A Flexible Teaching Module for Microbial Community Analysis in the Undergraduate Curriculum

Ben B. Whitlock, PhD[1] and Cathleen M. Dobbs, PhD[2*]

Affiliations:

[1]University of St. Francis, Department of Natural and Health Sciences, Joliet, IL

[2]Joliet Junior College, Department of Natural Science, Joliet IL

*Correspondence to: Cathleen Dobbs, cdobbs@jjc.edu

Type of Manuscript: *CourseSource* Lesson Manuscript

Article Context:

Should highlight differently for semester-long project vs short module and what fits both scenarios – right now this includes both.

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
- 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

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.

Scientific Teaching Context

Learning Goal(s)

Students will understand that microorganisms can be characterized by both phenotypic and genotypic methods.

Students will understand the process of characterizing microbial communities via genotypic methods.

Students will be able to interpret microbial community data to address testable hypotheses.

Students will develop an appreciation for the interaction between different microorganism and how these interactions contribute to the physical characteristics of a location.

Learning Objective(s)

Students will be able to give the advantages and disadvantages of genotypic vs phenotypic characterization of microbial communities.

Students will be able construct hypotheses concerning the make-up of microbial communities within different environmental samples from different types of ecosystems based on the physical characteristics of the environment.

Students will be able to design experiments and/or evaluate data to test hypotheses.

Students will successfully culture and biochemically characterize microorganisms and relate these characteristics to the community profiles.

Introduction

Development and implementation of inquiry-based laboratories and authentic research experiences is a large part of the *Vision and Change* mandate developed by the American Association of the Advancement in Science (2011) to improve undergraduate science education. In support of this, several institutions have implemented research-based courses and curriculum within various scientific disciplines (Need Refs).

The goal of this curriculum module is to design a project that can be taught at various levels of complexity to both introductory biology and microbiology students, but that can also be modified for upper level biology undergraduates and as part of a research course for community college students. Specifically, this project aims to expose students to modern molecular biology techniques, but within the context of some traditional biology and microbiology concepts. We aim to design a project that can be used both within and outside of traditional course structures. Here we present two modules, one that can be completed by students in 5 weeks and one that could extend over the course of a full semester. The shorter module is aimed at students within introductory biology and microbiology students; whereas the longer module is designed for students within.

Both modules will focus on an exploration of the natural areas that are found within the borders of the Joliet Junior College (JJC) campus. The 273 acre campus is home to several different several actively restored natural areas including a fen, oak savanna and prairie (Natural Areas Restoration). The campus also includes crop (used by the JJC agricultural programs) and athletic fields, which, in several cases, are found adjacent to the restored natural areas. This campus represents a unique opportunity to investigate several different natural areas all within close proximity to one another. It also gives us the chance to investigate the impact that restoration practices have on the natural areas as well as the influence of anthropogenic factors such as fertilizer, herbicide and pesticide administration on the athletic, crop and landscaped areas adjacent to the sites.

The semester-long project and the short modules will share a distinct feature. Students in both will initially develop hypotheses concerning what types of microorganisms might be found within the soil in different natural and/or agricultural areas on the campus at JJC. To develop these hypotheses students will be provided with a variety of different types of background information (appropriate to the level of students within the course) to help them understand the differences between soil types and the plant community. In upper level courses, they may also investigate metabolic pathways important for nutrient cycling. Students in in the semester long project will characterize the soil microbial community via phenotypic and genotypic methods and compare their results. To accomplish this the students will sample the soil at different depths and prepare the soil for culturing and homogenize the soil for DNA isolation and PCR for 16s ribosomal RNA characterization. As a result, students will directly address their hypotheses concerning the microbial community in different natural areas.

In contrast, the students completing the short module would be provided with the data generated by students as part of the semester-long projects and would address their hypotheses using this data. This approach could work with students in a variety of settings because while one class may not (due to time or money contraints) be able to carry out the 16s rRNA characterization they will still be able to address their hypotheses, learn about the techniques used to generate the data and think about the biology behind the results.

Intended Audience

The semester-long projects are intended for upper-level undergraduates at 4-year institutions or for community colleges students that have had some introductory coursework. The short module is intended for introductory biology or microbiology undergraduates.

Required Learning Time

The semester-long project will take approximately 16 weeks of 3-4 hours per week. The short module approximately 5 weeks with 1 hour per week.

Pre-requisite student knowledge

Students should have some knowledge of the scientific process including hypothesis writing and basic experimental design. Students should also have some basic cell biology knowledge and biodiversity appreciation. The foundation for all of this knowledge may be given within the courses in which these modules are taught.

Scientific Teaching Themes

Active Learning

Because this is designed as a laboratory activity we anticipate that students will be working in small groups in a problem-based learning format of reading, discussion and cooperative writing.

Assessments

Students will be assessed based on their understanding of phenotypic and genotypic methods, interpretation of the literature presented, hypothesis construction and data interpretation. Assessment tools will include written reports and examinations.

In addition, students in the semester-long projects will be assessed based on their laboratory techniques and ability to analyze and interpret data. Assessment tools. will include written reports and practical examinations.

Inclusive Teaching

By providing different lesson plans for different types of courses we anticipate that this will increase the accessibility of this project for a number of different types of institutions.

Lesson Plans

Semester-long project – targeted toward upper-level undergraduates and advanced community college students

Week 1: Introduction, tour of natural areas and formation of student groups

Week 2: Discussion of literature provided/ groups begin work on formulating hypothesis

Week 3: Finalize hypothesis/ Collect soil and other data as appropriate to hypothesis

Week 4: Process soil samples for culturing and initial DNA isolations

Week 5: Examine cultures and choose isolates for further characterization

Week 6: Carry out DNA isolations from soil samples/ continue isolate characterization

Week 7: Quantify DNA samples and set-up 16s rRNA PCR reactions / continue isolate characterization and begin phenotypic identification of isolates

Week 8: Purify PCR products and prepare to send for sequencing / continue phenotypic identification of isolates

Week 9: Introduction to analysis of 16s sequence data/ introduction to LINUX commands

Week 10: Introduction to sequence analysis software and tutorial

Week 11: Continue with software tutorials / continue with phenotypic identification of isolates

Week 12: Begin processing DNA sequences received from sequencing facility/ finish identification of isolates

Week 13: Analysis of sequence data – filtering and OTU picking

Week 14: Analysis of sequence data -- higher level analysis in QIIME to address initial hypothesis

Week 15: Analysis of sequence data – higher level analysis in QIIME to address initial hypothesis

Week 16: Comparison of genotypic characterization to phenotypic characterization to address hypothesis

Short module– targeted toward introductory biology/microbiology students

Week 1: Introduction, *focused* tour of natural areas and formation of student groups

Week 2: Discussion of literature provided/ groups begin work on formulating hypotheses as directed by instructor

Week 3: Finalize hypothesis/ Introduction to phenotypic vs genotypic characterization of community data and 16s rRNA sequencing

Week 4: Student groups provided with phylogenetic data analyzed by previous classes to begin investigating hypothesis

Week 5: Write focused report that addresses what the data reveals about their hypthesis and the differences between soil from different natural areas

References

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