Using a Tiered-Metagenomics Approach to Studying Microbial Communities

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Abstract

Through a tiered approach, two segments of undergraduate students will gain a greater understanding of microbial diversity and community structure through metagenomics. The primary audience will be undergraduate independent research students and the secondary audience will be undergraduate students enrolled in a microbiology course. The former group will research and develop questions addressing spatial and/or temporal variability in microbial communities in response to their environment. These students will spend a semester vetting their hypotheses, collecting samples, and processing them in preparation for NexGen sequencing. The research students will then complete post-sequence processing (i.e., filter, trim) of the data, analyses, and interpretation of results. These students will also be required to present the data in both written and oral form. Following this process, the data sets generated by the independent research students will then be shared with a general microbiology class, the secondary audience. Theses students will be familiarized with the research performed to generate the data set and the related background literature. In groups of four, these students will then generate new hypotheses and further analyze the sequenced data in novel ways. Through this approach, both populations of students will make connections between concepts to better understand how NexGen sequencing works, gain hands-on experience with molecular biology techniques, and elaborate their learning through the writing and presentation of their research. Such a multidimensional approach will foster continuity of research and demonstrate the effectiveness of implementing metagenomics within two different pedagogical settings.

Article Context: To make the submission process easier, you may want to examine the following form, which you will be asked to fill in during the submission process. Choose all applicable options that effectively **describe the conditions IN WHICH THE LESSON WAS TAUGHT**. Modifications to expand the usability of the Lesson will be addressed in the discussion.

****Not all categories will pertain to your article, in those cases, please select 'NA' when submitting on the website.**

Course

- Biochemistry
- Cell Biology
- Developmental Biology
- Genetics
- Microbiology
- Molecular Biology
- Introductory Biology
- Bioinformatics
- Evolution
- Ecology
- Anatomy-Physiology
- Neurobiology
- Plant Biology
- Science Process Skills
- *Independent Research

Course Level

- Introductory
- Upper Level
- Graduate
- High School
- Other

Class Type

- Lecture
- Lab
- Seminar
- Discussion Section
- On-line
- Other

Audience

- Life Sciences Major
- Non-Life Science Major
- Non-Traditional Student
- 2-year College
- 4-year College
- University
- Other

Class Size

- 1 – 50
- 51 – 100
- 101+

Assessment Type

- Assessment of individual student performance
- Assessment of student groups/teams
- Assignment
- Exam/quiz, in class
- Exam/quiz, take home
- Homework
- Answer clicker-type question(s)
- Answer essay question(s)
- Answer fill in the blank question(s)
- Answer multiple choice question(s)
- Answer short answer questions(s)
- Answer true/false question(s)
- Create a concept map
- Create a diagram, drawing, figure, etc.
- Create a website
- Create graph, table etc. to present data
- Design an experiment or research study
- Design/present a poster
- Give an oral presentation
- Informal in-class report
- Interpret data
- Order items (e.g. strip sequence)
- Participate in discussion
- Peer evaluation
- Post-test
- Pre-test
- Produce a video or video response
- Respond to metacognition/reflection prompt
- Self evaluation
- Solve problem(s)
- Written assignment: One minute paper
- Written assignment: Brochure
- Written assignment: Essay
- Written assignment: Figure and or figure legend
- Written assignment: Lab report
- Written assignment: Literature review
- Other

Lesson Length

- Portion of one class period
- One class period
- Multiple class periods
- One term (semester or quarter)
- One year
- Other

Key Scientific Process Skills

- Reading research papers
- Reviewing prior research
- Asking a question
- Formulating hypotheses
- Designing/conducting experiments
- Predicting outcomes
- Gathering data/making observations
- Analyzing data
- Interpreting results/data
- Displaying/modeling results/data
- Communicating results

Pedagogical Approaches

- Think-Pair-Share
- Brainstorming
- Case Study
- Clicker Question
- Collaborative Work
- One Minute Paper
- Reflective Writing
- Concept Maps
- Strip Sequence
- Computer Model
- Physical Model
- Interactive Lecture
- Pre/Post Questions
- *Other – Hands on Learning

Bloom's Cognitive Level (based on learning objectives & assessments)

- Foundational: factual knowledge & comprehension
- Application & Analysis
- Synthesis/Evaluation/Creation
- Principles of how people learn
- Motivates student to learn material
- Focuses student on the material to be learned
- Develops supportive community of learners
- Leverages differences among learners
- Reveals prior knowledge
- Requires student to do the bulk of the work

Vision and Change Core Concepts

- Evolution
- Structure and Function
- Information flow, exchange and storage
- Pathways and transformations of energy and matter
- Systems

Vision and Change Core Competencies

- Ability to apply the process of science
- Ability to use quantitative reasoning
- Ability to use modeling and simulation
- Ability to tap into the interdisciplinary nature of science
- Ability to communicate and collaborate with other disciplines
- Ability to understand the relationship between science and society

Key Words: List 3 to 10 key words that are relevant for the Lesson (e.g. mitosis; meiosis; reproduction; egg; etc.)

1. metagenomics
2. microbial diversity
3. community structure
4. experimental design
5. hypothesis testing
6. ecology

Scientific Teaching Context

Learning Goal(s)

Through a tiered approach employing metagenomics undergraduate independent research students and students enrolled in general microbiology will:

- gain a greater understanding of microbial diversity and community structure
- make connections between microbiology and molecular biology concepts to better understand how NexGen sequencing works
- learn how to use several computing programs to work with large data files
- demonstrate their understanding through the writing and presentation of their research

Additionally, independent research students will gain a more indepth understanding of literature review, experimental design, data analyses, and communication of research findings.

Learning Objective(s)

Through a tiered approach employing metagenomics, undergraduate independent research students and students enrolled in general microbiology will be able to:

- read and review research papers
- employ the scientific method for an independent research project
- perform bioinformatics data analysis
- present their research results

Additionally, independent research students will develop skills needed to collect environmental samples, conduct laboratory methods for sample preparation prior to sequencing, and present their findings in both an oral and written environments.

Introduction

The introduction should provide the origin and rationale for the design of the Lesson and provide enough background information to allow the reader to evaluate the Lesson without referring to extensive outside material. For complex topics, a Science Behind the Lesson article may be simultaneously submitted with the Lesson, so that potential instructors will have sufficient information to implement the Lesson. Do not forget to reference all appropriate sources relating to any part of the Lesson.

WORK IN PROGRESS: Recent studies of biology education highlight the importance of independent research in undergraduate education and the historical limitation of applying NextGen sequencing technologies in the classroom. Therefore, initiatives that implement NextGen sequencing and bioinformatics techniques across diverse instructional situations are imperative (Buonaccorsi, et al., 2011). (example lit review)

Using tiered research approach, undergraduate students conducting independent research will generate data sets that can then be used for hypothesis-driven research in a general microbiology courses. A tiered approach permits the independent research students the opportunity to learn the theory and basic techniques of research. These students have the opportunity to formulate an original hypothesis related to microbial community dynamics and to follow this research through the laboratory and data analysis components to share with the greater research community their research findings. In doing so, they also generate a data set of metagenomic data that can then be used by microbiology students. Thus all students are trained in the various aspects of the research.

Put in background - value of hands on learning…. molecular biology and metagenomic research…

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3228652/

Intended Audience

The primary audience for this research is undergraduate students who are majoring in Biology or Biotechnology and enrolled in an independent research course. Typically this population consists of third and fourth year students who will then take 4-8 credits of research over the course of a year. The secondary audience is undergraduate science majors interested in microbiology and enrolled in a semester-long microbiology course.

Required Learning Time

For the primary audience, it is expected that a student will be involved in a minimum of 4 credit hours of research. For greatest success, a student should be enrolled in research two semesters. However, a student who is motivated and has already identified a research question with standard sample collection practices, could take research for as little as one semester. For the secondary audience, learning will be divided between in-class and out-of-class time. Approximately four lectures and two labs will be designated to this work.

Pre-requisite student knowledge

The primary audience is expected to have taken three semesters of introductory biology courses and general microbiology. Students will also have completed a minimum of two semesters of chemistry. Although not required, students will be encouraged to take one-semester of computer

science, as well. The secondary audience is expected to have completed three semesters of introductory biology and two semesters of chemistry (sophomore level course and higher).

Scientific Teaching Themes

Active Learning

For the primary audience, the entire independent research project will necessitate active learning through reviews of the literature, identification of microbial ecology research questions, and application of the scientific method. In addition, weekly one-on-one meetings with the professor and laboratory group meetings will foster discussion and peer review. For the secondary audience, active learning will primarily occur through laboratory time dedicated to the research project and out-of-class assignments. Small group discussion and hypothesis generation will demonstrate the numerous applications of metagenomics. Data manipulation and analysis will illustrate the techniques employed by professionals in the field.

Assessment

For the primary audience, a final research paper and presentation (i.e., poster or oral) will be used to quantify student intellectual development. Students will grasp their competency with the material as they progress through the stages of research, grapple with unforeseen challenges, and craft the research paper summarizing their findings. For the secondary audience, progress on learning goals will be measured through laboratory practicals and exams throughout the semester. Microbiology students will also produce a written paper to assess overall concept mastery and creative ability. Additionally, both the primary and secondary audiences will take audience-specific pre/post assessment tests (similar to the GCAT-SEEK Google Doc) to quantify the net impact of the proposed instructional module.

Inclusive Teaching

The tiered method of implementation is inherently conducive to inclusive teaching as it encompasses both classroom and independent study. It will appeal and address the pedagogical needs of two groups of biology students. Furthermore, students will be exposed to the interdisciplinary nature of metagenomic research, which involves aspects of biology, computer science, statistics,, and chemistry. Finally, the module will include all students in the research process, including those barred from participating with environmental samples as a result of pre-existing medical conditions.

Lesson Plan

Provide a detailed description of the Lesson that is sufficiently complete and detailed to enable another teacher to replicate it. You may think of it as if you were explaining to a colleague how to teach your class for you next week, or preparing a detailed methods protocol for a lab technique. For clarity, you may need/want to include subsections such as: pre-class preparation and in-class script. Add subheadings as needed, following the embedded styles in Microsoft word:

Primary Audience Lesson Plan: Independent Research Students

Students enrolled in independent research will be required before the start of the semester to set-up with the professor a weekly 45 minute meeting time. They will also be encouraged to start reviewing microbial ecology literature to help them identify and develop questions addressing spatial and/or temporal variability in microbial communities that may be of interest to them.

During the first 3-4 weeks of the semester, students will use the literature to better formulate a research question and develop a working hypothesis. At this time, students will also be required to start thinking about sampling design and collection methods. By weeks 4-6, students will be encouraged to work on techniques related to sample collection, DNA extraction, and DNA amplification, so that they have confidence with upstream application of NexGen sequencing. If Institutional Review Board approval of samples is required for sample collection, by this time students should have completed and submitted an IRB protocol. Trouble shooting of techniques and experimental design will continue at this point, but it is hoped that by mid-semester students are prepared to start their research and sample collection. By the end of the semester, students should have DNA samples that will be submitted for NexGen sequencing and will have also started working with practice data sets and tutorials on bioinformatics in preparation for downstream data analyses and work.

During the second semester, students should have access to their sequence data and will spend the majority of this semester working with the data. Data interpretation should be completed within the first 5 weeks of the second semester to permit time for preparing oral and written findings.

Throughout the two semesters, students will meet individually with the professor for weekly meetings to troubleshoot and vet ideas. Additionally, weekly lab meetings will be used to discuss primary research related to the student research, problems in the lab, share success and troubleshooting findings, etc.

**To complete this research a lab with equipment for microbial community sample preparation, DNA extraction, PCR, and DNA quantification needs to be available. It would also be beneficial to have computers available with pre-installed programs such as cyberduck, putty, etc.

Secondary Audience Lesson Plan: Microbiology Students

WORK IN PROGRESS: To complete this portion of the project, students enrolled in microbiology will work together in small lab groups of 3-4 students. During the semester there will be 4 lectures dedicated to metagenomics and microbial ecology. These four lectures will generally cover: (1) What is metagenomics and how can it be used to advance our understanding of the world?, (2) Lab Techniques (i.e., sample preparation, sequencing) and Principles to Metagenomics, (3) Working with Sequencing Data, and (4) Data Interpretation

… IT set-up a computer lab with appropriate programs…
or the secondary audience, active learning will primarily occur through laboratory time dedicated to the research project and out-of-class assignments. Small group discussion and hypothesis generation will demonstrate the numerous applications of metagenomics. Data manipulation and analysis will illustrate the techniques employed by professionals in the field.