NIMBioS/SCMB Workshop on Quantitative Education in Life Science Graduate Programs

Organized by the National Institute for Mathematical and Biological Synthesis and the Southeast Center for Mathematics and Biology with support from the Burroughs Wellcome Fund, the National Science Foundation and the University of Tennessee, Knoxville. December 2020
Workshop website: http://www.nimbios.org/workshops/WS_quantedu

Workshop Final Report

Workshop Objectives:

- Summarize commonalities and alternative practices for inclusion of quantitative education in life science graduate programs.
- Identify potential research initiatives on the effectiveness of alternative education methods for quantitative concepts and skills.
- Elaborate the potential benefits of a uniform data collection process for quantitative education transitions across levels (undergrad to grad to postdoc) to establish a comparison baseline for evaluation of alternatives.

Possible outputs:

- Workshop report that would provide potential guidance based on experiences at diverse institutions and in biological sub-disciplines about what has been tried, how effective the results have been, and what still needs to be examined.
- Perspective articles submitted for publication in several venues on practices, outcomes and evaluation of alternatives.

Background on the Workshop:
This Workshop was designed to bring together a diverse group of researchers and educators working at the interface of various areas of the life sciences and quantitative science (e.g. mathematics, statistics, data science, informatics). The Workshop arose from discussions among faculty in quantitative biology. Based on our experience, there has been very little open discussion about educational aspects of graduate life science quantitative training, such as what topics to prioritize across the vast array of potential quantitative methods, how formal courses might be effectively mixed with on-line learning, and the effectiveness of boot-camps and tutorials. There have been meetings, conferences and projects focused on undergraduate education at this interface between the life sciences and quantitative methods, but there has been nothing like this for graduate education. Our intention for the Workshop is to gather some of the thought leaders on graduate life science education and its relation to quantitative training to determine commonalities of approaches and consider what evidence is available on the effectiveness of these approaches. Our expectation is that this would provide potential guidance based on experiences at diverse institutions and in biological sub-disciplines about what has been tried, how effective the results have been and what still needs to be examined. While we are aware of many of the major math and computational biology groups who train graduate

students, we are not aware of any previous attempt to gather advice from these on what has been effective in educating not only the few students specializing in these areas, but the broad range of life science graduate students.

The Workshop utilized a two-fold approach to ensure a breadth of perspectives would be obtained. The organizers initially identified approximately 20 individuals from a range of graduate programs who were invited to participate, some of whom gave presentations on their graduate education initiatives. Additionally, we made a broad announcement to the community to encourage applications for participation from those across other North American higher education institutions, though the virtual workshop also included individuals from outside North America. Applications were vetted by the organizers and an additional set of individuals were invited from this open application pool. NIMBioS acknowledges the importance of the process of evaluating our efforts, so an evaluation of the Workshop, as well as the pre-Conference webinar, was developed in conjunction with the organizers and carried out by the staff of the National Institute for STEM Evaluation and Research (NISER), a center which was established through NIMBioS but is now an independent entity based at UTK.

The format of the Workshop included an online webinar conducted in March 2020 prior to the original Workshop date, to provide background information for all attendees to ensure all are aware of the objectives, are provided some of the shared experiences from the organizers, and can discuss possible topics for breakout sessions during the Workshop. The webinar was recorded and made available to anyone interested whether they attended the Workshop virtually or not. The Workshop held in December 2020 consisted of a limited number of summary presentations from some of the programs with experience in educating life science PhD students, followed by breakout sessions with facilitators and rapporteurs who reported back to the whole gathering using a standard template. The Workshop was held in NIMBioS Interactive, an avatar-based platform using the sococo virtual workspace, that allowed informal interactions between individuals and small groups, with zoom being used for the formal presentations and whole-workshop gatherings. While the pandemic led to the cancellation of the original in-person Workshop, there were noted advantages arising from the postponement to a virtual Workshop in December 2020. These advantages included the opportunity for participation from a wider range of participants, including some from outside North America, as well as permitting a fluid set of breakout sessions with ease of choice among these by the participants.

Appended to this report is the schedule of the Workshop, a participant list including those who participated in at least one session during the virtual Workshop, a list of participants in the follow-on discussions focused on graduate students in January 2021, the evaluation report of the webinar and the evaluation report of the Workshop.

Objective of Report – To provide a summary of comments and recommendations for quantitative biology programs as well comments that can inform quantitative biology education for all graduate life science programs. This report is needed because there has been little previous effort focused on the broad impact on graduate life science education of the tremendous advances in quantitative methodologies.

Challenges considered: An overall challenge is that graduate education is multi-faceted with many routes through which a student may be obtaining conceptual foundations and skills. This includes the fact that much of graduate student learning is self-taught, self-motivated and self-advocated. Recognition of the benefit of taking individual initiative (by faculty or students) to obtain quantitative education or offer training opportunities may not be present and some advisors and departments may be resistant to the effort required. Thus, methods to acknowledge the benefits of the investment required and the subsequent skills developed would be helpful. One method is to foster the education of mentors on the need for quantitative skills on the part of their students.

Definition of quantitative biology - the use of mathematical, statistical or computational concepts and techniques to study life and living organisms, ensuring that these are carried out in a reproducible and transparent manner to allow independent evaluation of the results.

Discussions with students and recent graduates:

A suggestion from the Workshop was that some follow-on discussions be held with current graduate students or postdocs to obtain a perspective from those who have been dealing with the quantitative aspects of their education recently. In particular, since many of the Workshop participants had been away from their formal education for many years, it was suggested that comments from students would provide input that was not as readily available (though there were some students and postdocs in attendance at the Workshop). Thus, an opportunity was broadly announced to the NIMBioS community to participate in the NIMBioS Discussions with Students on Quantitative Education in the Life Sciences, which were held twice in January 2021.

There were 14 student/postdoc participants in these small-group discussions, joined by five faculty/advanced career members. The discussions were focused on (i) the quantitative education received as an undergraduate or graduate student; (ii) which educational experiences were found to be most helpful and which not; (iii) what quantitative education should there have been more of and how might it best have been delivered; and (iv) what suggestions might be included in a report on quantitative education for graduate students.

There was a great diversity of quantitative backgrounds for the participants as some had formal quantitative undergraduate backgrounds while others had minimal background at this level. Comments about what were the most helpful quantitative learning experiences included: having a course or short course taught by disciplinary experts who apply the method at hand to data but are intimately familiar with the theory; having instructors who effectively use their own research questions to guide the quantitative topics and/or fostering students to use their own data to encourage becoming invested in learning; having the time to sufficiently delve into the quantitative topic rather than rushing through a set of methods; having exposure to a diversity of quantitative ideas, including programming/coding, early in the undergraduate years so as not to be overwhelmed with novel quantitative approaches in graduate school; and having instructors

who emphasize the role and value of the quantitative ideas in the discipline, rather than just using these as tool.

Some recommendations from the participants included: recognizing that it can be very stressful for graduate students to do a lot of self-teaching, particularly if they lack the basics; be explicit that there is a *wide spectrum* of quantitative concepts and skills and that "math" is only part of the needed experience; there is a clear lack of diversity in quantitative fields relative to the broad field of life sciences and programs should develop to have the breadth of researchers in quantitative biology reflect the broader diversity of researchers in the life sciences; rather than detailed exposure to a limited a set of applications of coding and statistics, be sure that the underlying theory and algorithmic thinking be incorporated.

Summary of Key Points and Workshop Recommendations

Key Points:

1. ***Breadth:*** Quantitative Biology is a very broad field and the variety and breadth of quantitative methods has implications for educational initiatives in both quantitative biology graduate programs and quantitative education across all life science programs. While quantitative acumen is a goal for life science grad students, providing conceptual foundations and skills is not feasible in every quantitative area which has been useful in biological application. A desired outcome is that an appreciation is developed for the advantages of multiple conceptual approaches and techniques as well as the potential to combine techniques from diverse quantitative fields. See recommendations 1, 2, 4, 5.
2. ***Flexibility:*** One size does not fit all and flexibility of quantitative education initiatives is necessary. Some amount of tailoring at the program level and at the level of individual students within a program is appropriate. See recommendations 1, 4, 7, 8.
3. ***Demands:*** There are multiple demands on mentors and students. There has been difficulty convincing faculty across life science graduate programs that formal and informal quantitative education is critical for the success of all students and not just those with particular research questions that require modeling or quantitative analysis skills. The time constraints on graduate biology degree programs that include field/lab expectations on the part of students create tremendous pressure to limit the time spent on acquiring skills for other purposes not directly related to the field/lab effort. Advisers wouldn't send students out into the field or lab without prior training on appropriate techniques, but may well be expecting students to analyze data sets without any appropriate scaffolding of background. See recommendations 2, 4, 5, 8.
4. ***Diversity:*** The interdisciplinary nature of quantitative biology can be beneficial in encouraging a broader diversity of students to join than might arise in siloed departments constrained by history/funding at an institution. Thus, creation of formal interdisciplinary programs with a quantitative biology focus may be an effective means to enhance the representation of students from historically underrepresented groups in biology and associated quantitative fields. This aligns with the move away from the "pipeline" metaphor for education towards a "watershed" metaphor in which students with diverse background are encouraged to bring their own perspectives to bear on a

field, rather than being channelized down particular paths. There are challenges with regard to recruitment for ensuring diverse participation in formal quantitative biology programs but fostering broader inclusion of quantitative skills and concepts in life science programs generally can enlarge the pool of those who could be enticed to take a more quantitatively focused career path. See recommendations 2, 3, 4, 6.

5. ***Student-Centered Learning and Experiences:*** There are a range of alternative approaches to incorporate quantitative methods and concepts in life science educational initiatives (e.g. formal courses, short courses, tutorials, bootcamps, lab groups, journal clubs, peer groups etc. This diversity implies that graduate education is quite different from that of undergraduates in the range of options for learning. There is not a great deal of educational theory or evaluation data about the tradeoffs between alternative methods of quantitative learning at the graduate level. Finding mechanisms to encourage student-centered approaches including peer-learning and peer-mentoring, for example in joint research projects, is particularly important in quantitative biology given the breadth of topics, the quantitative skills necessary in many research areas and the differences in experiences of incoming students that provides the diversity of starting points for students. Enhancing this will allow students to more effectively learn from each other, including from those in quantitative areas outside life sciences, and reinforce other formal or informal quantitative training. Partnerships with industry/government/other agencies may be important to enhance a student's perception of the benefit of quantitative skills outside academia. See recommendations 1, 3, 6, 7, 9.

Recommendations:

1. It would be very helpful for guidance to be provided as to what quantitative education, conceptually and skills, are: (a) essential for all students in a particular program, (b) beneficial but not essential for all students, (c) helpful for some subset of students in an initiative. These tie in strongly with what the objectives of a particular program are relative to the expectations of graduates. How to assist in developing such guidance is critical: whether the guidance is based on education reports from professional societies or research projects, from historical constraints, or from localized faculty prioritization based on their assessment of quantitative needs. Some survey of perception of quantitative needs as determined by faculty, students and recent graduates could be very beneficial. Thus we recommend a survey to be funded that would provide broad guidance across different life science graduate programs that incorporates perspectives from the diversity of life science subdisciplines and encourage particularly that professional societies be consulted, including those which emphasize quantitative areas of life sciences.
2. Obtaining buy-in from both the academic administration for a program, the faculty associated with the program, and the students in the program is essential. To assist in this, listening to the desires of current and future students regarding what they need and what they view as necessary for their careers is important. Tracking employment and placement of graduates by following where they go after graduation can be helpful in obtaining buy-in. Connecting with economic workforce development data sets may be

helpful in providing guidance on how critical quantitative training is for career placement. NIH, NSF and other federal agencies are fostering a stronger focus on rigor and reproducibility that would benefit from broader quantitative training of the life science workforce.

3. Across diverse programs it is beneficial to create a culture among students that facilitates collaboration in both research and learning. If effective, such a culture will encourage student confidence to devote effort to building their quantitative expertise, enhance peer-learning of quantitative skills, and will encourage faculty to foster means by which students do this separate from formal program requirements.
4. It will require creative approaches at many institutions to obtain the institutional support for interdisciplinary programs such as those in quantitative biology. Developing programs that are welcoming and less imposing to students who may not have strong quantitative backgrounds will be important for program success. Formal quantitative biology programs, though perhaps limited in the number of students participating, may have much broader influence at an institution though, because the program can foster inclusion of quantitative education across the range of life science programs, not just those emphasizing quantitative connections. Given the acknowledged benefits of diversity in researching challenging problems, exposing underrepresented students to enhanced quantitative learning opportunities can also increase the participation of these students in quantitative biology programs.
5. It is important to obtain feedback from students who have gone into the workforce, particularly those outside academia, to assist in building out quantitative educational components in life science programs. A mechanism to obtain regular data on how graduates are relying upon their quantitative education would be helpful in assisting programs to adapt, faculty to modify the topics and methods included in their teaching and funding programs to assists institutions in creating programs that meet the needs of the current workforce. This may be fostered by government or institutional constraints that focus resources on efforts that are shown to be successful in workforce development.
6. Developing mechanism that embed life science students with those in quantitative fields or those in quantitative biology programs may be an effective means to foster peer-mentoring and build interactional expertise (e.g. the expertise to interact effectively across disciplines) There can be benefits from having a variety of student backgrounds represented in the teaching of undergraduates so that these students see options for those like themselves. Peer-collaboration is a model for less experienced students to enhance their success through peers with different skills while in graduate school. As occurs in many life science lab groups, collaborative interactions between undergraduates, graduate students and postdocs can both enhance quantitative learning that goes beyond that obtained through formal courses tutorials or bootcamps.
7. Individual development plans (IDP) constructed early in a student's academic career may be a useful means to design quantitative educational programs linked to that particular student's career goals and research objectives. IDP's could be the mechanism to identify the recommended formal courses for students, given the three types presented in Recommendation #1 (essential, beneficial, helpful). Then an advisor can

recommend supplemental forms of training to further fill in the gaps (e.g., short-courses, workshops, bootcamps, hackathons, clubs, etc. as per Key Point #5. Institutional flexibility (Key Point #2) is needed to provide these opportunities and possibly allow them to count towards degree requirements if no formal options are available.

8. Enhancing the appreciation of biology faculty at large on the importance of quantitative education by providing evidence so they can be more supportive of their graduate students in incorporating quantitative biology approaches in their research training. This includes infusing quantitative concepts into existing courses that do not traditionally include those concepts and providing support for faculty teaching these courses but do not have significant quantitative expertise in implementing this in the curriculum.
9. Enlarging the scope of quantitative biology education so that it particularly enhances the competitiveness of students in the expanding workforce outside academia that benefits from quantitatively expertise. In particular, it is beneficial to make curricular connections to multiple life science career paths and the associated quantitative skills that increase the likelihood of success in obtaining such positions.

Author contributions:
This report is based upon the comments of Workshop participants in the range of sessions carried out during the Workshop as well as the follow-on sessions focused on graduate students and postdoctoral fellows.

Lead authors: Louis Gross and Gregory Wiggins
Contributing authors (in alphabetical order): Albrecht von Arnim, Mehmet Aydeniz, Jessica Burnett, Jennifer Clarke , Kim Cuddington, Renee Dale, Elizabeth Hobson, Alexander Killion, Sondra LoRe, Audrey McCombs, Brad Peercy, Widodo Samyono, Shin-Han Shiu, Michelle Starz-Gaiano.

NIMBioS/SCMB Virtual Workshop on Quantitative Education in Life Science Graduate Programs: Draft Schedule

Note the introductory sessions scheduled on the use of the NIMBioS Interactive platform (built in Sococo) and pre-workshop opportunities for meeting other participants for collaborative discussions about the Workshop themes in Birds-of-a-Feather sessions.

All times below are p.m. Eastern Standard Time

***Meeting in Zoom**

+Meeting using Sococo audio/video

****List of Breakout Session Topics**

Thursday, Nov 19
4:00 - 5:00 Sococo Training session

Monday, Nov 23
4:30 - 5:00 Sococo Training session
5:00 - 6:00 Birds-of-a-Feather sessions

Tuesday, Nov 24
4:30 - 5:00 Sococo Training session
5:00 - 6:00 Birds-of-a-Feather sessions

Tuesday, Dec 1
11:30 – 12:00+ Sococo Training session
12:00 - 12:15* Introduction of workshop objectives and participants – Lou Gross (University of Tennessee, Knoxville)
12:15 - 12:45* "Prioritizing quantitative concepts and skills: Results from analysis of suggested readings from biomedical science faculty" – Lou Gross (University of Tennessee, Knoxville)
12:45 - 1:15* "Computing skills for biologists: Building a toolbox" – Stefano Allesina (University of Chicago)
1:15 - 1:45* "When good theory is not good enough: Practical and problem-centric approaches for developing PhD training programs in quantitative biosciences" – Joshua Weitz (Georgia Tech)
1:45 - 2:00* Questions and comments
2:00 - 2:15 Break
2:15 - 2:45* Discussion of breakout session topics and organization
2:45 - 3:15* "Experimenting with Graduate Course Formats for Statistics and Programming" – Nathalie Vladis (Harvard Medical School)
3:15 - 3:45* "The Future of Graduate Quantitative Education: An Education Ecosystem Perspective" – Jay Labov (National Academies)
3:45 - 4:45+ Breakout sessions 1 – 5**
4:45 - 5:00* Session reports
5:00+ Open Reception in lounge areas

Wednesday, Dec 2
12:00 - 12:15* Discussion of plans for the day– Lou Gross (University of Tennessee, Knoxville)
12:15 - 12:45* "Overview of quantitative/computational NIGMS training, workforce development, and diversity programs" – Alison Gammie (National Institutes of Health/National Institute of General Medical Sciences)
12:45 - 1:00* Organization of breakout topics for sessions 6 – 10**
1:00 - 2:30+ Breakout sessions 6 – 10
2:30 - 3:00* "A flexible graduate training program to build hard and soft skills: Integrating informatics and ecology" – Kiona Ogle (Northern Arizona University)
3:00 - 3:30* Break and session reports
3:30 - 4:00* Discussion of potential additional topics for breakout sessions
4:00 - 4:45+ Birds-of-a-feather sessions
4:45 - 5:00* Planning session for next day
5:00+ Open Reception in lounge areas

Thursday, Dec 3
12:00 - 12:30* Organization of report and consensus on topics
12:30 - 2:00+ Breakout sessions 11 – 14
2:00 - 2:30 Break
2:30 - 3:30* Synthesis sessions for each breakout topic
3:30 - 4:30* Final wrap up
4:30+ Goodbye reception in lounge areas

Breakout Session Topics
December 1
1) 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.)?

2) Are there consistent differences in what quantitative concepts and skills are emphasized in different life science disciplines and how should this affect educational initiatives?

3) 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?

4) In what ways might we change the landscape of quantitative skills being taught at the graduate level?

5) How might we enhance a culture in life science education that encourages diverse quantitative knowledge?

December 2
6) 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?

7) 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?

8) 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?

9) What lessons from efforts on quantitative education at the undergraduate level can be adapted or modified to enhance graduate education?

10) Are there effective ways to "downscale" quantitative education from programs that focus on educating quantitative biologists to the broader population of graduate biology programs?

December 3: Additional Topics

11) Quantitative skills admissions prerequisites as a barrier to program diversity. Broadly how might we enhance diversity of those in graduate life science programs while maintaining both the objectives of the program, whether quantitatively focused such as quantitative biology PhD or a general graduate degree, and maintain the program quality that might be affected by very large heterogeneity in quantitative expectations upon entry?

12) Self-confidence in the acquisition of quantitative skills. How might we both enhance how students respond to the tremendous breadth of potential expectations in quantitative areas, as well as assist in their training in these areas? How do we choose classroom and non-classroom techniques that optimize the building of quantitative self-confidence in order to have the best learning outcomes?

13) How might we effectively get buy-in on both building quantitatively focused grad programs from biology faculty and from students who might be assisted by these programs, as well as getting buy-in on enhancing quantitative components for all biology graduate programs, not just the quantitatively focused ones?

14) How might we go about getting input from quantitative biology faculty on priorities for quantitative concepts and skills to be included in graduate programs, both quantitative biology focused ones as well as general biology ones?

Participant List for NIMBioS/SCMB Investigative Workshop:
Quantitative Education in Life Science Graduate Programs
December 1-3, 2020

Participant	Institutional Affiliation
Karen Abbott	Biology, Case Western Reserve Univ.
Frederick Adler	Biology and Mathematics, Univ. of Utah
Linda Allen	Mathematics and Statistics, Texas Tech Univ.
Stefano Allesina	Ecology & Evolution and Computation Institute, Univ. of Chicago
Alexis Erich Almocera	Physical Sciences and Mathematics, Univ. of the Philippines, Visayas
Mehmet Aydeniz	STEM Education/Science, Univ. of Tennessee
Victoria Booth	Mathematics, Univ. of Michigan
Chad Brassil	Biological Sciences, Univ. of Nebraska
Jennifer Clarke	Neurology, Weill Institute for Neurosciences, Univ. of California San Francisco
Clay Cressler	Biological Sciences, Univ. of Nebraska
Kim Cuddington	Biology, Univ. of Waterloo
Marie Dahleh	Mathematics, Tulane Univ.
Renee Dale	Donald Danforth Plant Science Center
Don DeAngelis	Wetland and Aquatic Research Center, USGS
Yann Dufour	Microbiology and Molecular Genetics, Michigan State Univ.
Oluwaseun Egbelowo	Clinical Pharmacology, Univ. of Cape Town
Jake Ferguson	Biology, Univ. of Hawai‘i at Mānoa
Holly Gaff	Biological Sciences, Old Dominion Univ.
Alison Gammie	Director, Division of Training, Workforce Development, and Diversity, NIH
Erida Gjini	Mathematical Biology, Center for Computational and Stochastic Mathematics, Univ. of Lisbon, Portugal
Louis Gross	Ecology & Evolutionary Biology, Mathematics, Univ. of Tennessee, Knoxville
Abdel Halloway	Purdue Univ.
Alan Hastings	Environmental Science & Policy, Univ. of California, Davis
Christine Heitsch	Mathematics, Biological Sciences and Computational Science and Engineering, Georgia Tech
Elizabeth Hobson	Biological Sciences, Univ. of Cincinnati
Tian Hong	Biochemistry & Cellular and Molecular Biology, Univ. of Tennessee, Knoxville
Allison Horst	Bren School of Environmental Science and Management, UC Santa Barbara
Vadim Karatayev	Environmental Sciences, Univ. of Guelph, ON Canada

Participant	Institutional Affiliation
Alex Killion	Environment and Sustainability, Univ. of Michigan
Jay Labov	National Academies of Sciences, Engineering, and Medicine
Kate Laskowski	Evolution and Ecology, UC Davis
Karin Leiderman	Applied Mathematics and Statistics, Colorado School of Mines
Suzanne Lenhart	NIMBioS; Mathematics, Univ. of Tennessee
Sondra LoRe	NISER Evaluation Manager, Office of Research, Univ. of Tennessee, Knoxville
Sharon Lubkin	Mathematics, North Carolina State Univ.
Michelle Marraffini	Biological Sciences, Univ. of Canterbury, New Zealand
Audrey McCombs	Ecology and Statistics, Iowa State Univ.
Victoria McGovern	Burroughs Wellcome Fund
Kiona Ogle	School of Sustainability, Informatics and Computing, Northern Arizona Univ.
Samares Pal	Mathematical and Computational Biology, Univ. of Kalyani
Marina Papadopoulou	Science and Engineering, Univ. of Groningen, the Netherlands
Brad Peercy	Mathematics and Statistics, Univ. of Maryland, Baltimore Co.
Kristin Powell	Director of Interdisciplinary Education, BioFrontiers Institute, Univ. of Colorado Boulder
Widodo Samyono	Mathematics, Jarvis Christian College
Ioannis Sgouralis	Mathematics, Univ. of Tennessee, Knoxville
Shin-Han Shiu	Plant Biology, Michigan State Univ.
Michelle Starz-Gaiano	Biological Sciences, Univ. of Maryland, Baltimore Co.
David Talmy	Microbiology, Univ. of Tennessee, Knoxville
Mariel Vazquez	Mathematics and Microbiology & Molecular Genetics, Univ. of California, Davis
Nathalie Vladis	Harvard Medical School
Albrecht von Arnim	Biochemistry & Cellular and Molecular Biology, Univ. of Tennessee; Director, UT-ORNL Graduate School of Genome Science and Technology
Karen Watanabe	Mathematical and Natural Sciences, Arizona State Univ.
Joshua Weitz	Biological Sciences, Georgia Tech
David Westneat	Director, Ecological Research and Education Center, Biology, Univ. of Kentucky
Easton White	Biology, Univ. of Vermont
Greg Wiggins	NIMBioS Education and Outreach Coordinator, Univ. of Tennessee
Abdul-Aziz Yakubu	Mathematics, Howard Univ.
Hairui (Harry) Yu	Health Behavior, Univ. of Alabama, Birmingham

Evaluation Data Summary of the

Quantitative Education in Life Science Graduate Programs Webinar

Prepared by
Sondra LoRe, PhD
Evaluation Manager
National Institute for STEM Evaluation & Research (NISER)
June 2020

Table of Contents

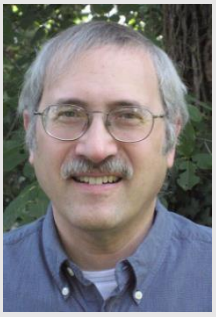
Table of Figures

Webinar Presenters

Moderator

Greg Wiggins, PhD
Education and Outreach Coordinator, National Institute for Mathematical and Biological Synthesis (NIMBioS)
University of Tennessee, Knoxville

Presenter



Louis J. Gross, PhD
Director, (NIMBioS),
Director, The Institute for Environmental Modeling, University of Tennessee,
Chancellor's Professor of Ecology and Evolutionary Biology and Mathematics, University of Tennessee

Quantitative Education in Life Science Graduate Programs

Webinar Description:

Before the planned Quantitative Education in Life Science Graduate Programs Workshop, (March 16th -20th, 2020) an online webinar was held on March 3, 2020. The workshop flier can be found in appendix A. The goal of the webinar was to provide background information to all workshop attendees and for others interested in the topic. The webinar summarized a variety of efforts to enhance the quantitative education of undergraduates in the life sciences. Due to Covid-19 CDC recommendations, the workshop was postponed. The link to the meeting website is: http://www.nimbios.org/workshops/WS_quantedu. Slides from the webinar can be found in appendix B.

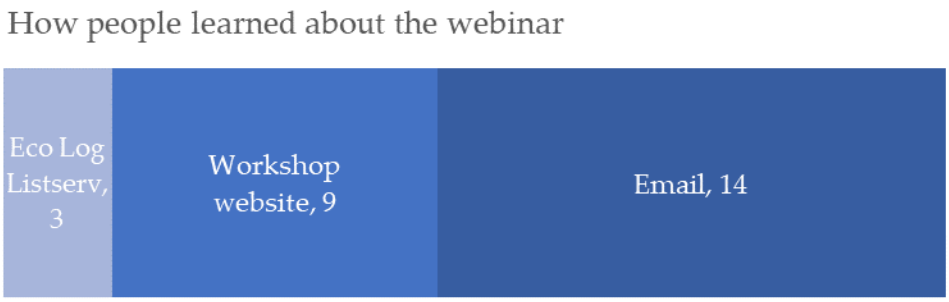
Evaluation Data Summary

This evaluation data summary report includes information gathered from a survey sent to all webinar registrants. The survey invitation email and survey questions can be found in appendix C and D. Sixty-four (64) people registered for the webinar and were sent surveys on March 6th with reminder emails sent weekly to non-respondents over a one month. The total survey respondents who had viewed the webinar live or recorded was twenty-two. (22). The following graphics and descriptions are analyses of survey respondents.

Descriptions of survey graphics

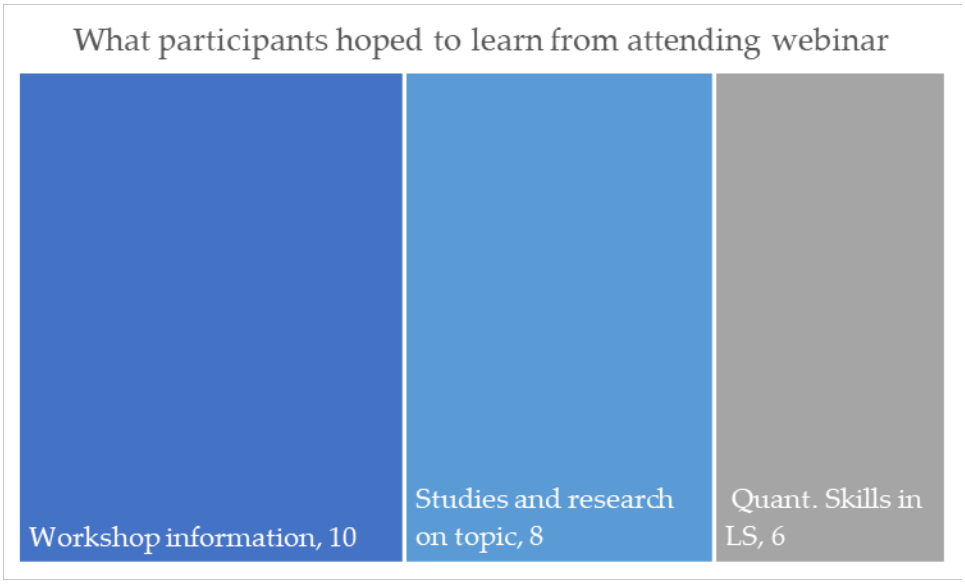
Survey respondents were asked in an open response to tell how they had heard about the webinar. Some participants indicated that they heard of the webinar from more than one source. These responses were themed and coded in Figure 1.

Figure 1: How people learned about the webinar



Next participants were asked to write what they hoped to learn from participating in the webinar. The open responses were themed and coded into categories in the following graphic. Some respondents named more than one thing that they hoped to learn and those were responses were coded in more than one category. Figure 2 displays these codes.

Figure 2: What participants hope to learn from the webinar



Survey respondents were then asked a closed response question about whether the webinar met their expectations with an optional comment box to describe their response. Of the twenty-two (22) survey responses, only two people indicated that the survey did not meet their expectations. We would like to note that the two negative responses are from people who were not registered for the workshop and may have misunderstood the relationship between the webinar and workshop. Figure 3 and the following quotes show these results.

Figure 3: Webinar expectations

Quotations for *Yes, it did meet my expectations*

“ *To some extent, though, I felt like there as a large amount of time devoted to historical studies, books, publications, and lots of time devoted to undergrad quantitative education. Comparatively less devoted to preparing participants for the workshop focused on "Quantitative Education in Life Science Graduate Programs.*

“ *Lou Gross did a good job of providing an historical perspective and pointing out current issues.*

“ *The webinar provided an outstanding history of efforts to evaluate the methods used to teach quantitative aspects of biology.*

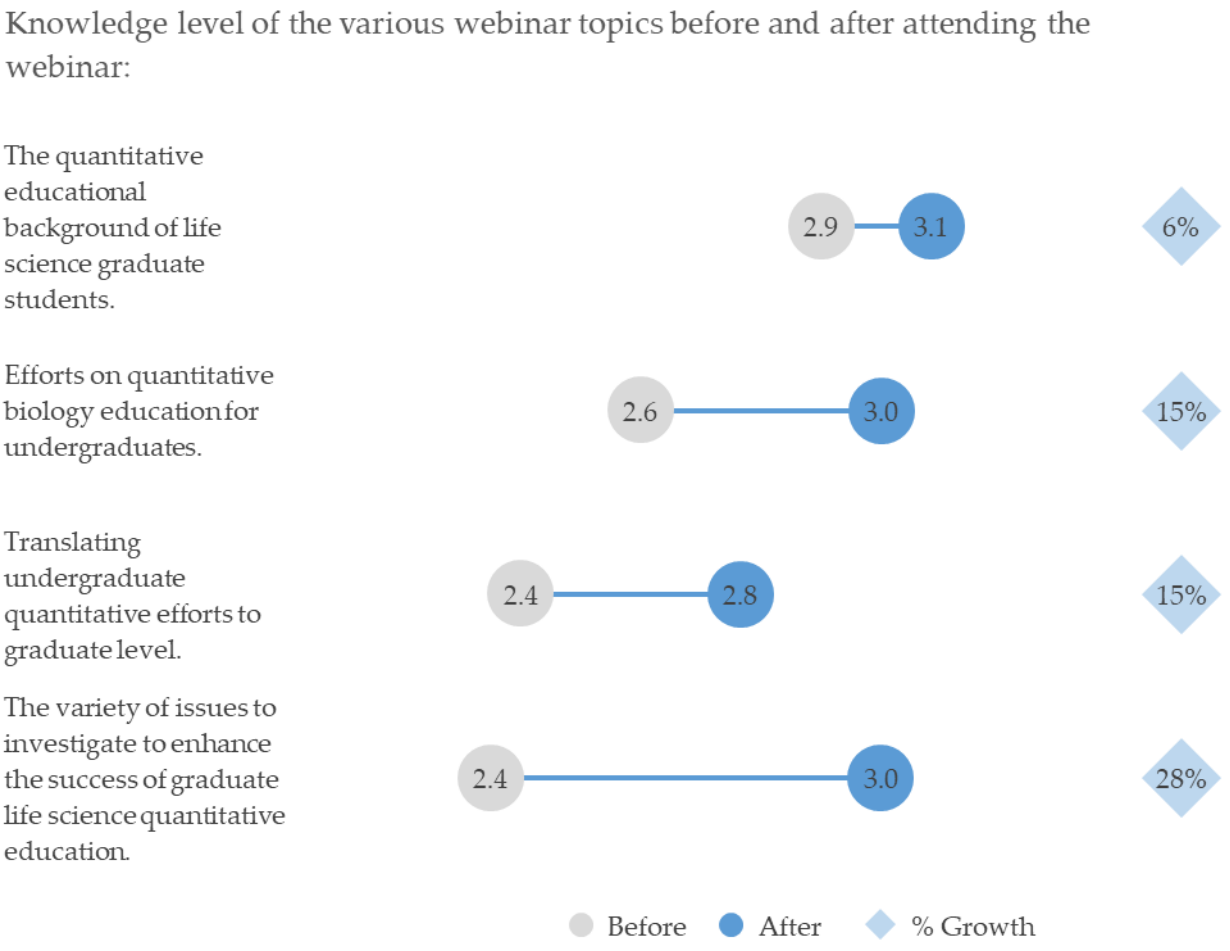
Quotations for *No, it did not meet my expectations*

“ *This may simply have been due to my mistaken expectations, but I was hoping for more detail about particular teaching approaches/materials that have been shown to be successful for quant. bio. education.*

“ *I did not realize upon registering for the webinar that it was mainly to provide some historical context of the topic before the workshop. Since I am not attending the workshop, I did not find this webinar particularly useful with the exception of a few online resources to reference.*

A matrix of questions was displayed to survey respondents with key points presented in the webinar. Participants were asked to mark their level of knowledge before and after attending the webinar. As figure 4 displays, respondent self-reported growth in all for key points of the webinar.

Figure 4: Knowledge growth in webinar key points



The next two questions in the webinar survey were open response asking attendees to describe topics they would like to see in future webinars and additional comments.

What topics would you like to see emphasized at the Workshop or in future webinars?

"*Whether and how teaching concepts of data science as an emerging discipline can increase quantitative skills of students. The webinar noted the lack of quantitative levels of graduate students. Perhaps a similar study needs to be done of the same skills of faculty mentors and how much faculty introduce quantitative concepts as a routine part of their teaching of biological topics and skills at both the undergraduate and graduate levels.*

"*Discussion of how we can compare between programs around the country so we don't duplicate efforts or keep reinventing the wheel.*

"*Applications to biomedical education, physiology, genetics, etc.*

"*How quantitative education varies among different life sciences.*

Please use this space for any additional comments:

"*Overall, it was a very useful experience for me (and I guess, it would be a very useful experience for other faculty developing mathematical/computational/quantitative life sciences curriculum). Thank you.*

"*Looking forward to the in-person workshop on "Quantitative Education in Life Science Graduate Programs." For the webinar, the most interesting part to me was the survey conducted at UT to evaluate the quantitative background of students in grad programs. I was in the process of preparing a similar survey for our grad programs, and will be interesting to see how they compare. I hope other participants do the same, I think such data could potentially be incorporated into a report or publication.*

"*John Z. Hearon, who supported mathematics in biomedicine at the NIH, subsequently became the chief of the Mathematical Research Branch (MRB) in the Intramural Program in NIDDK. MRB is now the Laboratory of Biological Modeling in NIDDK.*

A final question was asked about technology and connectivity to Zoom.

0% of participants had problems with technology used to present the webinar.

> *Actually, the technical quality was above my expectations (although I might have had low expectations).*

> *It did not work on the web browser, but downloading the app and installing it was easy.*

Evaluation Summary

Areas of strength:

Survey responses demonstrate growth in the webinar's key points as shown in figure 4. By asking a retrospective question tied directly to skills we can see that the attendees benefitted from the webinar.

Hosting the webinar and slides on YouTube enable people to engage with the material and complete the survey following a viewing.

Areas to strengthen:

Although just a couple of survey respondents indicated not getting what was expected from the webinar because they were not workshop registrants, it may be worth considering more explicit wording on future webinar materials. Particularly when the webinar is promoted on a large list-serve such as Ecolog.

Appendix A: Workshop Flyer

Quantitative Education in Life Science Graduate Programs

16-18 March 2020 | Knoxville

A NIMBioS/SCMB Investigative Workshop

This workshop will gather thought leaders on graduate life science education and its relation to quantitative training to determine commonalities of approaches across institutions and the effectiveness of these approaches. The workshop will focus on educational aspects of graduate life science quantitative training, such as what topics to prioritize across the vast array of potential quantitative methods, how formal courses might be effectively mixed with online learning, seminars and lab group activities, and the effectiveness of boot-camps and tutorials. The discussion drawn from experiences at diverse institutions and in biological sub-disciplines will provide potential guidance on future directions. Researchers and educators working at the interface of the life sciences and quantitative science (e.g. mathematics, statistics, computing, data science) are invited to apply to attend.

Participation in the workshop is by application only. If needed, financial support for travel, meals, and lodging is available for workshop attendees.

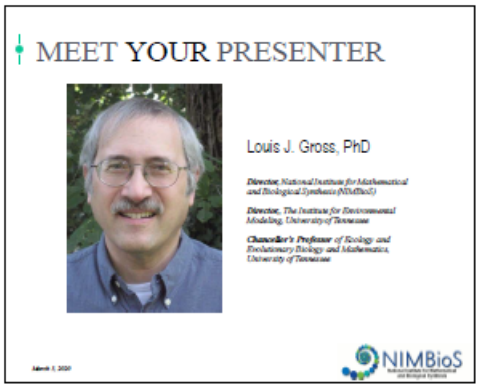
Application Deadline: January 5, 2020

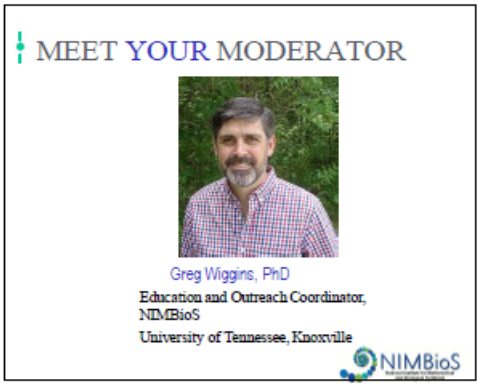
For more information and the link to register, visit
http://www.nimbios.org/workshops/WS_quantedu

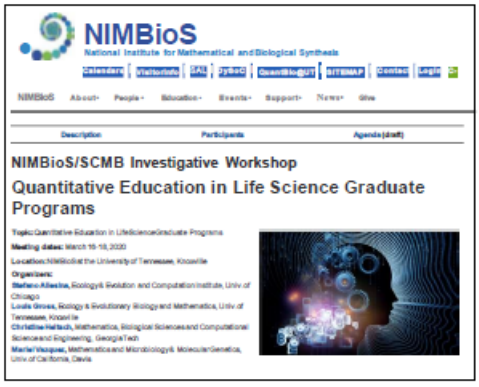
The Workshop arises from a partnership between NIMBioS and the Southeast Center for Mathematics and Biology (SCMB) with financial support from The Burroughs Wellcome Fund, the National Science Foundation through award #DBI-1300426, and additional support from The University of Tennessee, Knoxville.

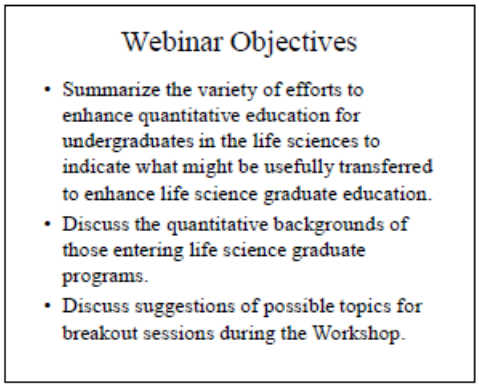
NIMBioS National Institute for Mathematical and Biological Synthesis | The University of Tennessee Knoxville | Burroughs Wellcome Fund | NSF

Appendix B: Webinar slides





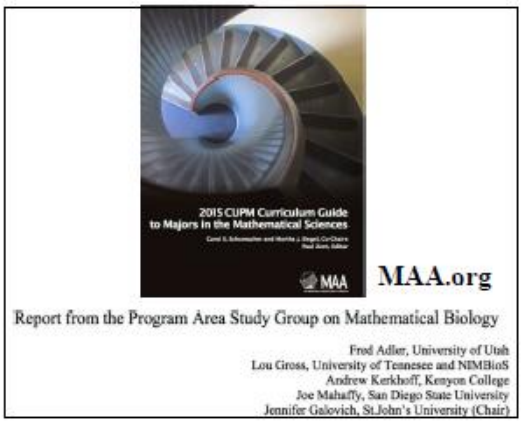


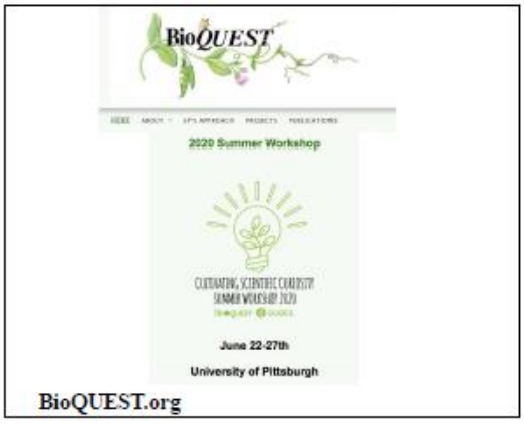


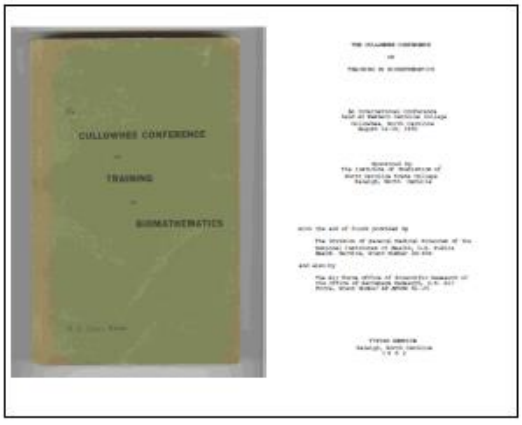

The Undergrad S&E Landscape
S&E bachelor's degrees awarded, by field: 2000–17
Biological and agricultural sciences
Computer sciences
Engineering
Mathematics and statistics
Physical sciences
Psychology
Social sciences
National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Completions Survey; National Center for Science and Engineering Statistics, National Science Foundation, Integrated Data System (IDS), Science and Engineering Indicators2019


QUBES
QUANTITATIVE UNDERGRADUATE BIOLOGY EDUCATION AND SYNTHESIS
QUBES Consortium
Alliance of societies, institutions, programs with a common goal
QUBESHub.org


Reports and more reports:
BIO 2010
Math & Bio 2010
A NEW BIOLOGY FOR THE 21st CENTURY
VISION AND CHANGE


2015 CUPM Curriculum Guide to Majors in the Mathematical Sciences
MAA.org
Report from the Program Area Study Group on Mathematical Biology
Fred Adler, University of Utah
Lou Gross, University of Tennesee and NIMBioS
Andrew Kerkhoff, Kenyon College
Joe Mahaffy, San Diego State University
Jennifer Galovich, St.John's University (Chair)

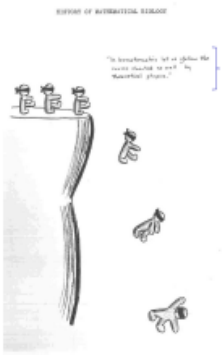

BioQUEST
2020 Summer Workshop
June 22-27th
University of Pittsburgh
BioQUEST.org


CULLOWHEE CONFERENCE
TRAINING
BIOMATHEMATICS

" 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)

So have we learned anything in the past 59 years?



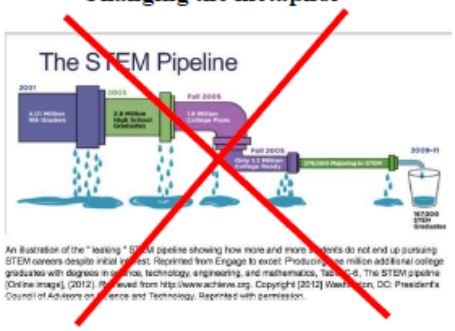
In biomathematics let us follow the course charted so well by theoretical physics

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

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



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, Tabs. 2-6, 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 tired 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.

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

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.

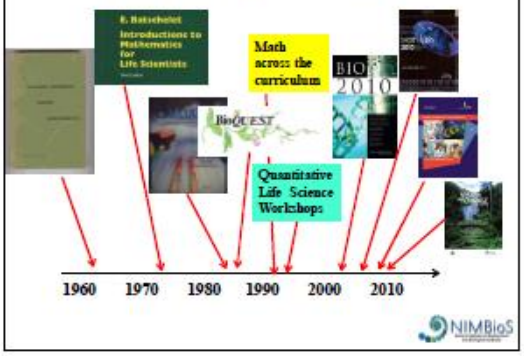
MCAT

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

Math and Bio Education



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

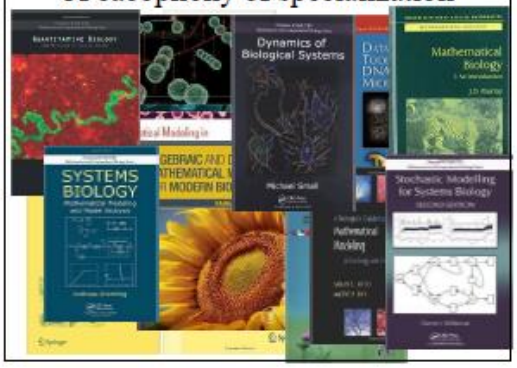
Suzanne Lenhart

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)

NIMBioS

A cacophony of specialization



What is holding back reform in quantitative bio education?

Lethargy

Inertia

Infrastructure

NIMBioS

Faculty Time Allocation

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

NIMBioS

The CPAR Approach to Quantitative Curriculum Development across Disciplines

Constraints
Prioritize
Aid
Repeat

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.

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

ascb LSE

HOME CURRENT ISSUE ARCHIVE ARTICLE AND FEATURE COLLECTIONS ASCB RESOURCES ABOUT

CBE—Life Sciences Education, Vol. 15, No. 1 | Articles

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

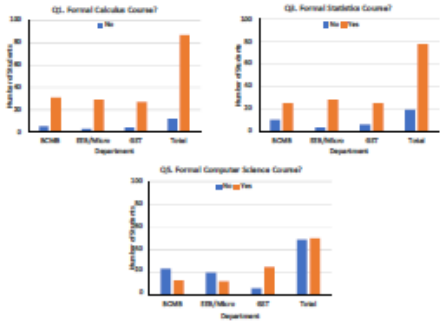
ascb LSE

HOME CURRENT ISSUE ARCHIVE ARTICLE AND FEATURE COLLECTIONS ASCB RESOURCES ABOUT

CBE—Life Sciences Education, Vol. 19, No. 1 | Article

Development of the BioCalculus Assessment (BCA)

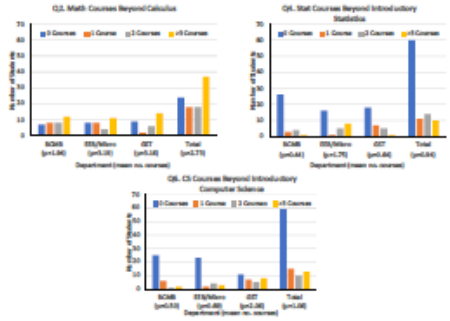
Data from Needs Assessment for UTK Life Science Grad Students



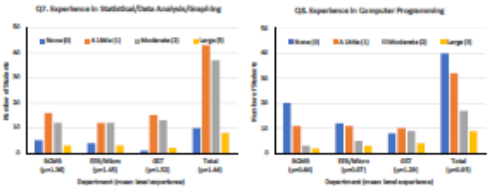
Needs Assessment for UTK Life Science Grad Students

- 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)

Data from Needs Assessment for UTK Life Science Grad Students



Data from Needs Assessment for UTK Life Science Grad Students



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?

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

- 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

- 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

- 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.

Appendix C: Survey Invitation Letter

Dates sent: March 6th, March 9th, March 11th, and March 19th

Dear ${m://FirstName},

Thank you for registering for the "Quantitative Education in Life Science Graduate Programs" webinar on March 3, 2020. Your responses will be used to prepare for the Quantitative Education in Life Science Graduate Programs Workshop at the National Institute for Mathematical and Biological Synthesis (NIMBioS). Information supplied on the survey will be confidential, and results will be reported only in the aggregate.

Follow this link to the Survey:
${l://SurveyLink?d=Take the Survey}
Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Thank you in advance for your participation.

Cheers,
Sondra

****

Sondra LoRe, Ph.D.
Manager | *National Institute for STEM Evaluation and Research (NISER)*
Adjunct Professor | *Evaluation, Statistics, and Measurement Program, Department of Educational Psychology & Counseling*

The University of Tennessee, Knoxville
Office of Research & Engagement
114 Philander P. Claxton Education Building
PH: 865-974-4962 | Fax: 865-974-9300 | https://www.stemeval.org
slore@utk.edu

Appendix D: Webinar Survey Questions

Thank you for registering for the "Quantitative Education in Life Science Graduate Programs" webinar on March 3, 2020.Your responses will be used to prepare for the Quantitative Education in Life Science Graduate Programs Workshop at the National Institute for Mathematical and Biological Synthesis (NIMBioS). Information supplied on the survey will be confidential, and results will be reported only in the aggregate.

How did you hear about the webinar?

_____

_____

Were you able to view the webinar "live" or as a recording?

- ○ Yes, I have viewed the webinar. (1)
- ○ No, I haven't viewed the webinar. (2)

Skip To: End of Survey If Were you able to view the webinar "live" or as a recording? = No, I haven't viewed the webinar.

What were you hoping to learn by attending the webinar?

_____

_____

_____

Did the webinar meet your expectations?

- ○ Yes (1)
- ○ No (2)

Comments:

_____

_____

Did you have any problems with the technology used to present the webinar (e.g. connectivity, sound, images)?

- ○ Yes (1)
- ○ No (2)

Comments:

_____

_____

Q9 Please rate your knowledge level of the various webinar topics before and after attending the webinar:

	Before Webinar	After Webinar
Efforts on quantitative biology education for undergraduates. (13)	▼Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼Extremely knolwedgeable (1 ... Not knowledgeable at all (5)
Translating undergraduate quantitative efforts to graduate level. (16)	▼Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼Extremely knolwedgeable (1 ... Not knowledgeable at all (5)
The quantitative educational background of life science graduate students. (19)	▼Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼Extremely knolwedgeable (1 ... Not knowledgeable at all (5)
The variety of issues to investigate to enhance the success of graduate life science quantitative education. (18)	▼Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼Extremely knolwedgeable (1 ... Not knowledgeable at all (5)

What topics would you like to see emphasized at the Workshop or in future webinars?

_____

_____

Do you feel there was sufficient opportunity for questions and comments from the webinar audience?

- ○ Yes (1)
- ○ No (2)

Q12 Do you feel the questions from the webinar audience were answered well?

- ○ Yes (1)
- ○ No (2)

Comments:

_____

_____

Q14 Please use this space for any additional comments:

_____

_____

Participant List for NIMBioS Discussions with Students on Quantitative Education in the Life Sciences
January 19 and 22, 2021

Name	Institution	Position
Erik Amezquita	Michigan State University	PhD student
Robin Andrews	University of Alaska-Fairbanks	PhD student
Sarah Bogen	Texas A&M University	PhD student
Jessica Burnett	U.S. Geological Survey	Postdoc
Daniele Cannarsa	Universite de Paris	PhD student
Joshua Franklin	Michigan State University	PhD student
Vitaly Ganusov	University of Tennessee-Knoxville	Faculty
Nikunj Goel	University of Texas-Austin	PhD student
Louis Gross	University of Tennessee-Knoxville	Faculty
Chrissy Hernandez	Cornell University	Postdoc
Sean Hoban	Morton Arboretum	Research Scientist
John Jungck	University of Delaware	Faculty
Serena Lotreck	Michigan State University	PhD student
Bobby Madamanchi	University of Michigan-Ann Arbor	Lecturer
Nate Thorngate-Rein	University of Wisconsin-Milwaukee	PhD student
Easton White	University of Vermont-Burlington	Postdoc
Greg Wiggins	University of Tennessee-Knoxville	Staff

NIMBioS
National Institute for Mathematical and Biological Synthesis

Southeast Center for Mathematics and Biology

Quantitative Education in Life Science Graduate Programs Virtual Investigation Workshop Data Summary Evaluation Report

Prepared by

Sondra LoRe, PhD
Manager

Pamela Bishop, PhD
Director

National Institute for STEM Evaluation & Research (NISER)

March 29, 2021

NISER
NATIONAL INSTITUTE FOR STEM EVALUATION AND RESEARCH

NSF

BURROUGHS WELLCOME FUND

THE UNIVERSITY OF TENNESSEE KNOXVILLE

Table of Contents

Table of Figures

Table of Tables

Executive summary

December 1st through 3rd, 2020, the National Institute for Mathematical and Biological Synthesis (NIMBioS) and the Southeast Center for Mathematics and Biology (SCMB) co-hosted the NIMBioS/SCMB Investigative Workshop: Quantitative Education in Life Science Graduate Programs. This workshop was initially planned as an in-person meeting in March of 2020. Due to the COVID 19 pandemic, it was postponed from March to December and transitioned to a virtual platform.

Workshop Goals:

The workshop's primary goal was to gather thought leaders at every level; (faculty, program, institutional leaders, graduate students, and postdocs) to engage in reflection, discussion, and strategy building at the intersection of life science and qualitative skills.

Workshop format:

The workshop was conducted on the Sococo virtual meeting platform (https://www.sococo.com/). The interactive nature of the Sococo platform allows attendees to visit "meeting rooms" by moving their icon through the meeting space. Aside from the main presentation room, workshop attendees could attend "breakout" and "birds of a feather" sessions and social hour events in the evenings.

Evaluation Metrics

This evaluation report contains results from a retrospective survey collaboratively designed by the external evaluation team and program leaders to workshop attendees—observation of workshop events and a discourse analysis breakout documents and products.

Recommendations: Areas of Strength

- Participants in the workshop reported a high level of engagement and interest in the workshop.
- The growth of knowledge in topics was substantial as measured in the workshop survey, with increased exposure and learned skills in every topic indicator.
- Open-ended responses to the survey indicated the workshop's value-added, particularly in the areas of exposure and appreciation of quantitative skills in graduate-level life science education.
- Discourse analysis of breakout sessions and small group documents and products provides examples of further engagement and strategies to increase skills and knowledge.

- Many of the respondents enjoyed the Sococo platform for interacting with participants despite the initial learning curve.

Recommendations: Areas to Strengthen

- The Sococo platform, while interactive, has a learning curve. Twenty-one of the fifty respondents to the survey did not attend a pre-workshop session. This may have contributed to some of the negative comments about the platform in the survey.

- Some respondents notice integration issues between the Sococo platform and Zoom. Before engaging in Sococo for future workshops, it is recommended that the organizers confirm that Sococo addresses any Zoom integration issues.

Survey Results

The evaluation team designed a post-workshop retrospective survey in collaboration with the program leadership team. The survey was sent to all workshop attendees the day after the workshop concluded via a personalized email invitation. Reminder emails were sent to non-respondents over three weeks. Appendix A contains a copy of the retrospective survey. Figures 1-6 on the following pages display results.

Figure 1: Please select any of the pre-workshop sessions you attended

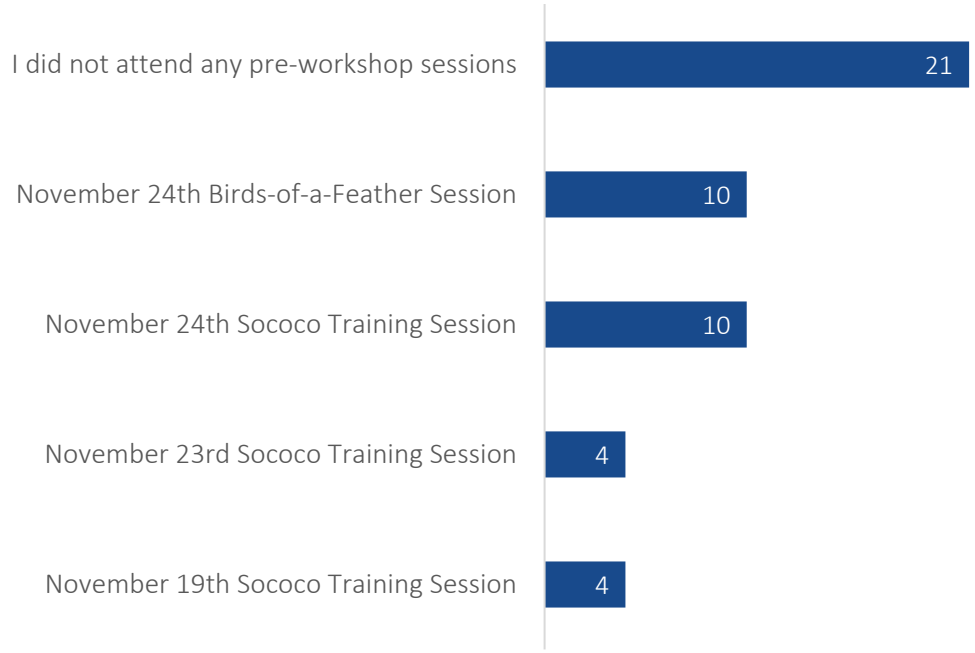


Figure 2: Please select the events you attended on Tuesday, December 1st

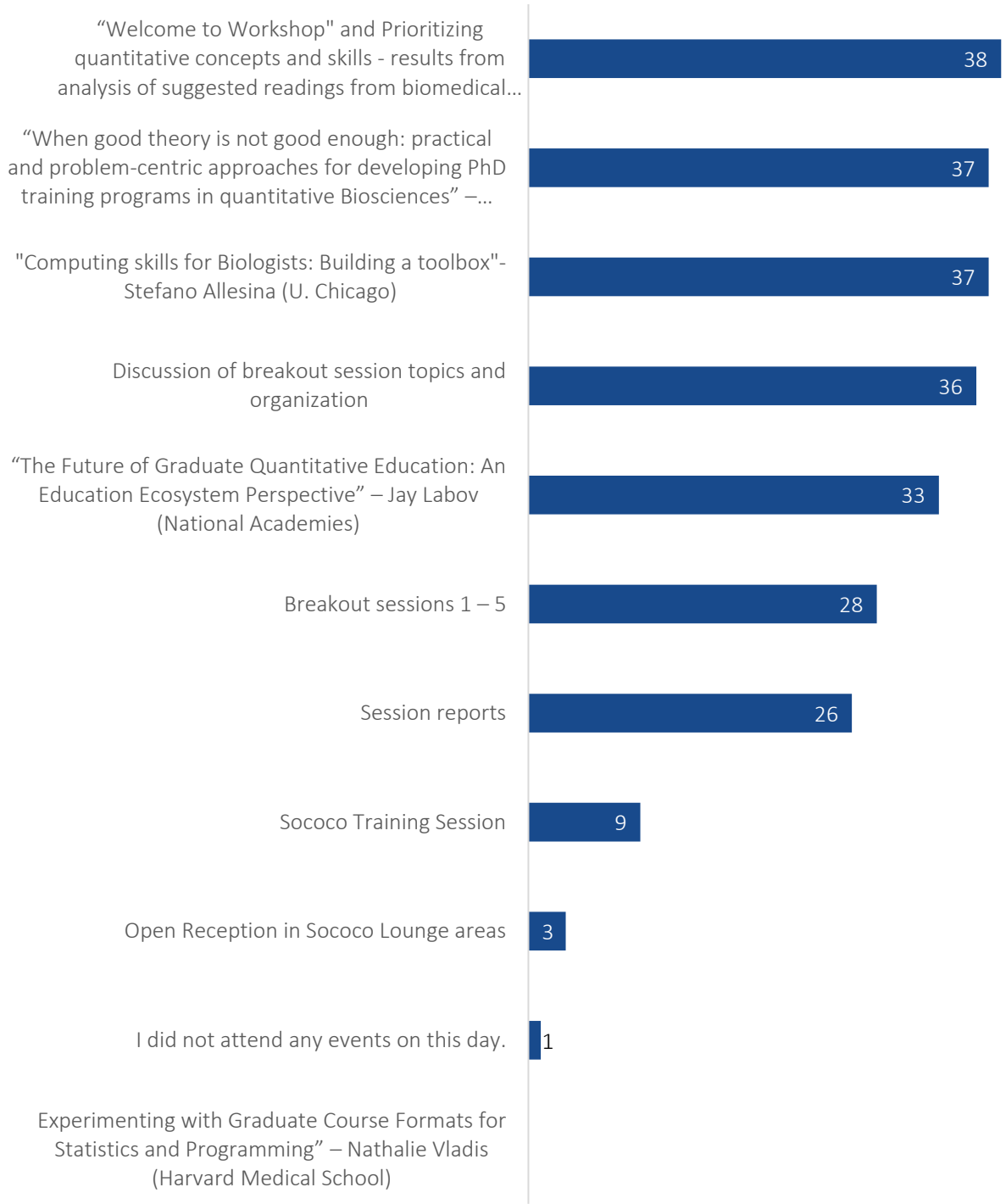


Figure 3: Please select the events you attended on Wednesday, December 2nd

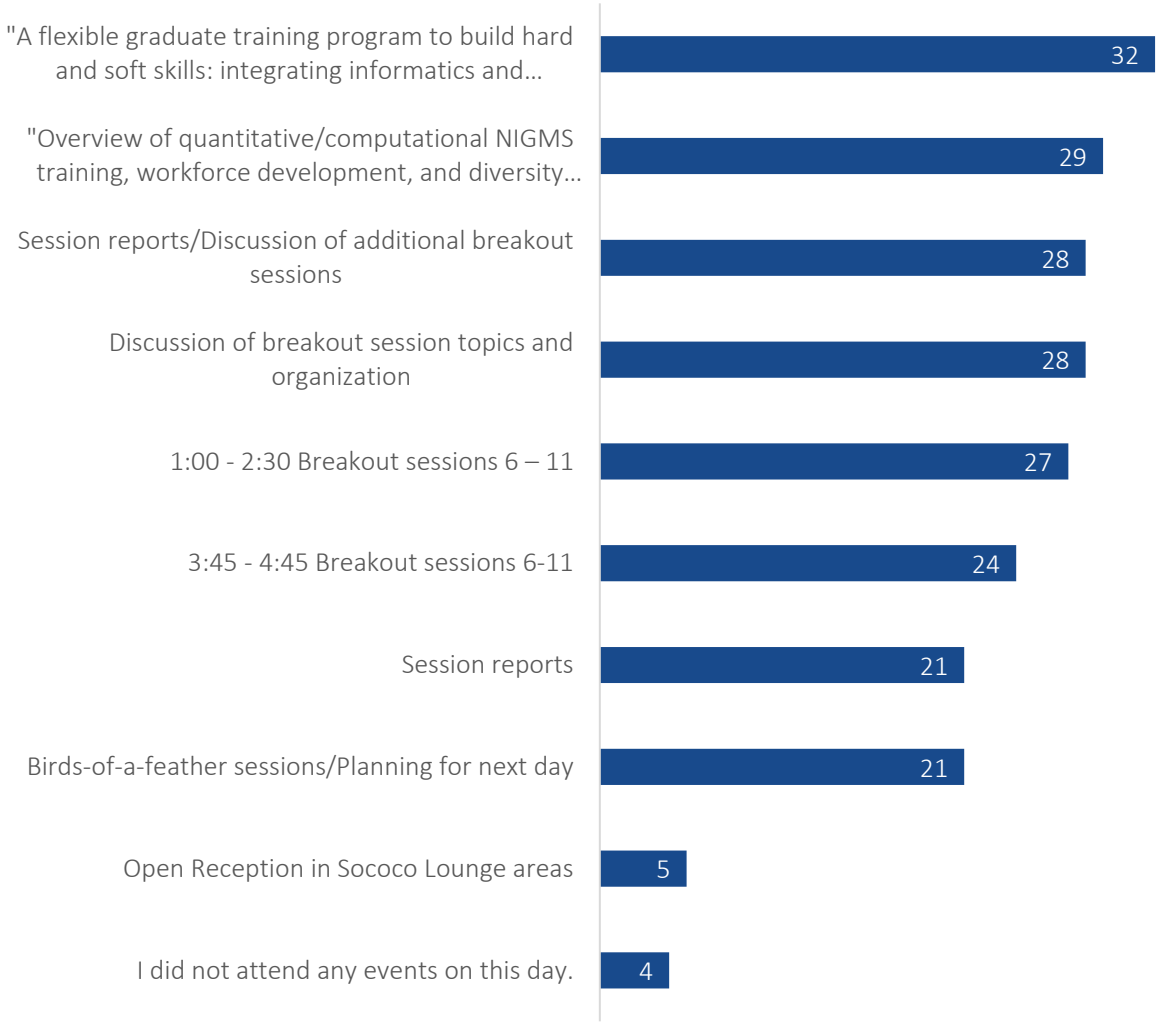


Figure 4: Please select the events you attended on Thursday, December 3rd

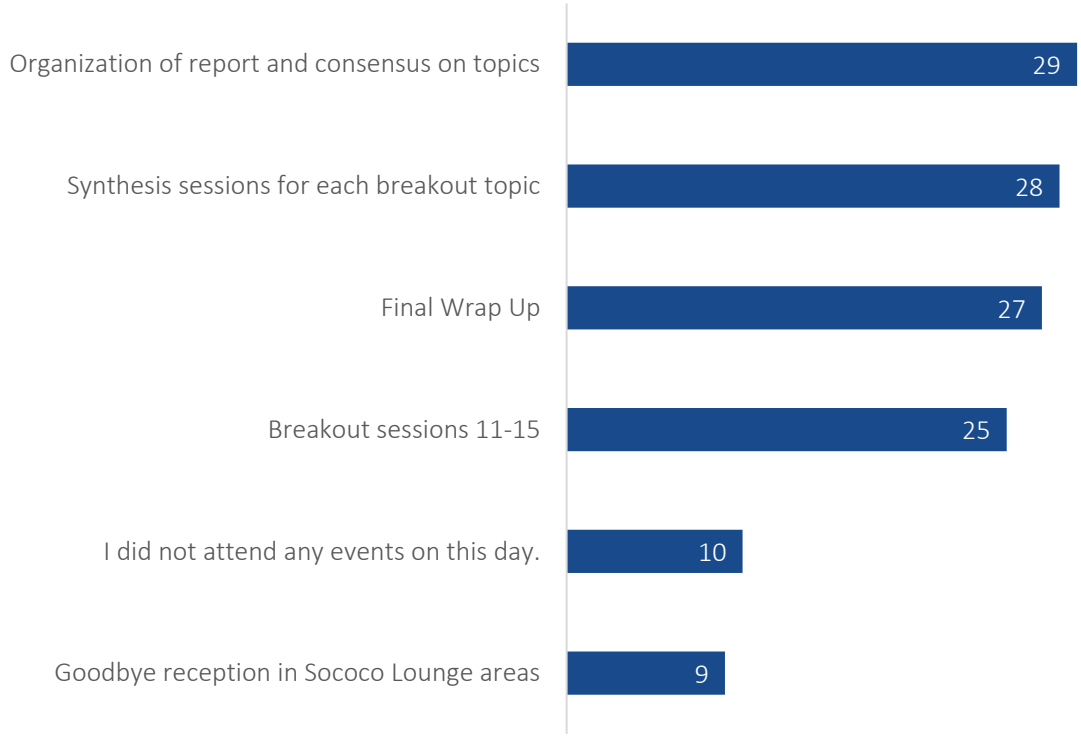


Figure 5: Please rate you knowledge level of the following topics before and after attending the workshop

Table 1: Open-Ended Response of how understanding of life science graduate education has evolved since participating in the workshop

Please describe how your understanding of quantitative education in life science graduate programs has changed/evolved since participating in the workshop.
I'm now in a position to better advise my students into pursuing this career options
The workshop has inspired me to run a survey on quantitative methods in my own program, with the goal of providing non-traditional ways to get the students acquainted with these approaches.
I have gained a broader perspective on such education and a better appreciation of the leadership and expertise available from a diverse set of institutions. I have a stronger network of colleagues for discussions and input.
I came away ideas about how to potentially overcome or address the often limited quantitative background, or diversity of backgrounds, of prospective students applying to interdisciplinary graduate degree programs that involve a heavy quantitative component.
Greater awareness of the range of the quantitative skills taught, greater appreciation for some methods of group learning
I find these workshops most useful for the networks--an understanding of what other experts interested in the topics are doing, and what the latest consensus on approaches to quantitative education. I wouldn't say may view has evolved so much as validation or redirection on ongoing interdisciplinary approaches to quantitative education.
I have come to appreciate better that colleagues in different domain science areas seem to have similar aspirations when it comes to the scope and breadth of quantitative training they are seeking for their students. Beforehand I had the impression that colleagues outside of my field had fairly distinct ideas, when in fact our general ideas are mostly overlapping. The workshop showed that colleagues valued not just the narrow skill set that was their own expertise but the broader skill sets that we wish our students would carry away from their PhD training (and some actually do).
It has helped me to become familiar with diverse challenges of integrating quantitative skills and concepts in graduate biology education and it has helped me to become more knowledgeable about diverse ways in which community is thinking to address these challenges.
Thinking more comprehensively at the level of the university rather than single programs.
I am more knowledgeable about the importance of the quantitative education in life science graduate programs.
I have a broader perspective on the value of very general skills, such as data science skills, as opposed to a narrow view of just mathematical skills. I purchase Stefano's book in order to learn more about this broader skill set.
I appreciated learning that the challenges I have faced are common to many others.
I learned more about the current programs out there and realized that they all have similar challenges.

I am thinking more and more deeply about the issues
It was interesting that there is a push to educate non-quant inclined students (at places with quant programs?) while simultaneously pushing for quant inclined students to get more access/quality of education (at other places).
I have some good ideas about how to improve my grad course to increase the diversity of quantitative skills I am covering. I also realize that actually very few of us had any real understanding of the set of skills that is most appropriate for a grad education.
I have gathered some knowledge.
It is critical to get institutional support and buy-in to offer new training opportunities.
Mostly enhanced awareness of how people are structuring programs elsewhere, but that unfortunately usually emphasized the unique situations present at those institutions and was less helpful generally than I had hoped.
Good to talk with like-minded people to reiterate the importance of this topic. Improved ideas about strategy to incorporate into graduate education without developing all new courses, and ideas for increasing buy-in among faculty mentors. Increased interest in getting students to build confidence as part of learning process.
I was able to gain a larger breadth of understanding on how other graduate programs are one. I took away a number of ideas that I could incorporate to my home institutions.
There was great deal of useful discussion about the challenges. I feel better versed in what hurdles lie in front of incorporating quantitative methods in a biology program.
Aside from more approaches to handling graduate courses, I also learned the administrative/institutional aspects, as well as the importance of student support.
I really valued discussions about how faculty/departments can support graduate students to pursue data science courses. I also really enjoyed hearing creative ways that departments are including data science in their curriculum. I really didn't know much about the overall landscape of quantitative education in life sciences overall (I'm in environmental science), so it was validating to hear that a lot of departments are dealing with similar issues re: preparing graduate students.
Thank you so much for this workshop. It was very useful to see how different teachers approach quantitative training.
Since the course was at the end of the semester, I have not had a chance to put much of what I learned into practice. However, I was reassured that a few of the struggles I am facing with mentorship are common to people at other institutions. One issue in particular, is issues I have faced providing non-mathematically trained students with the tools they need to advance. It turns out other graduate schools are also often inflexible with which classes they allow students to obtain credit in, and my frustration with not being allowed lower-level classes that are outside of a student's undergraduate area, not to count toward their degree, is something that is common to many institutions.

Figure 6: Was this the first time using the Sococo platform?

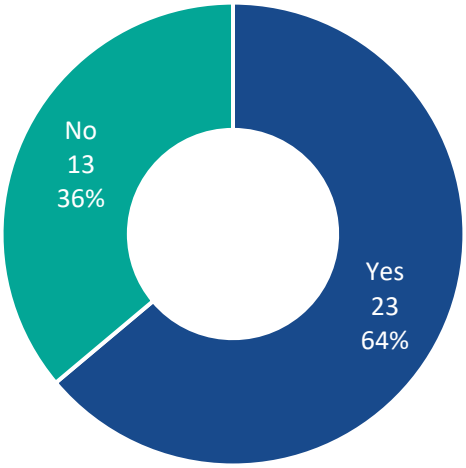


Table 2: Open-Ended responses to using Sococo platform

Please share your impressions of the Sococo platform including any advantages and challenges.
It worked well, I would say I prefer Slack as it is more familiar though Sococo was intuitive.
I loved it! The only downside was that the quality of sound/video was not as good as say zoom, and that when more than a handful of people were in a room, we could not see them all.
I liked the platform, and wish it was better integrated with Zoom.
This platform is not user friendly. I spent too much time trying to figure out how to move around even after attending the session to become familiar with the platform. I think Zoom works just as well with the breakout session feature. Make documents available separately in Google docs or Dropbox.
I thought it was pretty easy to use, but it would have been nice to see the names of people with their videos.
It's okay, I found the need to turn on mic and video in small room meetings lead many, and me to forget to do so, and then one would be unaware of some participants.

Advantages: simply a 'feel' for who is there and participating that you don't get with zoom alone. i actually found it not disruptive to pop into a room because you could turn video and mic off, and the only change for folks within a room with an 'open door' would be seeing a name added to a list of who was in the room. Challenges: sound; being in a room but also on zoom would do odd things.
It supported what the workshop intended to achieve rather well.
It was not a bad experience, it was easy to use but it is not the perfect platform either but it helped achieve the mission.
It was wonderful once I learned how to move between rooms. I recommended its use for a scientific conference at a recent planning committee meeting.
Worked well, interesting way to host a workshop/conference.
Not bad.
It's a good platform for a virtual conference. However, it's hard to navigate if you don't know how to use before.
I though it worked OK. The video/audio feed is definitely smoother in Zoom, but it was a nice organizing location.
I appreciate the feel of having physical spaces to "move" around, but I don't like the limitation to 8 videos on one screen or the lack of names beneath people's bubbles.
It is good! I quite like it for virtual conferences. No downsides that aren't present in virtual meeting platforms (e.g. Zoom).
I like it, I don't like the circle head video thing. It is too hard to tell who is talking.
It was fine. I didn't really see any advantage over Zoom breakout rooms.
Easy access.
Clunky
A fun and potentially useful platform, although it did not replace the interactions that would have happened if this had been in person.
it took me a day to get the hang of it, but it was nice to be able to pop in and out of spaces
I thought it worked well. I would use it again
After my initial foray into Sococo at SMB, the use of Sococo for the NIMBioS workshop I think utilized the features of Sococo to great effect. Would like to see names (Name Tags?) under pictures to solidify the association of name with face.
This is the second time I used the Sococo platform, and I was already acquainted with it as a participant in eSMB2020. In my opinion, it was an appropriate platform to hold breakout sessions. Besides briefly forgetting to activate my microphone when I have to speak, I report no issues with Sococo.
I thought it was so cool! Thanks Greg for the trainings!
OK, but using only one browser is curious.
It was great!

Table 3: Additional comments about the workshop from the survey

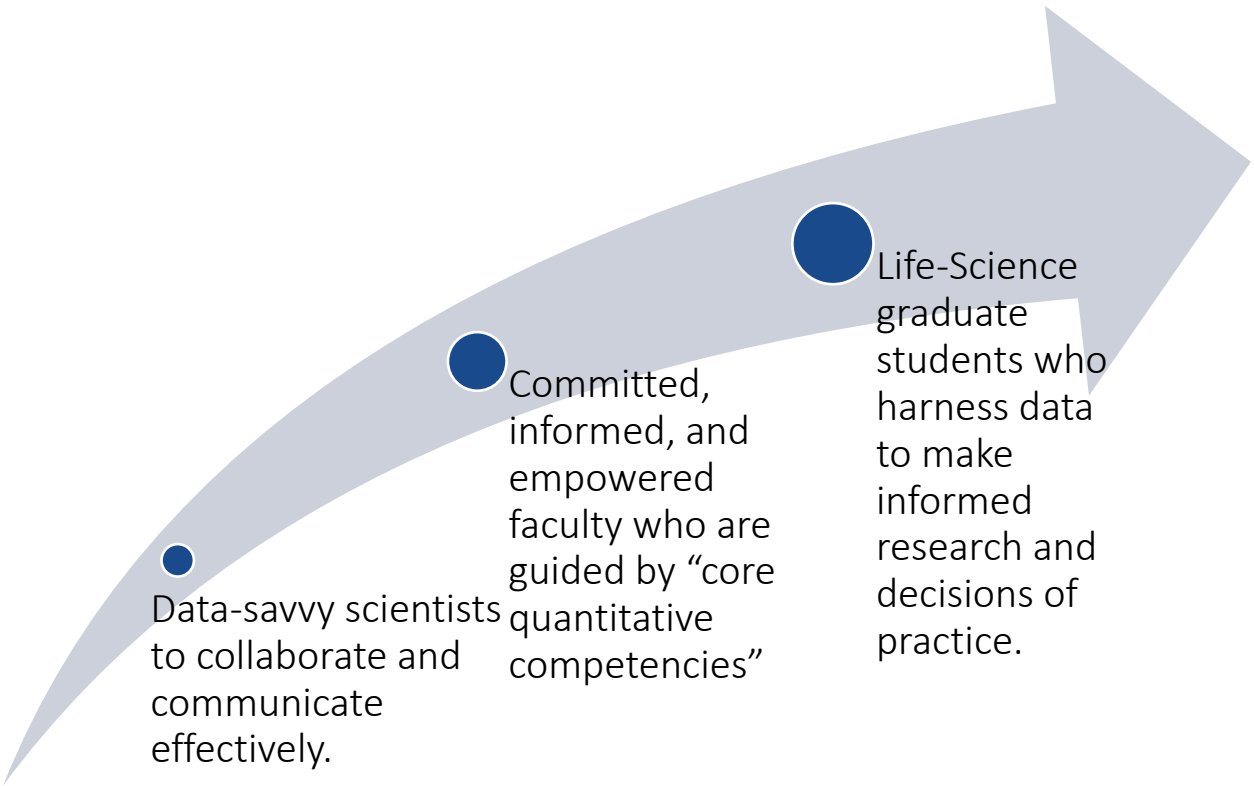
Please use this space for any additional comments:
Thanks to NIMBioS for providing this opportunity. I hope that the attendees form a discussion group (or something similar) for future collaboration, discussion, and events.
The full group sessions seemed less effective than the breakout sessions. Most participants would keep video off. I highly suggest better 'get to know others expertise' techniques. Just knowing where folk's perspectives were coming from, rather than relying only on seeing talks from a small number of participants. I also think expertise was so broad, that discussions remained broad--this is great but serves one purpose. If you also wanted specific feedback on quantitative skills useful under different disciplines, I think those break-out sessions or birds-of-a-feather sessions needed some facilitation. I really enjoyed being part of it, and hope to engage in more opportunities in the future.
The workshop was my first ever event of this type, i.e. focused on education. I wished it could have been in person.
It was a great conference. The scaffolding provided was very useful. I also liked the schedule.
I was glad I participated. Some of the broad overview of how different programs have been structured (like Kiona's presentation and Stefano's presentation) were very useful information. The breakout discussions were always lively.
Enjoyed the workshop!
Due to the time difference it was very difficult for me to attend all the sessions.
I found the workshop useful overall.
I think the conference was probably valuable for people already well embedded in quantitative programs as it was a good forum for sharing ideas. I had much more narrow goals that focused a lot more on detailed ways to organize short courses for maximum benefit to a diverse audience. I got some ideas, but the conference perhaps had too broad an agenda for my particular interest.
While much discussion was had about the challenges of implementing quantitative methods into bio curriculum and overall programs, I was disappointed that more action items were not suggested or decided upon. I understand how to implement methods may be quite varied, but perhaps a case study in how an existing program was reinvented (nice example of a new program by Kiona Ogle (NAU)) with concrete steps, be they incremental or dramatic, would have been informative. Maybe there are few, if any, examples of programs shifting quantitatively in this way...
I have no comments, but I wish to thank the organizers for the opportunity to participate in the workshop.
Thank you so much! This was my first NIMBioS event, and I am so happy that I was able to listen and participate -- it was great to meet so many people really invested in quantitative education & teaching at the graduate level. Really well organized, with nice pre-workshop trainings for Sococo. Thank you!
Thank you very much this was extremely valuable.

Discourse Analysis of Meeting Documents

Day one and two of the workshop included five breakout sessions each day. Workshop participants collaborated in Google Documents and slides guided by questions displayed in Appendix B. The external evaluator floated between groups to collect notes and observations. On the last day of the workshop, the evaluator observed closing remarks and presentations.

Following the workshop, the evaluator employed NVivo, a computer-assisted qualitative analysis software (CAQDAS), to assist in the theming and coding of the spoken and written word from the workshop. Focused or deductive coding (Merriam & Tisdell, 2016; Saldana, 2016) defined the categories and themes. After each section of text was coded, like terms are categorized in the following figures. Salient statements are included along with strategic action items as articulated by the groups.

Figure 7: Trajectory of needs



Data savvy life-scientists

Break session participants discussed the urgency for data-savvy scientists and a responsibility they feel for encouraging and training graduate students to work with data.

> *"Great data is being underutilized because students are not picking up quantitative skills"*

> *"Encourage committees for grad students to evaluation what student quantitative training is as they enter a grad program, providing guidance to individual grad students, leading to development for specific modules for specific skill development."*

Core-Competencies/Guiding principles of Quantitative Biology

Workshops participants described a need for "core quantitative competencies" or quantitative principles to guide graduate students. This was expressed in comparison to some existing tools and publications for undergraduate students and the tension of graduate students' specialization and research/lab experience.

> *"A challenge [is] to identify or agree on core quantitative competencies that everyone should know. "*

> *[To meet students where they are]. A possible solution is multiple entry points… expertise from different sub disciplines"*

> *"Many of these students' last had quantitative courses in the distant past [referring to early level undergrad courses and possible forgotten skills]"*

> *"Is there a need for Concept Inventory at the graduate level for Quantitative Biology? Measuring something can lead to change. Maybe start with a list of concepts."*

Harnessing data through quantitative skills

Several groups communicated an urgency for graduate students to transition to academic or industry careers ready to work with data. The groups shared challenges or disconnect points of knowing how to engage faculty and institutions on the need for quantitative skills within life-science graduate programs.

> *"Consider a survey of students that go into industry jobs and see their regrets of what quantitative skills they didn't learn. This may affect student buy-in when they see this data. Think of students trying to optimize their time in grad school."*

> *"We have more leverage to influence students at the next generation than our colleagues in our departments"*

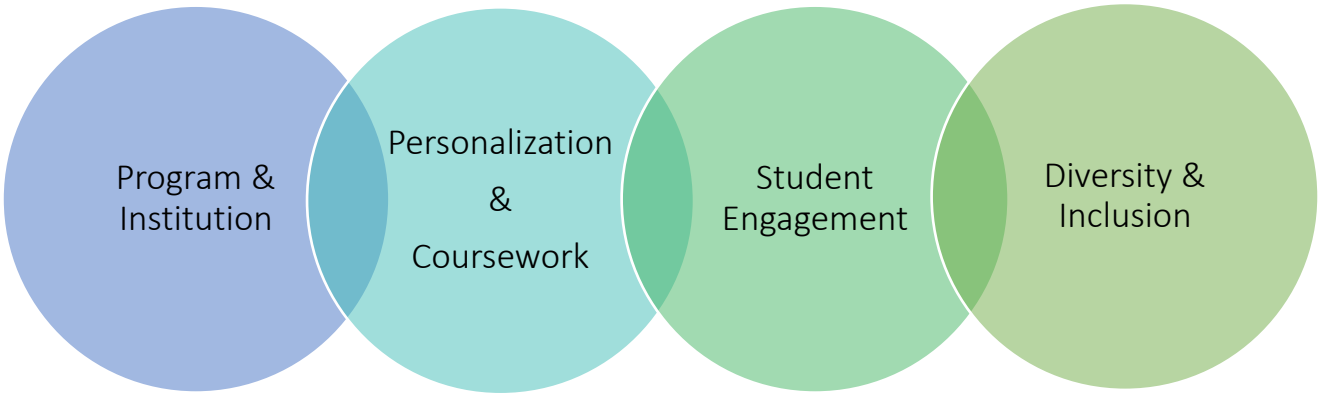
> *"A challenge is that bio faculty are not likely to support added courses to broaden quantitative education [without evidence]."*

> *"How to broaden the pool of quantitative focused students in grad programs is challenging. [We have] a need to get faculty to buy-in [with] evidenced basked policies for engaging diversity"*

Strengthening of Graduate Life Science Education

Break session groups had several interrelated strategies for improving graduate education in life sciences. Workshop participant strategies are displayed in the following figure as four overlapping circles to signify their related themes.

Figure 8: Strengthening of graduate life science education



Program and Institution

Engaging programs to encourage diversity of disciplines in student dissertation committees is one way to reinforce the value of quantitative skills and prepare students. Institutional initiatives and programs that support the broadening of diversity and inclusive practices are of urgent need. Supporting faculty and students as they broaden their learning networks increase the opportunities for collaborative research.

"One size does not fit all… Some tailoring at the program level of individual students is necessary"

"It will require creative approaches at many institutions to obtain the institutional support for interdisciplinary programs such as those in quantitative biology."

"It is important to obtain feedback from students who have gone into the workforce, particularly those outside academia, to assist in building out quantitative educational components in life science programs."

Personalization & Coursework

In this category workshop, participants are eager to develop, perhaps through modification of existing undergraduate quantitative biology measurements to encourage skill development. Also included in this category are training and initiatives for faculty to engage in project-based learning, case study development, and other active learning techniques. Peer mentor and team-based research are additional ways participants encouraged personalization of learning and skill development.

> *"Help faculty give talks or lead discussion on not just their research projects (tools, methods, how they approach science, novel approaches) but the story behind their research. [How they] went in the wrong direction, how they got ideas to develop, the unexpected dead ends."*

> *"Developing mechanism that embed life science students with those in quantitative fields or those in quant bio programs) may be an effective means to foster peer-mentoring and build interactional expertise."*

Student Engagement

Various formal and informal science engagement opportunities were discussed, such as cooperative and team-based learning strategies, clubs, interdisciplinary seminars, boot camps, and creative, graphics design components to displaying research. It was suggested that courses and programs that mirror our society's social networking and focused visual atmosphere in courses would help develop science's strong communicators.

> *"Contextualizing abstract tools in a charismatic way (i.e. relevant problems, fun problems, examples related to the personification for the students, etc.)"*

> *"Making thing approachable. Clubs, games, discussion groups".*

> *"A focus on creativity in an integrative approach".*

Diversity and Inclusion

A reoccurring discussion topic in breakout session groups is how to increase diversity in graduate programs and be mindful of inclusive practices in teaching and research. Participants discussed recruitment strategies, including funding and support at the institutional level through diverse course offerings. Also discussed is the interdisciplinary nature of quantitative biology to offer multiple entry points to life science graduate programs.

> *"There are challenges with regard to recruitment for ensuring diverse participation in formal programs and there are also advantages to fostering a more broadly inclusion environment."*

References

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Saldana, J. (2016). *The coding manual for qualitative researchers*. Thousand Oaks, CA: Sage Publications.

Appendix A: Workshop Survey

Quantitative Education in Life Science Graduate Programs
Virtual Investigation Workshop Survey

1.) Thank you for attending the "Quantitative Education in Life Science Graduate Programs" workshop, December 1st-3rd, 2020. Your responses will help in the design of future programs and products to support faculty, students, and institutions in this area. Information supplied on the survey will be confidential, and results will be reported only in the aggregate. Your participation is voluntary and welcomed.

- ○ OK, take me to the survey (4)
- ○ No, I would like to exit the survey (5)
- ○ I didn't attend the conference (6)

Skip To: End of Survey If Thank you for attending the "Quantitative Education in Life Science Graduate Programs" workshop,... = No, I would like to exit the survey

Skip To: End of Survey If Thank you for attending the "Quantitative Education in Life Science Graduate Programs" workshop,... = I didn't attend the conference

2.) Please select any of the **pre-workshop sessions** you attended.

- [ ] Thursday, November 19th Sococo Training Session (1)
- [ ] Monday, November 23rd Sococo Training Session (2)
- [ ] Tuesday, November 24th Sococo Training Session (3)
- [ ] Tuesday, November 24th Birds-of-a-Feather Session (4)
- [ ] I did not attend any pre-workshop sessions (5)

3.) Please select the events you attended on **Tuesday, December 1st**

☐ 11:30-12:00 Sococo Training Session (1)

☐ 12:00-12:45 “Welcome to Workshop" and Prioritizing quantitative concepts and skills - results from analysis of suggested readings from biomedical science faculty” – Lou Gross (UTK) (2)

☐ 12:45 - 1:15 "Computing skills for Biologists: Building a toolbox"-Stefano Allesina (U. Chicago) (3)

☐ 1:15 - 2:00 “When good theory is not good enough: practical and problem-centric approaches for developing PhD training programs in quantitative Biosciences” – Joshua Weitz (GA Tech) (4)

☐ 2:15 - 2:45 Discussion of breakout session topics and organization (5)

☐ 2:45 - 3:15 Experimenting with Graduate Course Formats for Statistics and Programming” – Nathalie Vladis (Harvard Medical School) (6)

☐ 3:15 - 3:45 “The Future of Graduate Quantitative Education: An Education Ecosystem Perspective” – Jay Labov (National Academies) (7)

☐ 3:45 - 4:45 Breakout sessions 1 – 5 (8)

☐ 4:45 - 5:00 Session reports (10)

☐ 5:00 + Open Reception in Sococo Lounge areas (11)

☐ I did not attend any events on this day. (12)

4.) Please select the events you attended on **Wednesday, December 2nd**

- [ ] 12:15-12:45 "Overview of quantitative/computational NIGMS training, workforce development, and diversity programs"- Alison Gammie (NIH/NIGMS) (2)
- [ ] 1:00 - 2:30 Breakout sessions 6 – 10 (3)
- [ ] 2:30 - 3:00 "A flexible graduate training program to build hard and soft skills: integrating informatics and ecology"-Kiona Ogle (NAU) (4)
- [ ] 2:15 - 2:45 Discussion of breakout session topics and organization (5)
- [ ] 3:00 - 4:00 Session reports/Discussion of additional breakout sessions (6)
- [ ] 4:00 - 5:00 Birds-of-a-feather sessions/Planning for next day (7)
- [ ] 3:45 - 4:45 Breakout sessions 6-10 (8)
- [ ] 4:45 - 5:00 Session reports (10)
- [ ] 5:00 + Open Reception in Sococo Lounge areas (11)
- [ ] I did not attend any events on this day. (12)

5.) Please select the events you attended on **Thursday, December 3rd**

- ☐ 12:15-12:30 Organization of report and consensus on topics (2)
- ☐ 12:30- 2:00 Breakout sessions 11-15 (3)
- ☐ 2:30 - 3:30 Synthesis sessions for each breakout topic (4)
- ☐ 3:30-4:30 Final Wrap Up (5)
- ☐ 4:30 + Goodbye reception in Sococo Lounge areas (11)
- ☐ I did not attend any events on this day. (12)

6.) Please rate you knowledge level of the following topics **before** and **after** attending the workshop:

	Before Workshop	**After** Workshop

Alternative perspectives on how to infuse quantitative perspectives in different life science graduate programs (Microbiology, Molecular, Genetics, Ecology and Evolution, Biomedical, MD, MD/PhD, etc.) (13)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Differences in what quantitative concepts and skills are emphasized in different life science disciplines and how should this affect educational initiatives. (16)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
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. (19)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
The landscape of quantitative skills being taught at the graduate level. (18)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Ways to enhance a culture in life science education that encourages diverse quantitative knowledge. (20)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Way to personalize a graduate student's experience in courses, research groups, labs, and seminars serve to increase quantitative core competencies. (21)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Ways to navigate the expansion of quantitative approaches when there may not be an individual with the necessary expertise available at a student's institution? (22)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Understanding which skills and concepts that are more effectively learned outside of a formal classroom setting and which benefit from an informal setting. (23)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)

Understanding what lessons in quantitative education at the undergraduate level can be adapted or modified to enhance graduate education. (24)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Effective ways to "downscale" quantitative education from programs that focus on educating quantitative biologists to the broader population of graduate biology programs. (25)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Alternative modes for graduate students to acquire quantitative concepts and skills. (26)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)
Ways to encourage diversity (both conceptual and skill-based) on graduate student committees. (27)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)	▼ Extremely knowledgeable (1 ... Not knowledgeable at all (5)

7.) Please describe how your understanding of quantitative education in life science graduate programs has changed/evolved since participating in the workshop.

_____
_____
_____

8.) Was this this the first time using the Sococo platform?

- ○ Yes (1)
- ○ No (2)
- ○ I'm not sure (4)

9.) Please share your impressions of the Sococo platform including any advantages and challenges.

_____

_____
_____

10.) Please use this space for any additional comments:

_____
_____
_____

Appendix B: Breakout Session Google Doc Template

Quantitative Education in Life Science Graduate Programs: Breakout Session [#]

Breakout session name:

Breakout group participants:

What is the problem under discussion? What are the different mechanisms/modalities

What are the alternative key assumptions and groups of students/faculty/programs under discussion?

What are some alternative approaches that have been taken including institutions and any evidence of success?

Are there any available data to assess this or are there real needs for new data that would be useful in analyzing and addressing the problem?

What methods might be employed to implement some of the approaches discussed?

What might be done to evaluate the success of the methods and what criteria do you suggest be applied to determine that the methods are useful in educating the students under consideration?

Other comments:

Key points to include in report-out:

Relevant references: