Metagenomics BIO-373

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List of Tables, Figures and Supplemental Material:

Article Context:

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

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

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

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

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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. Statistics
3. Environmental Microbiology
4. Bioinformatics
5. Ecology
6. Genetics
7. QIIME

Scientific Teaching Context

Learning Goal(s)

- Students will understand the principles of metagenomics and appreciate the techniques required to gather and analyze metagenomic data.
- Students will know how to compare and contrast different microbial community structures and microbial ecology/diversity based on metagenomic data.
- Students will demonstrate basic mastery of computer programing.
- Students will appreciate the value and power of sound experimental design.
- Students will have experience with statistics and data visualization

Learning Objective(s)

- Students will apply experimental design to metagenomics problem
- Students will isolate DNA from environmental samples, measure concentration, and amplify metagenomic libraries
- Students will characterize sequencing results using Linux compute cluster, Qiime, and other statistical software packages.
- Students will evaluate the outcomes of metagenomic-based hypothesis based on computational analysis.
- Students will present primary literature and data to peers to deepen understanding of the metagenomic principles.

Introduction

Intended Audience

This is an upper college course that is a precursor to a year-long senior thesis experience. To that end, special emphasis is placed on providing students with ways to become independent in their approach to scientific design and experimentation as well as learn to work cooperatively and collaboratively. This course requires small group work, with frequent shifting of group members, collaboration and sharing of data, social experiences, peer teaching of protocols, responsibility to prepare materials for class use. Content from the course is readily accessible from the course website, in the form of primary readings, lecture slides, handouts and audio lectures.

Required Learning Time

The course will consist of two distinct scheduling modules. The course starts with a weeklong immersive laboratory research experience where the students meet daily both in the morning and in the afternoon. The morning sessions are run like a lab meeting where concepts and ideas that will be used in the lab in the afternoon are taught and discussed. Afternoon sessions are mostly devoted to laboratory training. This first immersion section of the course will provide the unique opportunity to develop and conduct a full research project in response to a simulated environmental crisis. The second section of the course will take place during the scheduled semester weeks. Students meet twice weekly for periods of three hours with the instructor. During these sessions, content is delivered by way of primary literature papers posted to course site; mini lectures provide targeted instructions, and computer-based sessions.

Pre-requisite student knowledge

Students in this course are part of the Upper College, and are expected to have taken a minimum of five laboratory courses in biology, including Genetics & Evolution, and Ecology & Evolution. Students should be moderately comfortable in a laboratory environment being familiar with normal lab safety issues and equipment. Exceptions for prerequisites are made for students from programs with overlapping interests, including Computer Sciences and Applied Mathematics.

Scientific Teaching Themes

Active Learning

In this course students will be participating actively in each course meeting. Students will be working in groups of four to design and execute experiments, present primary papers in a journal club format, and peer review experimental proposals, posters and other writing assignments. Small group work to learn and execute computing tasks will also allow for peer facilitated learning. To that matter, for specific activities, each group will be given one task to understand and complete. One member of each group will then form a new group and teach each other how to perform the said task before join their original group to share the new finding. Additionally, the immersive nature of the first week of laboratory work will provide for a collaborative and inclusive learning environment to begin the semester work.

Assessment

This course will utilize multiple assessment strategies implemented throughout the semester. Pre-assessment of course expectations and learning goals will allow for clear communication of how the course content will be delivered, and give students best opportunity to prepare for future assignments. This writing intensive course will rely primarily on scaffolded writing assignments that will be both peer and faculty reviewed. The syllabus is also designed to allow for most written assignment types (distillations, log books, metagenomic analysis papers) to be repeated allowing for improvement based on feedback. Oral presentations and posters will be graded using a rubric to allow for immediate feedback, as well as numerous opportunities for presentations to allow for practice.

Inclusive Teaching

Students in this course will work in pre-determined groups throughout the semester on laboratory tasks, written documents and oral presentations. Students in the groups will be selected based on their individual strengths that they can bring to the research team, and will be able to help through peer teaching. The mixture of written work, oral presentations and feedback on drafts will allow for students of multiple learning styles to engage with the material. The course requires group work, with frequent changing of group make up based on previous work, collaboration and sharing of data, social experiences, peer teaching of protocols, responsibility to prepare materials for class use.

Lesson Plan

Pre-semester preparation

Before the start of the semester, a user account will be set up for each student to give access to the compute cluster at Juniata College. To prepare, a few trials of the analysis will be run to make sure that cluster and bioinformatics pipelines are working appropriately. In the lab, material will be prepared that will be required for field sampling , DNA extraction, and 16S metagenomic library preparation. Students will be assigned to read Caporaso et al. PNAS 1977 and fill in pre-assessment evaluation forms prior to the first meeting.

Immersive research training

Students will first gain access to their respective dorms in the afternoon of Monday August 25th. The first meeting in class will be held in the evening of August 25th. During this meeting, the course's syllabus, objectives and schedule are introduced to the students. The instructor will then present a brief introduction to microbial diversity and lead a discussion using Caporaso et al. (2011). The students will then be asked to design methods to quantify microbial diversity. In the morning session of the second day, the instructor will discuss the different methodologies proposed by the students. The discussion will lead to the discussion of Woese et al. (1977), introducing the 16S operon. In the afternoon, the groups will discus fundamental principles that apply to experimental design in microbiological field studies using Lennon et al. (2011). On August 27th, students will be trained for lab safety in the morning before discussing the necessity of replication in sound experimental design using Prosser (2011). On August 28th, the group will discuss the choice of primers and the methods to construct 16S metagenomics libraries using Soergel et al. (2012) before designing and conducting a field experiment in environmental metagenomics. On August 29th, students will construct the 16S metagenomic libraries, quantify the DNA, and libraries will be sent for sequencing.

During semester

Throughout the semester, the classes will follow a regular schedule of activities. Most classes will begin with a short lecture with instructions and/or with a discussion of a paper lead by a group of students. In most cases for paper discussion, each student within the assigned group will be responsible to present and discuss one figure of the selected paper. Groups will alternate throughout the year so that most students will have multiple opportunities to present/discuss figures and papers. Most classes will also leave adequate in class time for computer lab exercises. To complete the exercises, the students will follow indications and scripts provided in the laboratory manual. The students will not produce lab reports, but instead will submit a single "log book" twice during the semester. The logbook documents the progression and the completion of the student's analyses throughout the semester. The student will submit one logbook after the completion of the first set of data and a second one at the end of the semester after the completion of the second set of data. The first five weeks of the semester will focus on analyzing the set of data generated during the immersive research training. After completing their analyses, the students will propose a new study based on their new knowledge acquired in the first part of the course. Their idea will be presented via a written proposal and orally in front the class. Both presentations will be peer-reviewed by other students in the class. A final proposal must be submitted to the instructor before the fall break. After approval from the instructor, the students will be responsible to conduct a field sampling and library preparation with their respective group. The students will have two weeks to do so. During that time, the class will meet to discuss papers that will be selected by each group in relation to their research questions. Following this period of independent research, the class will meet twice a week for three hours once again. During this period, different topics will be presented and discussed in class. The topics will include applications of 16S metagenomics to medicine and public health, agriculture, ecology and evolution. Finally, the students will use the last two weeks of the semester to conclude their analyses and produce a final paper and a poster presentation. The students will have the opportunity to produce a podcast instead of a poster if desired.

Table 1. Timeline of lessons

Dates	Topics	Readings
8/25	PM: Course description Paper discussion – Microbial diversity	 Caporaso et al. *PNAS* 2011.
8/26	AM: Paper discussion – 16S operon PM: Paper discussion – Sampling design	Woese et al. *PNAS* 1977. Lennon. *Env. Microbiol*. 2011.

8/27 8/28 8/29	PM: Safety training Paper discussion – Replication AM: Paper discussion – Primers, etc Designing field experiment PM: Field Sampling & DNA extraction AM: Library prep PM: Library prep	 Prosser. *Env. Microbil*. 2010. Soergel et al. *ISME J.* 2012. Lab manual pages: in development Lab manual pages: 8-15 Lab manual pages: 8-15
8/31 9/2	Introduction to Linux and Compute Cluster Lab exercises Introduction to Linux and QIIME Lab exercises → **Distillation I Due**	 Lab manual pages: 24-42 Lab manual pages: 42-48
9/7 9/9	Data filtering Paper discussion Lab exercises Metadata labeling and Picking up OTU Paper discussion Lab exercises	 Bokulich et al. *Nat. Method.* 2013. Lab manual pages: 48-60 Caporaso et al. *Nat. Method.* 2010. Lab manual pages: 60-68
9/14 9/16	Alpha diversity Paper discussion Lab exercises Beta diversity Paper discussion Lab exercises	Hughes et al. *AEM*. 2001 Lozupone and Knight *FEMS Microbiol. Rev.* 2010 Lab manual pages: 71-75 Jost. *Ecology* 2010. Lab manual pages: 75-77
9/21 9/23	Multivariate statistics Lab exercises Proposal workshop Core Microbiomes Paper discussion Lab exercises → **Proposal due on 9.25**	 Lab manual pages: 77-81 TBD Lab manual pages: 81-82
9/28 9/30	→**Proposal oral presentations** Data visualization Lab exercises	 Each group of students develops their own tutorial to

	Paper presentation → **Peer-review due 10/2**	share with other groups.
10/5 10/7	Data visualization Lab exercises → **Final proposal due on 10/5** Discussion/Approval of final proposal Independent experiment → **Log book I due on 10/9**	Each group of students develops their own tutorial to share with other groups.
10/12 10/15	Fall Break Paper discussion Independent experiment	 TBD by group 1 and 2
10/26 10/28	Paper discussion Independent experiment Metagenomics in ecology and evolution Paper discussion	TBD by group 3 and 4 TBD
11/2 11/4	Metagenomics in medicine Paper discussion Metagenomics in agriculture Paper discussion	 TBD Hess et al. *Science* 2011.
11/9 11/11	Metagenomics and environmental sciences Paper discussion Metagenomics and biofuel Paper discussion	 Texler et al. *Front. Microbiol.* 2014. TBD
11/23 11/25	Looking into the future Ethical, legal, and social implications → **Distillation II due** Data analysis	
11/30 12/2	Data analysis Data analysis	
12/7 12/9	Data analysis Data analysis	

12/14	Data analysis	
12/16	→ **Poster presentation or <u>podcast</u>**	
	→ **Log book II due on 12/18** → **Final Paper due on 12/18**	

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