Metagenomics Module for an Interdisciplinary Research Course at the Community College Level

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Abstract

Active engagement of students in their first two years of college is critical to retention in science, technology, engineering and math (STEM) fields (1). However, there are critically few research-based STEM courses and authentic STEM research experiences available to students at the community college level. This lesson plan presents a scientific research course including didactic and hands-on research components. The didactic component is generalized to all students enrolled in the scientific research course. The hands-on research component presented herein is specific to those students participating in the metagenomics module (the course currently offers, alternatively, a physics of sound module, a biochemistry module, or a water ecology module).

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

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. st
- rip 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 : all three above-listed items to be included in one formal research report

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
- Ecosyst
- 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. Microbiome
3. Soil
4. Ecosystem
5. Prairie
6. Wetland
7. Forest
8. Oak Savanna
9. Research
10. 16s rRNA

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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 natural area ecosystem*

Learning Objective(s)

- *Students will be able to design an experiment employing next generation sequencing to identify prokaryotic organisms in soil from natural areas*
- *Students will be able to collect soil samples for metagenomic analysis*
- *Students will be able to analyze chemical and physical properties of soil*
- *Students will be able to extract DNA from soil samples*
- *Students will be able to quantitate DNA from soil samples*
- *Students will be able to run 16s rRNA PCR on DNA from soil samples in order to prepare them for sequencing*
- *Students will able to analyze a metagenomic data set using QIIME to determine the set of prokaryotic organisms present in soil samples.*
- *Students will be able to present their research findings orally and in writing*

Introduction

It has been shown that interventions to enhance minority students' identification with a field equalize retention between minority and majority students (2). In addition, active engagement of students during the first two years of their college career is associated with retention in STEM fields. (1, 3). The development and implementation of research-based courses and authentic research experiences at community colleges, like Joliet Junior College (JJC), that serve an ever-growing minority, underrepresented and underprepared student population is critical for student engagement as part of a STEM community.

The goal of this project is to actively engage community college students in modern molecular biology research via a metagenomics module within the context of a scientific research course. The didactic portion of the scientific research course is designed to introduce students to basic skills important for scientific communication, literature research, analysis, and ethics. The metagenomics module is aimed at students who have completed an introductory major's level biology or chemistry course. The module focuses on an exploration of the natural areas that are found within the borders of JJC campus. The 273 acre campus is home to several different several natural areas at various states of restoration including a fen, an oak savanna, a deciduous forest and a prairie. 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.

Students 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 to help them understand the differences between soil types and the plant community. Students will characterize the soil microbial community via genotypic methods. 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.

Intended Audience

The Lesson is targeted to Biology and Chemistry majors who have completed their first-year of undergraduate coursework.

Required Learning Time

This is a six week module.

Pre-requisite student knowledge

BIO 151 with a minimum grade of C or CHEM 101 with a minimum grade of C and MATH 098 with a minimum grade of C . Consent of faculty member required.

Scientific Teaching Themes

Active Learning

Students will design and conduct laboratory experiments in metagenomics. They will analyze results using statistical analysis and will present the research and findings in the form of a scientific paper and public presentation.

Assessment

- Written
  - Project proposal
  - Laboratory notebook
  - Individual research report
- Other
  - Collaborative oral presentation (poster or power point)
  - Laboratory participation/skills

Inclusive Teaching

The course incorporates lecture and hands-on learning. The assessments include both written and oral assignments and individual and group work. Thus, both the

learning activities and assessments accommodate the needs of students with diverse learning styles and abilities.

Lesson Plan

The Metagenomics module will consist of two main components: a classroom component involving the entire cohort of students enrolled in NSCI 296 (General Research Group Meeting in table below) and a research component mentored by Dr. Dobbs. There are currently four faculty mentors participating in NSCI 296. Each faculty member, along with the college learning resource center (LRC) staff, will be responsible for a given classroom topic. The topics, designed to introduce the students to general aspects of scientific research, are as follows:

I. Introduction to Research/Laboratory Safety - Each participating NSCI 296 faculty member will give a presentation describing their research interests. Students will also be schooled in laboratory safety.

II. Introduction to Literature Search Methods - Science database search project. Students will learn to utilize the various data bases and literature search engines provided through the Learning Resource Center. Faculty will provide specific topics for research. LRC staff will direct this component.

III. Research Ethics Seminar

- Falsification: what it is and how to avoid it
- Fabrication: what it is and how to avoid it
- Plagiarism: what it is and how to avoid it
- Authorship issues
- Institutional Review Boards, Human participants and Animal Subjects

IV. Scientific Writing Seminar

- 'What's in a Title' – how to be specific, concise and clear.
- Abstracts – How to present a clear overview and stimulate reader interest.
- 'Why is Research Useful?' – The goals and aspirations of the current research project.
- Literature review – How the objectives of a project mesh with the broader, current understanding of this topic. How will such research add to this broader knowledge?
- Composition of a scientific paper - Discussion of how and why specific research strategies are adopted in order to reach the desired outcomes; how the data generated is presented, analyzed and discussed. How a conclusion summarizes the papers, key findings and results.
- References – how to accurately and concisely cite others work.

V. Analysis Methods - Excel based statistical analysis and graphing project. Students will utilize appropriate statistical tools (significance testing, chi square, variance, linear regression, curve fitting or other methods) to analyze experimentally derived data.

Students will formally present their research in poster form or via a power point presentation to the entire cohort of NSCI 296 students during the final General Research Group Meeting. Students will spend 2 hours per week in the classroom as part of the General Research Group Meeting.

For their individual research projects, students are expected to spend a minimum of 14 hours a week in the laboratory or in the field and up to 12 hours a week outside of class/lab time working on their projects. For the Metagenomics research module students will investigate the microbial communities in the soil within the natural areas at Joliet Junior College. They will have the opportunity to design projects analyzing and comparing the microbiome of fen, prairie oak savanna, and/or deciduous forest sites. The long term goal of this project will be to develop a microbial heat map of all natural areas to see how microbial taxa vary across land types. As such, a thorough analysis of the soil will be done to determine chemical composition, wet weight, pH, texture, and color. After designing their projects, students will collect soil samples from the various natural areas at the JJC campus. Soil samples will be tested as described above. DNA will be purified from the soil samples and 16s analysis using Illumina-bar coded primers will be done in anticipation of sequencing via MiSeq. Sequencing will be conducted by a GCAT-SEEK associated sequencing core facility (http://lycofs01.lycoming.edu/~gcat-seek/cores.html). Following sequencing, analysis will be carried out using Qiime.

Week	Day(s)	Activity	Topic
1	M	General Research Group Meeting	Review of projects Safety
		Metagenomics Group Meeting	Tour of Natural Areas Discussion of Soil Microbiome & Chemistry Discussion of Metagenomics
			Project Proposal (students will have started this prior to the first course meeting, upon their acceptance to the course)

	T	Metagenomics Group Meeting	Project Proposal Evaluation and Modification
	W	Metagenomics Group Lab	Soil Sample Collection Isolate and Quantify DNA (MoBio PowerSoil and Qubit) Begin Chemical/Dry Weight/Texture Analysis of Soil Samples
	R	Metagenomics Group Lab	Continue Analysis of Soil Samples 16s rRNA gene Illumina tag PCR
2	M	General Research Group Meeting	Literature Search Methods
		Metagenomics Group Lab	Check PCR Amplification (Qubit Gel electrophoresis) Purification of PCR products (SPRI beads) Pooling of amplicons Submission for sequencing
	T	Metagenomics Group Meeting	NextGen Sequencing Tutorial/Journal Club
	W	Metagenomics Group Meeting	QIIME Tutorial
	R	Metagenomics Group Meeting	QIIME Tutorial
3	M	General Research Group Meeting	Research Ethics
		Metagenomics Group Fieldtrip	Morton Arboretum or Chicago Botanic Gardens Soil Science Department
	T-R	Metagenomics Group Meeting	QIIME Analysis of Previously generated sequence
4	M	General Research Group Meeting	Scientific Writing
	M-W	Metagenomics Group	Students work on research reports/presentations
	R	Metagenomics Group Fieldtrip	Argonne National Laboratory
5	M	General Research Group Meeting	Analysis
	M-R	Metagenomics Group	Students work on research reports/presentations and begin to analyze sequence data when available
6	M-W	Metagenomics Group	Students work on research reports/presentations and analyze sequence data
	R	General Research Group Meeting	Student Presentations

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References

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2. The National Academies (2010). Expanding Minority Participation: America's Science and Technology Talent at the Crossroads. Washington, DC: National Academy Press.

3. President's Council of Advisors on Science and Technology (PCAST), "Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics." Available from: http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf