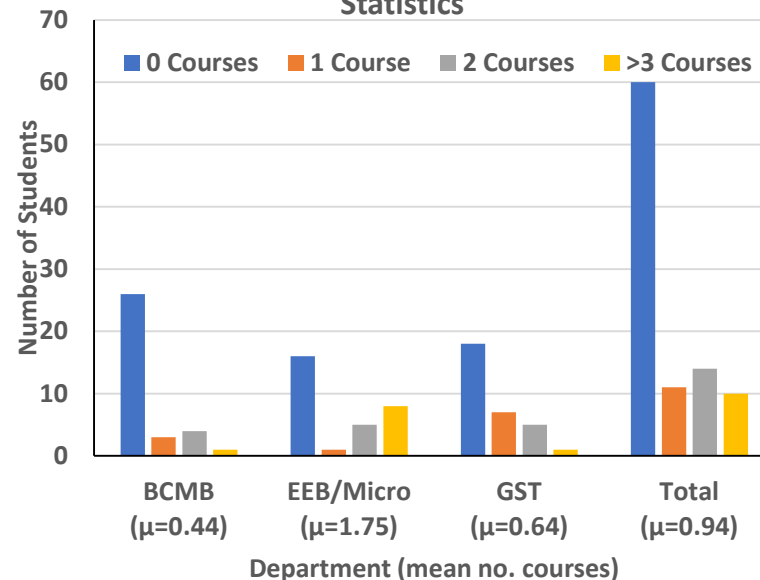


Data from Needs Assessment for UTK Life Science Grad Students

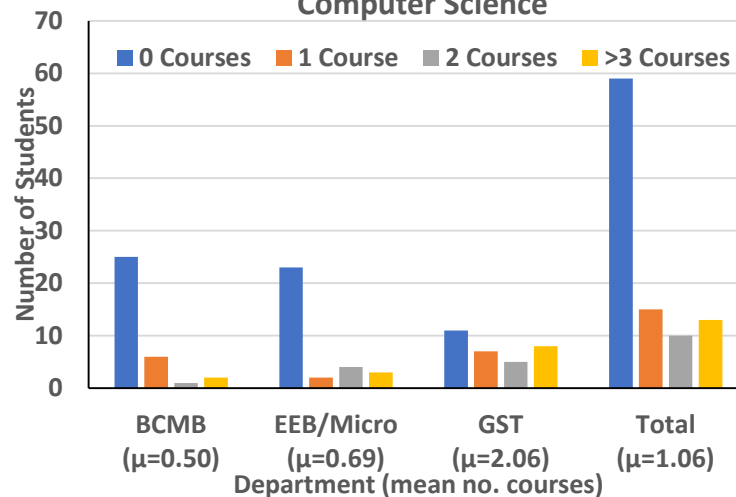
Q2. Math Courses Beyond Calculus



Q4. Stat Courses Beyond Introductory Statistics

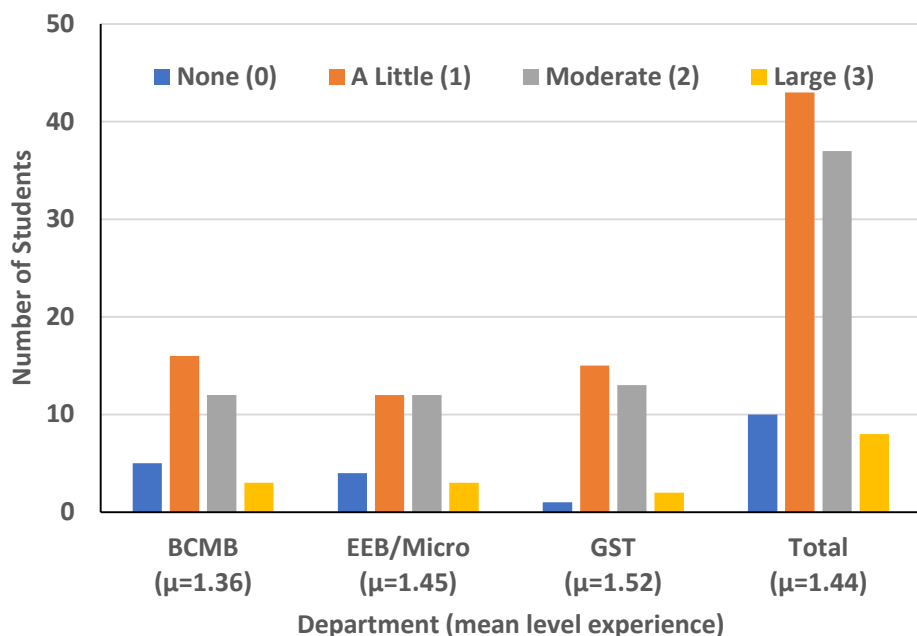


Q6. CS Courses Beyond Introductory Computer Science

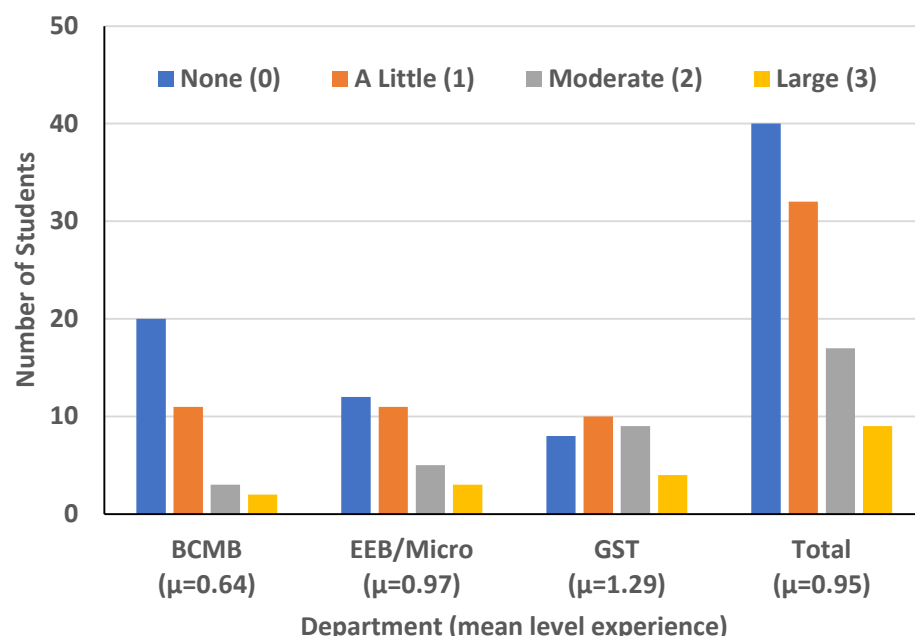


Data from Needs Assessment for UTK Life Science Grad Students

Q7. Experience in Statistical/Data Analysis/Graphing



Q8. Experience in Computer Programming



Lessons from Needs Assessment

1. There is significant variability at both the within- and between-graduate program level in quantitative preparation.
2. Calculus and basic statistics are much more likely to be included than basic computer science.
3. Math courses beyond calculus are much more likely to be included than more advanced statistics/computing courses
4. Students self-assess their experience in use of statistics and computing packages higher than is evident from formal courses.

But we have no data to determine how indicative these conclusions are for life science programs elsewhere

Quantitative Life Science Graduate Education: Potential Topics for Discussion

- What are alternative perspectives on how to infuse quantitative perspectives in different life science graduate programs (Microbiology, Molecular, Genetics, Development, Behavior, Ecology and Evolution, Biomedical, MD, MD/PhD, etc.)?
- Are there consistent differences in what quantitative concepts and skills are emphasized in different life science disciplines and how should this affect educational initiatives?
- What lessons from efforts on quantitative education at the undergraduate level can be adapted or modified to enhance graduate education?
- Are there effective ways to “downscale” quantitative education from programs that focus on educating quantitative biologists to the broader population of graduate biology programs?

Quantitative Life Science Graduate Education: Potential Topics for Discussion

- What are the benefits and issues with the use of alternative modes of learning at the graduate level (formal courses, lab groups, journal clubs, seminars, boot-camps, etc.) to enhance quantitative concept and skill development?
- Considering the portfolio of alternative modes for graduate students to acquire quantitative concepts and skills, are there different optimal portfolios for different types of life science graduate programs?
- In what ways might we change the landscape of quantitative skills being taught at the graduate level?
- Are there particular skills and concepts that are more effectively learned outside of a formal classroom setting and are there ones for which formal class settings are most appropriate?

Quantitative Life Science Graduate Education: Potential Topics for Discussion

- How might we encourage diversity (both conceptual and skill-based) on graduate student committees?
- How might we enhance a culture in life science education that encourages diverse quantitative knowledge?
- In what ways will personalizing a graduate student's experience in courses, research groups, labs, and seminars serve to increase quantitative core competencies and what institutional challenges might occur as a result of this personalization?
- How do we deal with the tremendous expansion of complicated quantitative approaches when there may not be an individual with the necessary expertise available at a student's institution?

Quantitative Life Science Graduate Education: Potential Topics for Discussion

- From where do issues regarding quantitative education for graduate students originate (quantitative-averse students, quantitative-averse faculty, faculty ‘shielding’ students from quantitative education in courses, etc.)?
- What are the relationships and connections between quantitative skills and data science? What are the opportunities to use data science to help motivate and foster quantitative literacy for graduate students?
- What are the networks and techniques for dissemination of graduate training and educational resources (including the outcomes of this workshop)?
- What are good ways to facilitate training for students with disparate backgrounds?

How to learn more:

The presentations at the Workshop will be live-streamed and information will be posted on the website at

NIMBioS.org/workshops/WS_quantedu

A report summarizing discussions at the Workshop will be compiled and made available within a few months.

Thank you for your participation

You will receive a request to evaluate this webinar from the National Institute for STEM Evaluation and Research – we would appreciate your response.

Questions/comments? Please use the chat to post these.